AMERICAN CINEMATOGRAPHER MANUAL

SEVENTH EDITION

EDITED BY

DR. ROD RYAN

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— Rod Ryan

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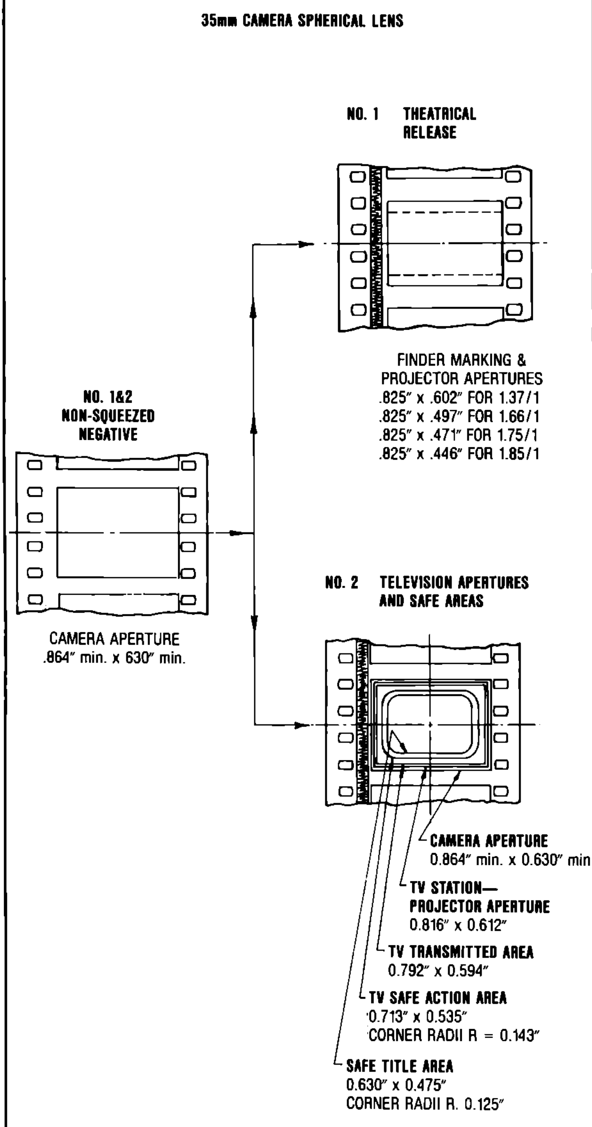
Cinematographic Systems

Most films produced for theatrical presentation are photographed in one of the systems intended for projection in an aspect ratio greater than 1.33:1. These are loosely categorized as "wide screen" systems. All films produced for use in television systems and most of those produced for industrial and educational use are photographed in an aspect ratio of 1.33:1.

Following are the photographic systems currently employed in the preparation of motion picture negatives or reversal originals from which the various projection systems can be supplied with the proper prints.

Most films produced for theatrical presentation are later used for television. It is desirable that the cinematographer allow for this in composing. The accompanying drawings will show dimensions of finder markings to aid the transition. Certain other enlarged or reduced copy dimensions are also shown. The dimensions shown are those of primary interest to the cinematographer; for detailed specifications, refer to the following Standards and Recommended Practices, published by the American National Standards Institute (ANSI) and the Society of Motion Picture and Television Engineers (SMPTE).

Image Areas, Camera	
16mm	SMPTE 7 -1988
16mm Type W (Super 16)	SMPTE 201M -1992
35mm	SMPTE 59 -1991
65mm	SMPTE 215 -1990
Image Areas, Projector	
16mm	SMPTE 233-1987
35mm	PH22.195 -1984
70mm	SMPTE 152 -1989
Copy Dimensions	
35mm to 16mm	RP65 -1991
16mm to 35mm	RP66 -1991
Super 16 to 35mm	SMPTE 201M-1992
35mm to 70mm	None
Television:	
Safe Action and Title Area	RP27.3 - 1989



35mm CAMERA SPHERICAL LENS
NO. 1 THEATRICAL RELEASE
FINDER MARKING & PROJECTOR APERTURES
.825″ x .602″ FOR 1.37/1
.825″ x .497″ FOR 1.66/1
.825″ x .471″ FOR 1.75/1
.825″ x .446″ FOR 1.85/1
NO. 1&2 NON-SQUEEZED NEGATIVE
CAMERA APERTURE
.864″ min. x 630″ min.
NO. 2 TELEVISION APERTURES AND SAFE AREAS
CAMERA APERTURE
0.864″ min. x 0.630″ min
TV STATION— PROJECTOR APERTURE
0.816″ x 0.612″
TV TRANSMITTED AREA
0.792″ x 0.594″
TV SAFE ACTION AREA
0.713″ x 0.535″
CORNER RADII R = 0.143″
SAFE TITLE AREA
0.630″ x 0.475″
CORNER RADII R. 0.125″

Figure 1.

35mm Systems

1. 35mm camera, spherical lens (non-squeezed) photography for theatrical presentation (Sound area blocked). (See Figure 1.)

The ANSI standard calls for cameras for nonanamorphic photography to be equipped with an aperture of 0.864" by 0.630" minimum. Many cameras, however, are equipped with apertures which will cover the area required for anamorphic images as well, and it is occasional practice to use a "hard matte" to limit the area in the vertical dimension to the wide screen format desired by the director. It should be understood, of course, that while the use of a hard matte ensures correct framing in the theater, it also limits the future use of the image for television releases in 1.33:1 aspect ratio. In addition to the necessity for (and the expense of) a special duplicate negative for television, it should also be noted that the side lines for 1.33:1 within a hard matted wide screen frame may have to be respected by the cinematographer to protect for such later use. When theatrical subjects are photographed without the hard matte, it is wise to protect the height of the image for later television release by excluding extraneous objects, such as microphones or goboes, from the areas above and below the 1.85:1 frame line and by being careful not to overshoot the set within the television area of 0.594 inches high as measured on the film.

2. 35mm camera, spherical lens (non-squeezed) photography for television presentation (Sound area blocked). (Figure 1) (See also "Television Film Cinematography.")

The television aspect ratio is 1.33:1 and the dimensions given on the accompanying diagram indicate not only the actual headroom but also suggested "safe areas" for both action and titles. In television transmission, maladjustment or electrical errors can cause cropping of the image before it reaches the home viewer. The areas so indicated delineate the usual limits of such cropping.

3. 35mm camera, spherical lens (non-squeezed) photography (full aperture). Camera aperture fills 4-perforation area, full space between perforations (0.980 inches by 0.735 inches).

A. Used for special effects duplication. No protection dimension given (image size depends on user). (Figure 2)

B. For theatrical presentation, negative image is anamorphosed or reduced spherically in laboratory prepa-

NO. 3: 35mm FULL APERTURE
SPHERICAL LENS
(FOR PARTIAL FRAME EXTRACTION)
PRINTS

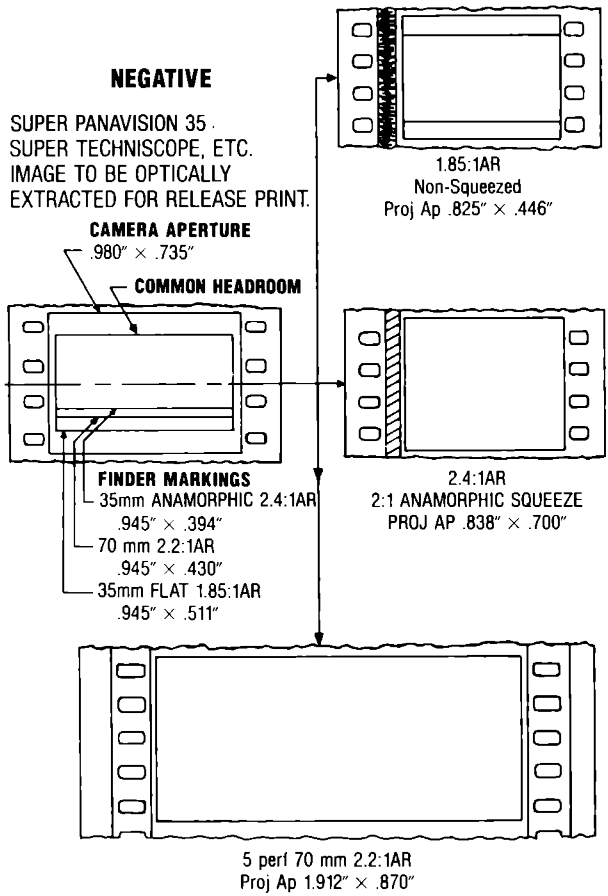


Figure 2.

ration of release printing duplicate negative. Prints must be projected with an anamorphic lens. (Alternate finder markings are shown for 35mm "flat" and 70mm extraction. Note that all extractions use the same headroom. Television extraction is not fixed at this writing; alternate versions would crop sides and extend to the bottom of the camera aperture or use the same side lines and protect the area above the nominal headroom line. There have been minor variations on this system, and guidelines are under consideration for ultimate standardization of dimensions. Use of the system depends on capability and willingness of the laboratory to make the image extractions on the release printing duplicate negatives.) (Super Panavision 35 and Super Techniscope) (Figure 2) (See also "Special Systems.")

4. 35mm camera, 2:1 anamorphic lens (squeezed) photography for theatrical presentation (Panavision and Todd-A0 35). (Figure 3)

A. 35mm contact or 1:1 prints. For this system, cameras are equipped with anamorphic lens attachments which compress the image horizontally in a 2 to 1 ratio, resulting in a lens field twice as wide as would otherwise be photographed with lenses of equal focal length. Prints from negatives photographed in this system must be projected in the theater with anamorphic lenses. At least in the United States, for all practical purposes all theaters are so equipped.

For non-theatrical distribution, 16mm prints are made either with anamorphic images or by unsqueezing to spherical ("flat") images with a 1.85:1 aspect ratio, cropping each side of the image about 12%. Because of the 16mm projector aspect ratio, anamorphic prints made at the reduction ratio of RP65-1991 will crop the top and bottom of the 35mm image. Some reduction prints have been made at 2.4:1 aspect ratio with printed-in mattes at the sides to avoid this problem, but this is not yet standard practice.

Because of the aspect ratio and the anamorphic squeeze, direct prints from this system cannot be run on television, except in letterbox. In most instances a 1.33:1 aspect ratio extraction from the center of the screen loses significant action. This problem has been circumvented in the past by "scanning" the image to follow action in the preparation of a duplicate negative from which television prints may be made — an unsatisfactory but common solution. The accompanying diagram shows the transition. A number of optical houses are prepared to supply this type of duplicate negative either in 35mm or 16mm. (Figure 4)

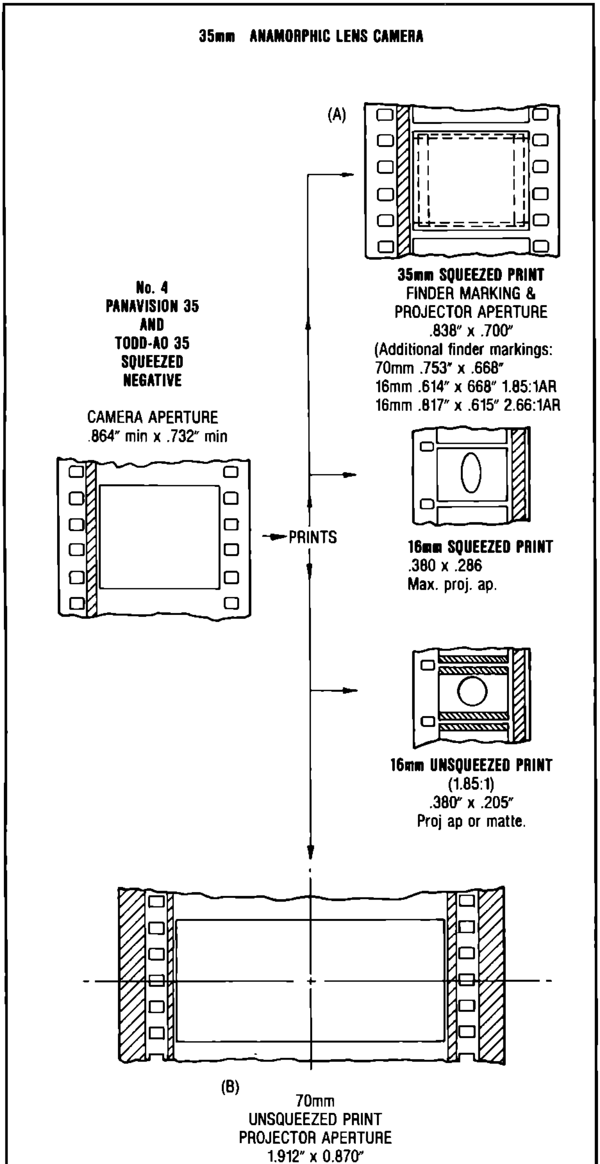
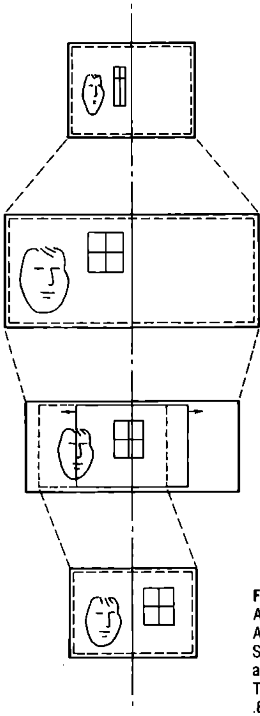

35mm ANAMORPHIC LENS CAMERA
(A)
35mm SQUEEZED PRINT
FINDER MARKING &
PROJECTOR APERTURE
.838″ x .700″
(Additional finder markings:
70mm .753″ x .668″
16mm .614″ x 668″ 1.85:1AR
16mm .817″ x .615″ 2.66:1AR
No. 4
PANAVISION 35
AND
TODD-AO 35
SQUEEZED
NEGATIVE
CAMERA APERTURE
.864″ min x .732″ min
PRINTS
16mm SQUEEZED PRINT
.380 x .286
Max. proj. ap.
16mm UNSQUEEZED PRINT
(1.85:1)
.380″ x .205″
Proj ap or matte.
(B)
70mm
UNSQUEEZED PRINT
PROJECTOR APERTURE
1.912″ x 0.870″

Figure 3.

SCANNING ANAMORPHIC IMAGES FOR TELEVISION



ORIGINAL PHOTOGRAPHY
Camera Aperture .864″ x .732″ min.
Projector Outline .838″ x .700″
Squeeze Ratio 2:1
Anamorphic camera lens

Schematic figure:
TOTAL IMAGE OF ORIGINAL PHOTOGRAPHY—UNSQUEEZED
Screen Aspect Ratio 2.36:1
Areas 1.728″ x .732″
1.676″ x .700″

LINEAR REDUCTION OF ABOVE TOTAL UNSQUEEZED IMAGE AREA
Area for selective scanning: 1.459″ x .616″

MASKING to follow important action equals **TV SAFE ACTION AREA**: .713″ x .535″

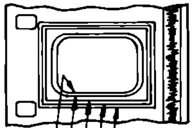
FINAL PRINTED IMAGE
Aspect Ratio: 1.33:1
Area: .868″ x .616″ (35mm)
Suitable for TV projector aperture: .816″ x .612″ and Theatre projector aperture .825″ x .602″
or: .380″ x .286″ (16mm)

Figure 4.

16mm FILM APERTURES

TELEVISION SAFE AREA

NO. 5



CAMERA APERTURE
.404″ x .295″

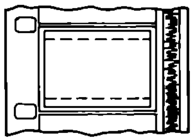
TV STATION—
PROJECTOR APERTURE
.380″ x .286″

TV TRANSMITTED AREA
.368″ x .276″

TV SAFE ACTION AREA
.331″ x .248″
CORNER RADII R = .066″

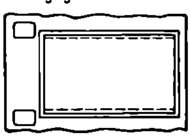
SAFE TITLE AREA
.293″ x .221″
CORNER RADII R = .058″

NO. 6 16mm FINDER MARKINGS
for enlarging to 35mm



Camera aperture .404″ x .295″
Projector aperture .378″ x .276″ (max).
Projector aperture .378″ x .205″ (1.85:1)
(enlarging ratio 1:2.18)

SUPER 16 (16mm Type W)
for enlarging to 35mm



Camera aperture .493″ x .292″
Projector aperture .463″ x .279″
Projector aperture .463″ x .251

Figure 5.

B. 70mm de-anamorphosed (unsqueezed) prints. Several laboratories are equipped to manufacture 70mm positive prints from such negatives. The aspect ratio of 70mm prints (2.2:1) crops very little from the 35mm image, which is anamorphically unsqueezed in the making of the prints. The resulting 70mm print therefore is projected with spherical lenses. 70mm prints are striped with magnetic oxide, and their soundtracks are capable of carrying six channels.

16mm Systems

5. 16mm camera, spherical lens photography for television, industrial and educational use. (Figure 5) (See also "Television Film Cinematography.") 16mm cameras equipped with spherical (nonanamorphic or "normal") lenses are used for this type of photography. Either reversal or negative films may be used as camera originals. Because 16mm is used for economy as well as portability, direct contact release prints are often made from the camera original film when only a few are required. In such cases, extreme care should be taken to protect the original. For prints in quantity, duplicate negatives are made on appropriate raw stock. The same comments as to the limitations of television transmission apply as were noted in the 35mm television section above (#2). The accompanying diagram shows the dimensions for the ground glass to be used for 16mm photography for television.

6. 16mm camera, spherical lens photography for enlargement to 35mm for theatrical presentation. (Figure 5) (See also "Shooting 16mm Color Negative for Blowup to 35mm.") From 16mm originals, 35mm duplicate negatives may be prepared by optical enlargement for the manufacture of 35mm release prints for theatrical distribution. Most theaters in the United States are currently matting 35mm prints to a 1.85:1 aspect ratio.

The accompanying diagram shows the height of the ground glass mark suggested for this type of photography. As with 35mm photography, it is wise to protect the balance of the aperture so that both theatrical and television prints will be suitable.

7. 16mm special camera, spherical lens photography specifically for enlargement to 35mm wide screen for theatrical presentation. (Figure 5) (See also "Shooting 16mm Color Negative for Blowup to 35mm.") (Super 16 or 16mm Type W) Special 16mm cameras with extended-width apertures extending into the area usually reserved for the sound track are used for this system. The aspect ratio of the resulting negative is 1.66:1, and this image is enlarged to the standard 35mm sound film aperture. 1.66:1 is commonly used in Europe and 1.85:1 in the U.S. Both dimensions are given for finder marks. A specially centered 1.33:1 16mm or 35mm duplicate negative and/or print is required for television display.

Special Purpose Systems

During the history of motion pictures, there have been numerous camera and projection systems, some of which have had widespread use for a period and then have become obsolete. It is the purpose of the American Cinematographer Manual to explain and display current systems; for history, please refer to earlier editions of the manual and *American Cinematographer* magazine.

8. 65mm, 5-perforation, frame photography for compositing to one of the 35mm systems. Any part of the negative image may be used.

9. 65mm, 5-perforation, frame photography for printing on 70mm. The difference in camera and projector apertures allows for a magnetic sound track between picture and perforations on each side, and the added 5mm width allows for two magnetic sound tracks outside the perforations on each side. (Figure 6)

A. General theatrical distribution; rarely used presently.

B. Showscan; uses this format but photographed and projected at 60 fps in a specially designed theater environment on a large screen at higher than standard brightness and with terraced seating to improve sightlines. Grain, flicker and image "strobing" are minimized.

C. For special purpose projection systems such as Disney's 3-D at EPCOT.

10. 65mm, 15-perforation, horizontal frame photography (24 fps) (Imax/Omnimax). (Figure 7) The film format for the two systems is the same. Imax is projected on a large flat screen in specially designed theaters.

Omnimax is photographed with a "fisheye" lens, optically centered 0.37 inches above the film centerline and displayed on a dome screen, filling 180 degrees laterally and 20 degrees below and 110 degrees above the horizon for central viewers. The picture shape is thus elliptical. Both systems use terraced seating to improve sightlines.

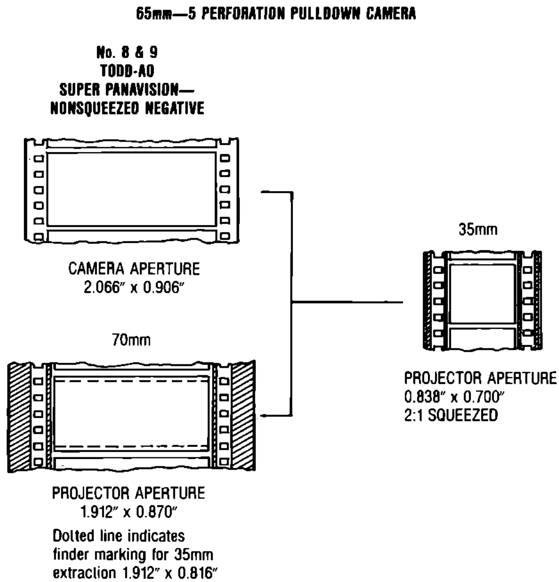


Figure 6.

11. 35mm, 8-perforation, horizontal frame photography (VistaVision) for compositing to one of the 35mm systems. As any part of the negative image may be used to suit the user, no projection aperture or finder markings are shown. (Figure 8) (Lens angles are given in the tables only for the full negative aperture.)

Depth of field is also affected by the ultimate use; it is therefore suggested that the 35mm tables be used as a guide to the relative depth of field, one lens to another, until test results are seen on the screen.

12. Proposed 35mm anamorphic projection systems using 1.5:1 squeeze and the conventional (ANSI PH22.195 Style B) anamorphic projection aperture for a 1.8:1 aspect ratio. Source camera negative would be VistaVision (Figure 8) or 35mm full aperture (Figure 2) from either of which a laboratory printing duplicate negative would be anamorphically printed; alternately, 1.5:1 anamorphic lenses would be used on standard 35mm cameras.

13. 65mm 8-perforation, frame (vertical pulldown) photography (24 or 30 fps) (Dynavision). Camera aperture 2.080" X 1.480" for printing on 70mm positive film. Lenses may be "fisheye" for dome theater projection or conventional focal lengths for 4 X 3 aspect ratio projection.

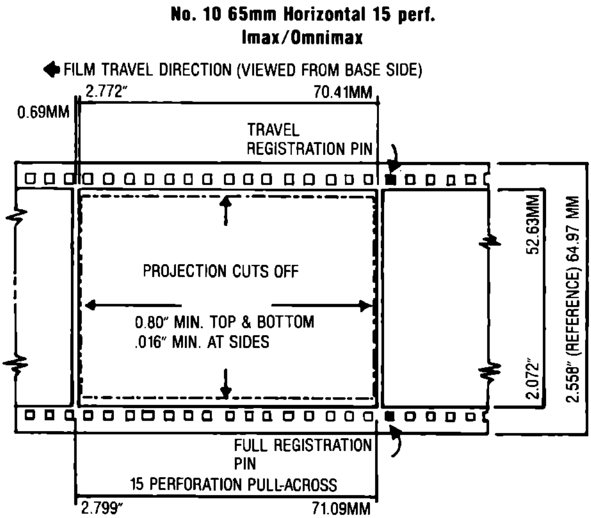


Figure 7.

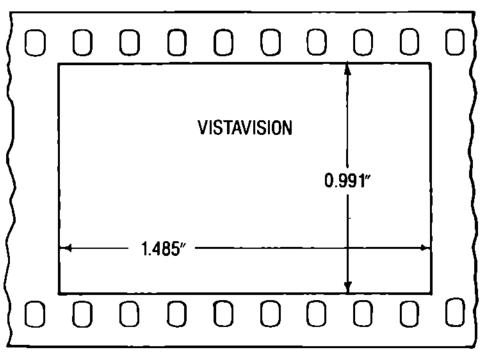


Figure 8.

Pros and Cons of 1.85, 2.35 and Super 35 Film Formats

by Rob Hummel

The most prevalent film formats, or aspect ratios, projected in the United States are 1.85 and 2.35. As a point of reference, these ratios are determined by dividing the width of the picture by the height, which is why you will sometimes see them written as 1.85:1 or 2.35:1 Verbally, you will hear them referred to as *"One Eight Five"* or *"Two Three Five"* (2.35 is also often referred to as *"Scope,"* referring to its origins as Cinemascope).

An examination of films over the past forty years shows that format is not automatically dictated by dramatic content. It is a creative choice on the part of the cinematographer and the director. The full range of drama, comedy, romance, action or science fiction can be found in both aspect ratios. The purpose here is to advise on the pros and cons of both aspect ratios and the photographic alternatives available to achieve them. This should help a filmmaker make an informed decision as to which format is best for a given project.

As a clarification in this discussion, *Full Aperture* will refer to the total area between the 35mm perforations, including the area normally reserved for the soundtrack (this *Full Aperture* area is also referred to as the camera aperture). *Academy Aperture* will refer to that area of the negative excluding the soundtrack area. Academy Aperture got its name when the Motion Picture Academy established the standard for where to place sound and picture information when the first talkies were produced.

While all 1.85 composed films are achieved with *normal*, spherical lenses, the 2.35 aspect ratio can be achieved in two ways. The most common method is with the use of anamorphic lenses that *squeeze* the image to fit within the Academy Aperture (see Illustration 6). The alternate method (Super 35, Super Techniscope) uses *normal* lenses without any distortion of the image. Both methods will be discussed here.

Also, the formats discussed here deal with general 35mm motion picture photography. Formats such as VistaVision and 65mm are most often used for visual effects and special event cinematography and would require a separate article.

Composition

Before getting into specifics about the different formats, I want to point out the composition differences between the two aspect ratios of 2.35 and 1.85, regardless of how they are achieved photographically.

Illustration 1 displays a given scene of the Tàj Mahal. On this image, a 2.35 aspect ratio is outlined by a white rectangle.

In Illustration 2, two 1.85 aspect ratios are outlined by white rectangles. The larger of those two rectangles repre-

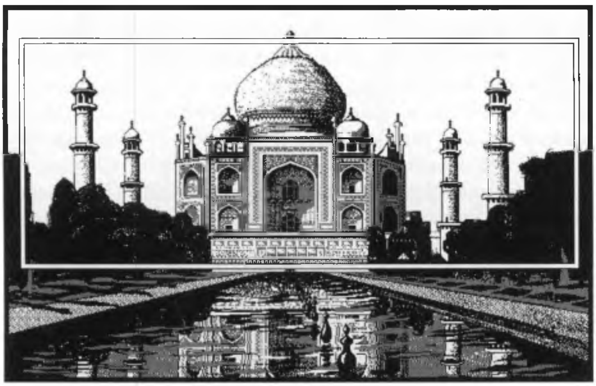


Illustration 1 - Aspect Ratio 2.35:1

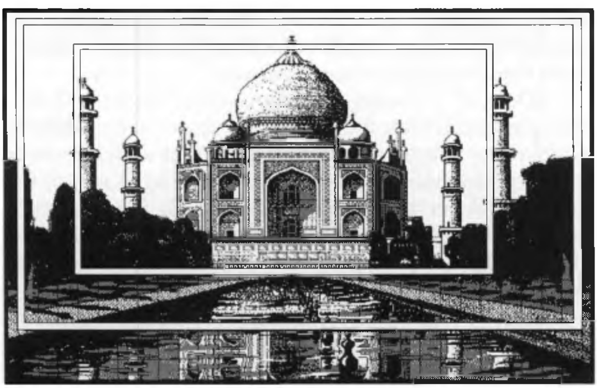


Illustration 2 - Aspect Ratio 1.85:1

sents a 1.85 composition equal in its *width* to the 2.35 aspect ratio in Illustration 1. The smaller 1.85 rectangle is equal in *height* to Illustration 1's 2.35 rectangle.

Illustrations 1 and 2 demonstrate that a 1.85 image has potential of encompassing as much width as a 2.35 image. Although 1.85 will take in the same width with greater height in the composition, it's important to realize that wide sets and vistas are not restricted to the 2.35 format.

I. The 1.85 Aspect Ratio

Photographed in NORMAL Academy Aperture Photography

1.85 is far and away the most common aspect ratio for motion pictures filmed in the United States. I say the U.S., since around the world the aspect ratio most commonly used swings between 1.85 and 1.66 depending on the country.

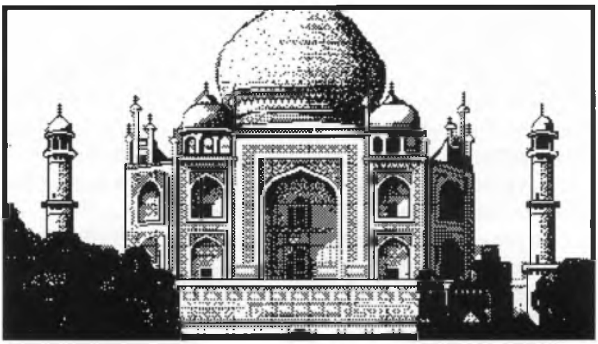


Illustration 3 - 1.85:1

Illustration 3 portrays how a 1.85 film composition would be framed in the viewfinder of the camera.

Illustration 4 shows how that image appears on the negative and subsequently on a positive print for projection. Although you wouldn't have an optical track until final composite prints are made, the track is illustrated here for clarity. The shaded areas of the film frames indicate that area of the Academy aperture that goes unused in a 1.85 film. Although additional picture information is usually contained within that shaded area, it is masked out when the film is projected.

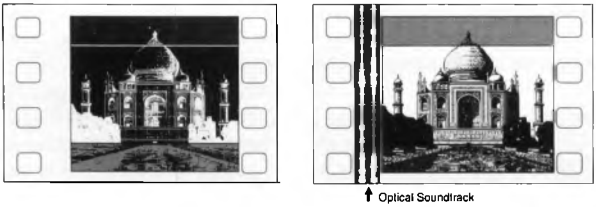


Illustration 4 - 1.85:1. Above Left: The scene as it appears on the negative. Above Right: the scene as it appears on a contact print for projection.

When the film is finally projected in a theater (assuming it is projected properly), it will appear the same as originally composed in the viewfinder (see Illustration 3).

A. Advantages of 1.85

1. Many perceive 1.85 as more appropriate for pictures that lend themselves to more compact visuals. Since close-ups virtually fill the entire frame, it is often considered a more "intimate" format.

2. If a film is largely interiors, 1.85 is often argued as the preferred format, since interiors usually don't involve the wide panoramic vistas associated with 2.35. On the other hand, many do not weigh interiors or exteriors in their choice of format.

3. Greater depth of field (the total area in focus at a given distance). Since 1.85 uses shorter focal length lenses as compared with anamorphic, greater depth of field is more easily attainable, making photography less prone to focus problems. This advantage is sometimes negated by cinematographers using such small amounts of light that they have to shoot with lenses "wide open," resulting in a small gain in depth of field.

4. An opinion often expressed is that sets don't need to be as wide on a 1.85 film as one photographed in 2.35, resulting in savings in set construction. However, many would argue that film format has no bearing on the width of set construction. As Illustrations 1 and 2 pointed out, it's possible for 1.85 to require as wide a set as 2.35, depending on the composition.

5. 1.85 is the simplest format to execute from a mechanical/technical standpoint. The choice of photographic equipment is virtually unlimited, as any standard 35mm camera will accommodate this format.

6. If a stunt camera mount is required that risks destroying a camera, there are a number of expendable cam-

era bodies available.

7. With some effort on the shooting company's part, composition can protect for video so that a simple one-to-one transfer can be done without panning and scanning. While left and right image integrity remain virtually intact this way, there is an approximate 33% increase in the vertical height of the composition.

Although many think it routine to protect the TV area from intruding objects (e.g., lights, microphones, etc.), it makes the cinematographer's job more difficult, by preventing him or her from bringing lights down close to the area of composition. This is why many cinematographers shooting 1.85 prefer to shoot with a 1.66:1 aspect ratio hard matte. 1.66 is slightly larger than 1.85, closely approximating the height of the TV frame, and it gives the cinematographer more freedom to light his subjects, without fear of a light or microphone showing up when transferred to video.

8. Many people believe it is an advantage to shoot 1.85 because spherical lenses are sharper than 2.35's anamorphic lenses. This is a misconception. It is true that spherical lenses are sharper than anamorphic; however, the much greater negative area used with anamorphic more than makes up for the subtle difference in resolution from spherical lenses.

B. Disadvantages of 1.85

1. The main disadvantage is the actual size of the 1.85 format on the negative. Because of the smaller area, 1.85 is noticeably grainier than anamorphic 2.35. This is not as noticeable in the original negative stage, but becomes more pronounced after going through dupe negatives.

The negative area of 2.35 anamorphic is a 59% increase over the 1.85 area.

2. Because of the greater height of 1.85's aspect ratio, ceilings of sets are more prone to being photographed. This can be a restriction on how easily a cameraperson can light an interior set (visible ceilings limit light placement). On some sets, it may require additional construction.

3. Opticals (dissolves, repositions, etc.) tend to be grainier than with anamorphic 2.35.

A current trend is for editors to order "double IP" opticals, compensating for the smaller negative area of 1.85. This improves the quality of opticals, but at greater expense.

4. Not truly compatible with 70mm. Although it can be done, there is a large amount of unused print on the sides when blown up to 70mm (see Illustration 11). Also, because of the greater magnification in 1.85 70mm prints, grain is much more apparent than in anamorphic blow-ups to 70mm.

5. When projected, the area of the frame for 1.85 is subjected to much greater magnification on a screen than an anamorphic frame, resulting in more apparent grain in the image.

II. The 2.35 Aspect Ratio

Photographed with *Anamorphic (Scope)* Lenses

The following is a discussion of the 2.35 aspect ratio photographed with anamorphic lenses. A discussion of Super 35 composed for 2.35 will follow.

Anamorphic 2.35:1 (also known as "Cinemascope" or "Panavision") optically *"squeezes"* the width of the image to fit within the 35mm Academy Aperture. Illustration 5 portrays how an anamorphic 2.35 scene would appear in the viewfinder.

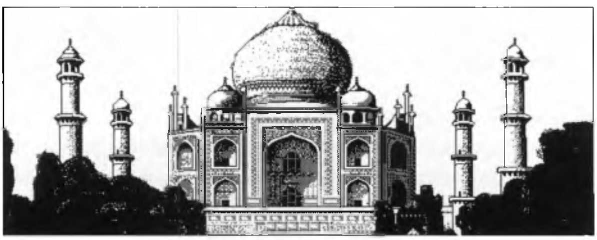


Illustration 5

Illustration 6 shows how that image appears on the negative and subsequently on a positive print for projection.

When the film is finally projected in a theater (assuming it is projected properly), it will be *"unsqueezed"* by an anamorphic projection lens and appear on the screen the same as originally composed in the viewfinder (see Illustration 5).

A. Advantages of Anamorphic 2.35

1. The most salient advantage is the much larger negative area. A 59% increase in negative area over 1.85 results

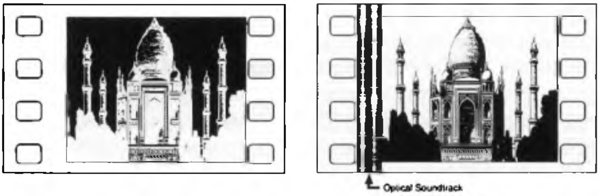


Illustration 6 - Anamorphic 2.35:1, Above Left: The scene as it appears on the Negative *"squeezed"* by the anamorphic lenses. Above Right: The scene as it appears on a Contact Print for projection.

in finer grain, better opticals, and an increase in apparent sharpness (apparent because while a similar image photographed in 1.85 will be sharper, the increase in grain and greater magnification actually make it appear less sharp). This difference becomes most apparent after going through the dupe negatives.

2. More compatible with 70mm. Because of the original negative area, there is less of a blow-up than with 1.85, resulting in finer grain in the 70mm print. Also, the aspect ratio can fill the entire 70mm print frame.

3. Allows for complex compositions. Able to do a tight close-up on two individuals simultaneously. Action can be spread across a wide expanse of the frame.

4. Most often the format of choice for films with a lot of action or big production values.

5. Most closely approximates the normal field of vision.

6. When shooting interiors, ceilings become obscured, giving the cinematographer more alternatives for placement of lighting.

7. A possible advantage may come with continuing advances in High Definition TV. The area of negative used in anamorphic films means you will exceed HDTV's resolution capability for many years to come. Some HDTV technologies are already almost equal to 1.85's resolution capability.

B. Disadvantages of Anamorphic 2.35

1. Difficult video transfer. To extract a video image directly from the center of the 2.35 frame usually results in odd compositions and the exclusion of relevant action.

An alternative is to "pan and scan" the image (panning the width of the 2.35 frame, following the most important action). While not mechanically more expensive than regular video transfer, panning and scanning usually costs more due to the extra time required by each scene's composition decisions. While panning and scanning makes the best of a bad situation, many people feel it compromises the original compositions. Many filmmakers have released videos of their films in "letterbox" format, where the 2.35 format is maintained by putting black mattes above and below the frame. This is a common practice in videodisc releases of films.

The difficulty in video transfer is the most often stated disadvantage of the 2.35 format.

2. It is often said that anamorphic is more expensive than 1.85. However, the difference in cost between an anamorphic lens package vs. a 1.85 lens package is negligible. Anamorphic would be approximately $2,400.00 more expensive over the course of a ten-week film schedule.

Also, discussions with a number of prominent cinematographers indicate that they wouldn't increase the size of their lighting package significantly for the 2.35 aspect ratio (in fact, one said it wouldn't change at all).

3. Single close-ups result in wide areas on either side of a face, with potential for distracting objects in the frame. However, due to the nature of anamorphic's longer focal length lenses, usually anything in the background on either side of a face would be severely out of focus.

4. Many people feel that sets need to be built wider because of the wider aspect ratio. There are also many who feel it doesn't matter, and that sets can be accommodated by choosing lenses carefully. See again Illustrations 1 and 2 and the discussion under Composition.

5. Some directors have a hard time blocking action within the larger frame.

6. Expense of more extras may be necessary for some crowd scenes.

III. Super 35 Formats

The Super 35 Formats, known under a variety of names such as Super Techniscope, Super 1.85, and Super 2.35, are all flat, spherical lens formats using equipment similar to that used in 1.85 photography. All of the Super 35 formats require an optical step when making dupe negatives for release prints.

Illustration 7 is a diagram of a standard Super 35 frame of film where all aspect ratios are aligned on Full Aperture center. As the illustration shows, information is usually exposed over the entire Full Aperture area of the film. The filmmaker decides what format he is composing for, and it is that aspect ratio the film lab will eventually extract from the frame for release prints.

When speaking of Super 35, people are usually referring to its use in composing for a 2.35:1 aspect ratio, the same ratio as 2.35 anamorphic.

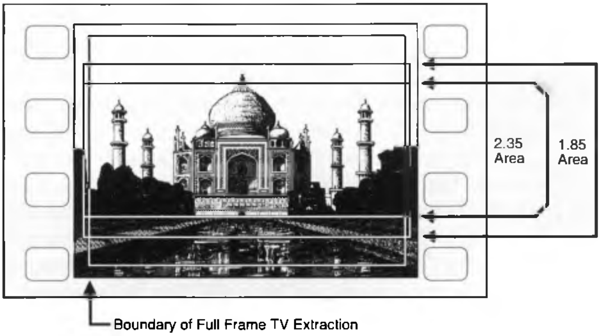


Illustration 7 - Standard Super 35/Super Techniscope

Anamorphic 2.35 uses special lenses that squeeze the wide image to fit within the standard Academy Aperture frame. Super 35 composes for 2.35 with standard lenses and extends the width of the frame into that area of the negative reserved for the soundtrack. Although most cameras already expose picture information in the soundtrack area, it normally goes unused.

At times, people will suggest shooting Super 35 composed for 1.85 (a. k. a. Super 1.85). The reason for this is a belief that the slight increase in negative area with Super 1.85 will yield a finer-grain image for release. Tests have shown this is not so. Once the negative has gone through interpositive and internegative, and been optically repositioned for standard 1.85 release, there is at best no difference between Super 1.85 and standard 1.85 photography, and depending on the scene, Super 1.85 can look worse than standard 1.85.

Standard 1.85 produces all dupe negatives and prints with contact printing, while Super 1.85 requires an optical step to reduce the image into the standard 1.85 area. Contact printing significantly reduces the appearance of grain, while any optical step precisely focuses the grain in a negative, effectively enhancing the appearance of grain.

As for arguments that Super 1.85 yields a better 1.85 blow-up to 70mm, the difference is slight, and only noticeable in a direct A/B or side-by-side comparison. Otherwise it is indistinguishable. If, however, a scene is already committed to an optical step (i.e., a visual effects shot), Super 1.85 may provide an improvement in negative area that results in a better image quality when compared with a standard 1.85 image going through the same optical process.

Another method of photography for Super 35 is referred to as *common topline* (see Illustration 8). *Common topline* derives its name from the ground glass of the camera having multiple formats scribed on it, all having the same, or common, topline. This variant of Super 35 is based on the notion that it could be a generic film format; the filmmaker may shoot a movie with the option of releasing it in any aspect ratio desired. The *common topline* is supposed to lessen the effect of changing aspect ratios by maintaining the headroom and raising or lowering the bottom of the frame. In actual practice, most cinematographers find it disagreeable to compose for multiple formats. Also, the change in composition from 2.35 to 1.85 or television's 1.33 can be quite objectionable (close-ups become medium shots, etc.).

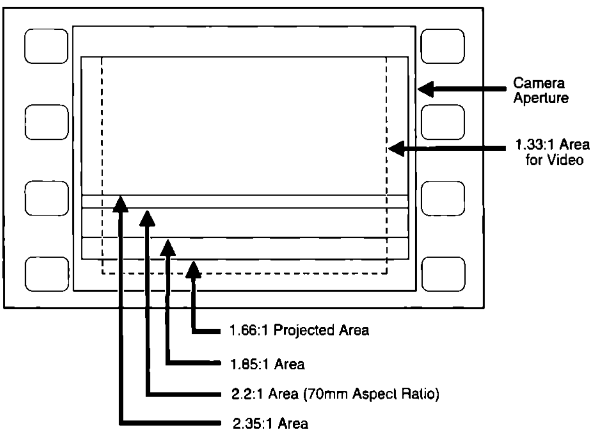


Illustration 8 - Super 35/Super Techniscope Common Topline

Experience has shown, most filmmakers agree, that just modifying a film's aspect ratio to fit within the video realm is a creative process. To assume that a generic format will automatically deliver pleasing compositions no matter what aspect ratio you choose does not hold up creatively.

The rest of this discussion will only deal with Super 35 composed for a 2.35:1 aspect ratio. Illustration 9 portrays how Super 35 composed for 2.35:1 would appear in the viewfinder.

A. Advantages of Super 35 Composed for 2.35 Aspect Ratio

1. The main reason for choosing this format is its greatly increased depth of field over anamorphic 2.35. Where anamorphic lenses have to rack focus to keep near and distant objects sharp, Super 35 has a greater potential for keeping both objects in focus simultaneously.

However, as stated in the advantages of 1.85, the potential for greater depth of field can be negated if cinematographers choose to use such small amounts of light that they must shoot with lenses "wide open," resulting in a small gain in depth of field.

2. An often-stated advantage is the production savings in the lens/camera package over anamorphic. This is erroneous, since the expense of optical Super 35 dupe negatives (needed for release prints) negate any cost savings in production.

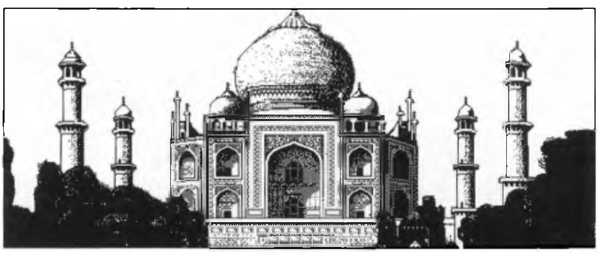


Illustration 9 - Super 35 Aspect Ratio 2.35:1

3. The ability to shoot a film composed for 2.35 and, if necessary, change directions and release in 1.85 by increasing the top and bottom of the frame. For most filmmakers, however, this would be a serious compromise of the original composition (see Illustration 7).

4. Lenses are much smaller than anamorphic, resulting in a smaller, more lightweight and portable camera package. This smaller size allows the camera to fit in smaller places than the large anamorphic optics allow (this is one

of the reasons the format was chosen for *Top Gun;* the cameras were able to fit in the aircraft cockpits).

5. Often claimed to be more compatible with 70mm than anamorphic. Some have this impression because Super 35 is a straight blow-up to 70mm, while anamorphic has to be unsqueezed when enlarged to 70mm.

This would be true if Super 35 had an equivalent negative area to anamorphic. As it stands, anamorphic's greater negative area makes up for any possible loss of resolution when unsqueezed to 70mm. As a result, 70mm prints from Super 35 appear significantly grainier than those from anamorphic negatives.

6. Claimed to be a simpler video transfer by just doing a 4-perf frame extraction, resulting in dramatic increase in top and bottom areas over the original 2.35 composition (See Illustration 7). In practice this never works, since a full frame extraction is such a distortion of the original composition (for example, close-ups become medium shots). A panned and scanned video transfer is what ends up being done for the bulk of the film with a few full-framed extractions where appropriate (*Ferris Bueller's Day Off* is an example).

B. Disadvantages of Super 35 Composed for 2.35 Aspect Ratio

1. Most notable is the small negative area. Anamorphic 2.35 has an increase in negative area of more than 60%. It also has slightly less negative area than *standard* 1.85 photography. The difference in negative area becomes most pronounced after 35mm dupe negatives are made. Anamorphic dupe negs are made with contact printing, which in itself tends to lessen the appearance of grain. Super 35 dupe negs involve an optical step during which the image is blown up, then squeezed to produce an anamorphic image for release prints. Because of this optical step, grain in the negative tends to be more sharply resolved, making it more objectionable.

2. For best quality, all dissolves and fades must be done with A & B printing in the laboratories. When these effects are done by an optical house they become excessively grainy in release prints.

3. Because of the optical step involved, composite prints cannot be struck until after dupe negatives have been made.

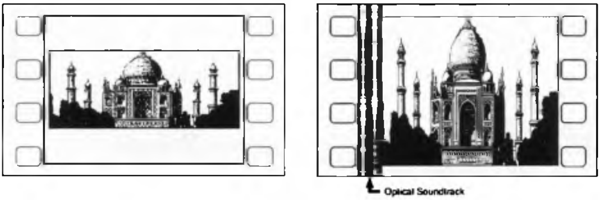


Illustration 10 - Super 35 Aspect Ratio 2.35:1. Above Left: The scene as it appears on the negative, positioned within the FULL aperture frame. Above Right: The scene as it appears on a print for projection, after being blown up & *"squeezed"* to make room for the optical soundtrack.

4. Again, because of the optical step involved, original negative composite prints cannot be struck. Actually, it is technically possible, but can only be done with complex procedures and such a high risk of failure that it doesn't merit subjecting the original negative to the handling involved.

5. More difficult to preview because of a special projection mask required for the Full Aperture work print. Since Super 35 uses the area reserved for a soundtrack in the work print stage, many theaters cannot be adapted to project the format.

6. Main title opticals must be done with the "double IP" method to maintain quality, doubling the expense of such opticals.

7. Editing equipment must be adapted to show the soundtrack area.

8. Because of the small negative area, many cinematographers limit choice of negatives to slower speed stocks (i.e., 5245, 5248), or overexpose high-speed negatives 1-½ to 2 stops for better grain quality, often negating the advantage of the high-speed negative.

9. Video transfers usually involve panning and scanning because of the wide-screen aspect ratio. This is also a pan and scan of a much smaller negative area than anamorphic 2.35, resulting in a lower quality video transfer. This becomes most evident in letterbox versions of a film and particularly on HDTV.

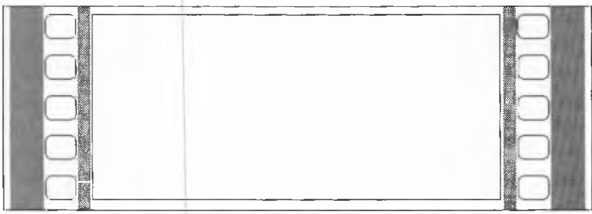
10. There is potential for more expensive visual effects, if a decision is made to have coverage beyond the 2.35 composition, allowing for full frame video transfers. Matte shots, miniatures, etc., might be compromised on full frame transfers if the image isn't protected completely to 1.33 (see Illustration 7).

The author wishes to thank Marty Katz for making him write this in the first place, and Harrison Ellenshaw, Stephen H. Burum, ASC, Skip Nicholson and Evans Wetmore for their help in bringing greater clarity to the article and keeping him honest. Also, thanks to Trici Venola for the use of her computer graphic of the Taj Mahal.

35mm Blowups to 70mm Prints

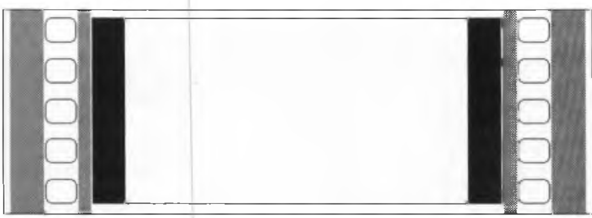
Aspect Ratio 2.2:1

The aspect ratio of 70mm prints (and 65mm camera negative) is 2.2:1. Since 35mm films are not usually photographed in this aspect ratio, they must adapt their composition to fit within this area. In this illustration of a 70mm frame, the gray area represents a magnetic soundtrack.



Aspect Ratio 1.85:1

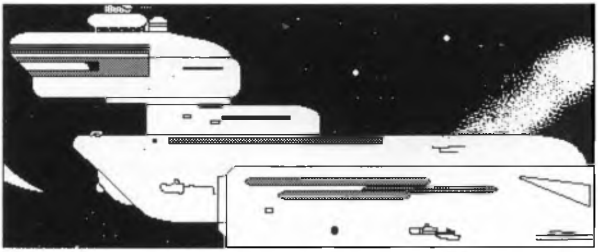
When 1.85:1 films are blown up to 70mm, the full height of the 70mm frame is utilized. All 1.85 picture information is maintained with black burned into the unused area of the frame.



Most theaters have black screen masking (black curtains) that they use to cover areas of the screen that don't have any image on them. In a 1.85 70mm print, although the black area does not contain any picture information, theaters must be careful not to close their screen masking over the black area on the screen. Were they to do so, the masking might cover speakers placed behind the screen that are utilized for 70mm soundtracks. The only exception to this rule are theaters that have acoustically transparent masking (all THX 70mm theaters have transparent masking).

Aspect Ratio 2.35:1

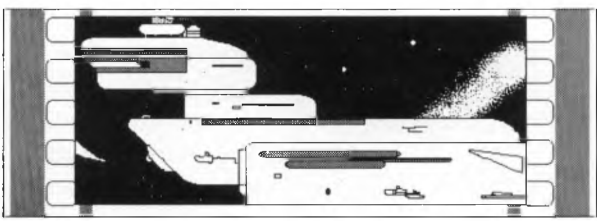
The image below has a 2.35:1 aspect ratio.



What follows are examples of the options, and potential compromises, available to adapt a 2.35:1 composition for 70mm release.

Most often, film labs will enlarge the 2.35 image to fill the entire area of the 70mm frame. Although the height of the 2.35 composition is not affected this way (i.e., all North-South picture information remains intact), information is lost on the right and left sides of the composition.

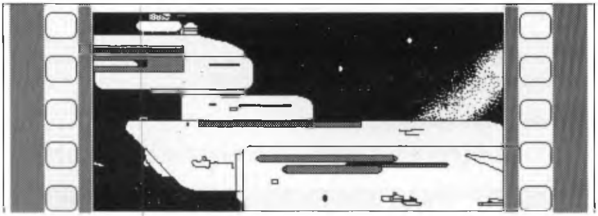
The frame below graphically illustrates what information is lost when 2.35:1 is blown up to fill the entire 70mm frame.



2.35 to 70mm Prints Continued

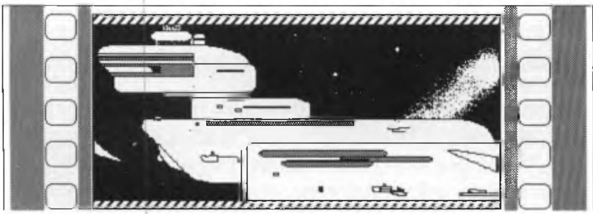
The following illustration shows how the image actually appears on the 70mm print and when projected in the theater after being blown up to fill the entire 70mm frame.

The alternative method for blowing up 2.35:1 images to 70mm is to maintain the full width of the aspect ratio. This is accomplished by fitting the 2.35 area within 70mm's



2.2 area and burning black above and below the picture, effectively giving the film thicker frame lines. A number of films have been released in this manner in recent years, including *Superman, The Untouchables,* and *Star Trek IV.*

In this example, the area that would be a thick black frameline is crosshatched for clarity in this illustration. It would not appear this way in an actual 70mm print.



Cameras

65mm

35mm

35mm continued

VistaVision

16mm

65mm Cameras

Arriflex 765

Movement: The 765 uses advanced microprocessor control technology to link two quartz-controlled DC motors in a direct drive configuration to control shutter and film transport. No belts or mechanical couplings are used in the drive system. Dual registration pins, triple-pin pull-down claws and user-adjustable pitch control assure image quality to optical printer standards.

Speed Range: Quartz-accurate sync at 15/24/25/29.97/30/60/75 fps on-board; 2-100 fps with the CCU; 24 fps reverse; and 1 fps with the 765's Remote Control Unit. Run-up time is less than 1 second at 24 fps.

Shutter: Rotating, microprocessor-controlled silicon mirror shutter, mechanically variable from 15° to 165°, plus 144°, 172.8°, and 180°.

Reflex Viewfinder: The viewfinder has a built-in optical turret that permits on-the-fly selection of either 80:20 or 100:0 video/viewing ratios, and has a switchable ND.6 contrast viewing glass, ArriGlow illuminated frame lines, and a finder extender with built-in 2X image magnification. A short finder (for portable operation) and a video finder are also available. A wide-angle eyepiece with manual iris closure, 8X magnification, and 2± diopter adjustment is standard.

Camera Control Unit (CCU): The CCU remotely turns the 765 on and off, and also activates speed changes, from up to 100 feet away.

Lens Mount: 64mm diameter Maxi-PL (Positive Lock) lens mount; flange focal distance of 63.5mm; designed for ARRI Maxi-PL prime and RTH Cooke zoom, wide-angle and telephoto lenses.

Drive: Microprocessor-controlled 24V DC motor in direct-drive configuration to shutter and movement. Power input via a 3-pin connector: pin 1 is (-), pin 2 is + 24V. Operating temperature range is -4°F to +122°F (-20°C to +50°C).

Operating Noise Level: 25 dBa at 24 fps; 28.5 dBa at 30 fps.

Indicators: In-finder displays: out-of-sync and film-end. Digital LCD Tachometer and Footage Displays: camera left/right; audible and visible out-of-sync; low battery; and feet/meters footage display.

Magazines: 400' (160m) and 1000' (300m) displacement with microprocessor-controlled torque motors. Microprocessor samples and adjusts feed/take-up tension and all other functions continuously. Automatic connection and data transfer to camera via multi-plug pin plug. Mechanical and digital LCD counters.

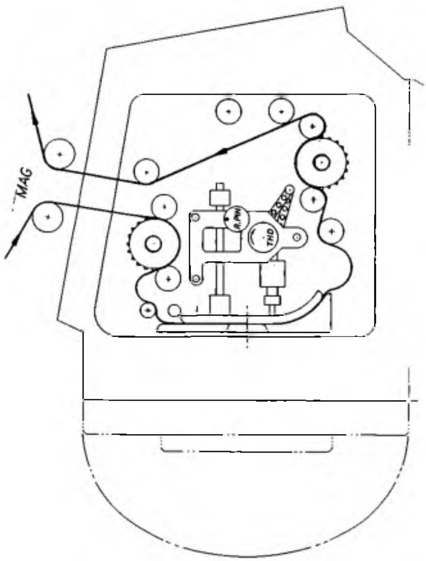
Lenses: ARRI/Zeiss 65mm format lenses include 30mm, 40mm, 50mm, 60mm, 80mm, 100mm, 110mm, 120mm, 150mm, 250mm, 350mm, 2X Mutar Extender, and a 38-210mm zoom. Maximum aperture ranges from T-1.8 to T-4.2 for prime lenses, and T-6.2 on the zoom.

Matte Boxes: The 765's 6.6x6.6 Swingaway Production Matte Box covers all 65mm format lenses. Has two fully rotatable 2-filter stages. Geared filter frames.

Electronic Accessories: 1. Variable Speed and Sync Unit (VSSU): The VSSU module allows remote speed changes between 6 and 100 fps non-crystal; provides synchronization with external PAL or NTSC video signal (50/60 Hz) via up to 100' BNC cable. 2. Video Optics Module (VOM): Color and B & W CCD video tap cameras, with flicker reduction and iris control.

Additional Accessories: 2-Speed follow focus; bridgeplate support system for CG balance and mount for matte box, follow focus, servo zoom drive, and heavy lenses; finder extender and leveling rod; barney and heated barney; Arri Geared Head.

Cinema Products CP-65



This camera, designed in conjunction with Wilcam, is intended to meet the exacting needs of Showscan cinematography (60 fps) but operates at conventional speeds as well. Photographed aperture is standard 5-perf 65mm (2.072" x 0.906").

Movement: Compensating link, with dual registration pins and four pull-down claws. Retractable register pins and 2-axis stroke adjustment that permits tuning the movement for most silent operation. Removable aperture and pressure plates for ease of cleaning.

Shutter: 170° fixed-opening focal plane shutter.

Speed Range: 1-72 fps, forward or reverse, by 4-decade digital dial that is crystal accurate at all selected speeds up to 2 decimal digits. Single-frame operation under control of external intervalometer also available.

Reflex Viewing System: Rotating mirror reflex image through ground glass, with provision for film clip insertion, to a 360° erect image orientable viewfinder. Easily attached eyepiece extender with automatic leveler also available. Built-in video tap for high-resolution CCD chip camera also included.

Lens Mount: Quick-acting bayonet lock for specially mounted CP-65 lenses.

Lenses: A complete series of specially mounted prime lenses varying from 24 to 1200mm, as well as high-quality zoom lenses, are available.

Sound Blimp: The camera's self-blimped design permits sync-sound shooting at 24 fps. At Showscan speed of 60 fps, a lightweight composite material sound blimp is provided to meet exacting sound level requirements of sync sound filming.

Magazines: 1000-ft. magazines and 2500-ft. individual supply and take-up cassettes are available. Magazine blimps for both sizes are also available.

Special Features: Camera can be externally controlled for phase locking as required by process photography and 3-D filming.

Fries Model 865 65mm/8-perf.

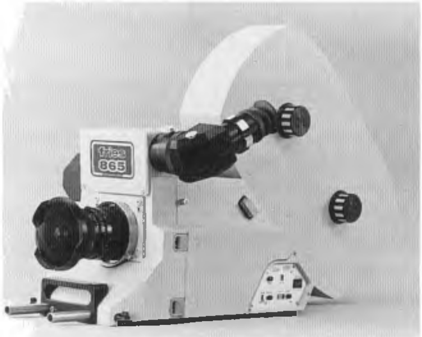
This is a large-format 65mm 8-perforation camera designed to meet the requirements of new formats for special venue productions. Photographed aperture is 2.072" x 1.450"

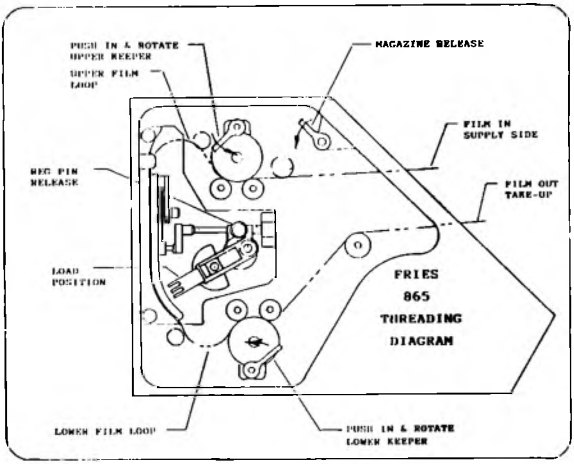
Movement: Dual registration pins and six pull-down claws. A cam and eccentric mounted on a single shaft actuate the pull-down and operate the register pins. Removable aperture and pressure plates for ease of cleaning.

Shutter: 170° fixed opening blanking shutter.

Speed Range: 2-72 fps forward or 2-30 fps reverse. All speeds crystal controlled.

Reflex Viewing System: Rotating mirror reflex image. Viewfinder is orientable through a full 360° and self-





corrected through approximately 180°. Built-in video tap for high resolution CCD chip camera also included.

Lens Mount: Universal bayonet type with a large port diameter. Special mounts available upon request.

Lenses: A complete series of Hasselblad lenses is available.

Drive: Internal 30 VDC crystal controled

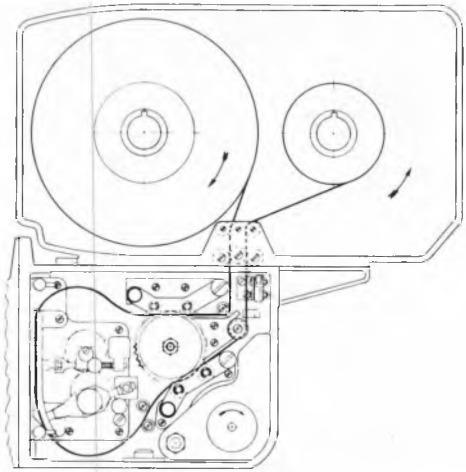
Magazines: 500ft. and 1000ft. displacement magazines with torque motor take up and hold back.

Special Features: Valve which allows the operator to direct light to the viewing system, or to the video assist or combo which splits the light between both viewing and video assist.

Weights: Camera body 45 lbs., 1000 ft. 13 ½ lbs.

Accessories: Standard Arri matte box.

Mitchell 65mm Reflex TODD-AO



(FILM TAKES UP EMULSION SIDE OUT)

Movement: Dual registration pins. Four pull-down claws. Adjustable pull-down stroke. Removable aperture plate with built-in matte slot. Aperture 2.072" x .9055" Speed range 12 fps-32.

Shutter: Focal plane 175°.

Reflex Viewfinder: Pellicle beam splitter (shock mounted) views more than full aperture area. High magnification for critical focusing; contrast viewing filters.

External Viewfinder: Large erect image viewfinder calibrated for different focal-length lenses. Calibrated for any two aspect ratios. Parallax correcting cams for all focal-length lenses.

Lens Mount: Single mount with quick-release flange T-stop calibration allows for mirror absorption. Accepts all Todd-AO fixed focal-length and zoom lenses. All lenses geared for manual follow-focus control.

Drive: Internal 28V DC motor, solid-state speed control.

Speeds: 12, 18, 20, 22, 24, 28, and 32 fps. Manual threading knob provided. Belt pack batteries. Rectifier unit

110V AC-28V DC. Camera will also accept externally mounted motors for special purposes.

Magazines: 350' lightweight magnesium displacement type; remaining footage indicator; positive clutch drive 1000' magazine also available.

Features: Weight: 27 pounds with 350' of film. Shoulder support and hand grip or tripod mount. Dual gelatin filter slot in front of film aperture. Heating system. Film runout indicator. Remote control.

Accessories: Zoom lenses: 60-150mm, 100-300mm, and 65-390mm. Underwater blimp with internal battery and externally controlled film speed, stops and focus; designed for 50' depth or less. Built-in exposure meter.

MSM Model 8870 65mm/8-perf.

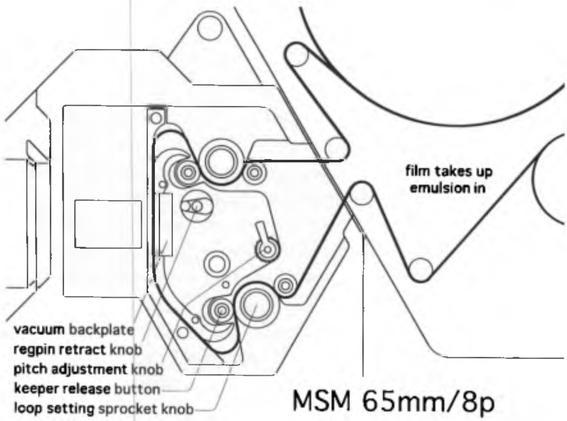
Movement: MSM Monoblock high-speed, dual-register pins, claw engages six perfs. Shrinkage adjustment changes both stroke and entry position. Indexable loop-setting sprockets have independent locking keeper rollers. Vacuum backplate assures filmplane accuracy, removes without tools for cleaning. Aperture and movement remove easily for cleaning and lubrication. Aperture size 2.072" wide x 1.485" high. Frame-rates from timelapse to 60 fps forward, also to 30 fps reverse.

Shutter: Focal plane shutter, manually variable from 172.8° to 55° with stops at 144° and 108°.

Viewfinder: Spinning mirror reflex. Interchangeable ground glasses with register pins for film clips. Finder rotates 360° with erect image; image can be manually rotated for unusual setups. Finder shows 105% of frame, magnifier allows critical focusing at center of interest. Single lever controls internal filter and douser. Heated eyepiece has large exit pupil and long eye relief. High resolution B & W or optional color CCD video tap is built into camera door with swingaway 50/50 beamsplitter. Viewfinder removes completely for aerial or underwater housing use.

Lens Mount: MSM 75mm diameter x 80mm flange depth.

BNC-style lens mount is vertically adjustable 7mm for flat or dome screen composition. Mount accepts modified Zeiss (Hasselblad), Pentax, Mamiya, and other large-format lenses. 15mm matte rods are on ARRI BL centers for accessory compatibility.



Magazines: 1000' displacement magazines use the MSM TiltLock mount. Magazines lock to the camera with a pair of 8mm hardened pins, and can tilt away from the operator to allow easier camera threading. Optional minimum profile 1000' coaxial magazines use same mount without tilt feature. Both magazines operate bidirectionally at all camera speeds. A positive camlock secures the mag in running position and switches power to the motor and heater contacts in the magfoot. Expanding core hubs have integral DC servomotors controlled by film tension in both directions, with soft startup to eliminate slack. Tightwind rollers guide film winding for smooth solid rolls at any camera angle. Non-contact light traps feature infrared end-of-film sensors.

Features: Crystal sync from 5 to 60 fps in .001 increments. Status LEDs for power, heat, low battery, mag ready, buckle, and speed sync. Two illuminated LCD footage counters. Digital battery volt/amp meter. Circuit breakers for camera, mag, heat, and accessories. Control port allows operation from handheld remote or interface with computers and external accessories.

Panavision 65mm AC (Auxiliary Camera) SPC (Speed Camera)

Movement: AC: Compensating link, dual registration pins, four pull-down claws. Low noise level.

SPC: Dual registration pins and four pull-down claws ensure same degree of steadiness as AC model.

Both Models: Movement has matte slot, removable aperture and pressure plates that can be removed for cleaning. Timing marks provided for reassembly. Aperture 2.072" by 9.055".

Speed Range: AC: Stop-motion to 32 fps.

SPC: 16 fps-72fps.

Shutter: AC: Variable 50°-200°, forward or reverse.

SPC: Variable 0°-170°, forward or reverse, segments calibrated to 10°.

Focusing: Rack over for critical focusing and lineup. Erect image telescope built-in, variable magnification, contrast viewing filters, interchangeable ground glasses, slot for mattes.

Viewfinder: Large erect image nonreflex viewfinder. Cam operated parallax correction.

Lenses: Quick-acting bayonet lock for Panavision lenses. Lenses do not rotate.

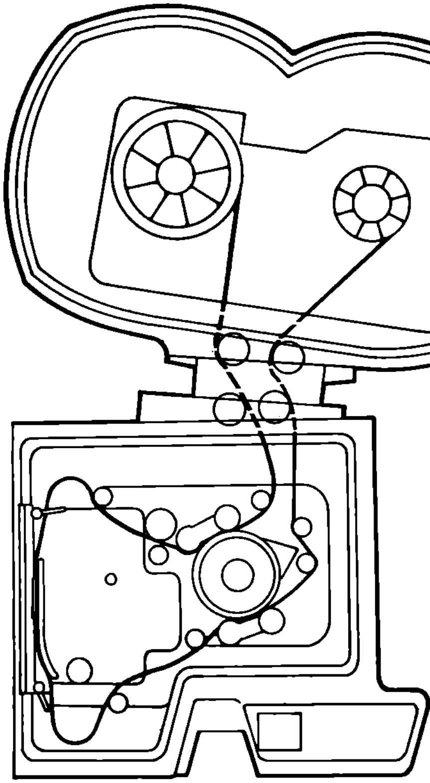
Drive: Both cameras accept all Mitchell motors. Panaspeed motor has 24 fps crystal sync and may be varied from 12 fps-32 fps. Operates on a 36V battery. For high speed, a precisely controlled motor capable of 12 fps-72 fps is provided. It operates on two 30V batteries.

Magazines: 500' and 1000' double chamber. 500' bipack magazine available for special effects.

Panavision System-65 65mm

Movement: Dual pilot pin registration ensures process-plate image steadiness. Four pull-down claws. Pitch adjustment to optimize camera quietness. Entire movement may be removed for servicing.

Aperture plate: Removable for checking and cleaning.



Shutter: Focal plane shutter with infinitely variable opening and adjustable in-shot. Maximum opening: 180°; minimum: 40° with adjustable maximum and minimum opening stops. A digital display allows adjustments in $1/10°$ increments. Micrometer adjustment allows critical synchronization with computers, TV monitors and HMI lighting at unusual frame-rates. Manual and electronic remote-control units available.

Reflex system: Reflex rotating mirror is standard and is independent of the light shutter system.

Optical viewfinder system: High magnification optical system. The viewfinder tube is orientable and gives a constantly upright image through 360°. Short, Intermediate and Long viewfinder tubes are available. System incorporates an optical magnifier for critical focusing and picture composition, a contrast viewing filter and a light-proof shutter. Wide-range ocular adjustment with marker bezel to note individual settings. A built-in "Panaclear" eyepiece heater ensures mist-free viewing. Adjustable eyepiece leveling link-arm is supplied with every Panahead to keep the eyepiece position constant while tilting. An eyepiece diopter to suit the operator's own eyesight can be provided on request.

Ground Glasses: Interchangeable ground glasses available with any marking, or combination of markings. "Panaglow" illuminated reticle system with brightness control is standard. Ground glasses with finer or coarser texture available on request. Provision for a cut frame to be placed in the viewfinder system for optical frame alignment.

Lens Mounting System: Panavision positive clamp lens mount for maintaining critical flange focal depth setting. All lenses are pinned to ensure proper rotational orientation.

Lenses: A wide range of color-matched lenses, ranging from a distortion-free 24mm to 400mm. Most are T-2 or T-2.8. Also available are a 60-360mm T-6.3 zoom and 35 and 45mm pivoting lenses for slant focusing. In addition, many of the mid-range Primo and Zeiss lenses, and the long focal length Canon and Nikon lenses, can be used with a special adaptor. All lenses checked and calibrated by MTF. All lenses have widely spaced lens focus calibrations and low image veiling glare. Lenses are supplied with adequate length iris rods for matte box and filter support. Focus control can be used from either side. Zooms are supplied with and electronic zoom control unit as standard.

Matte Boxes: A standard matte box incorporating a sunshade, provision for two 4 x 5.650" filters which can be individually slid up and down. Special matte boxes incorporating more filter stages, with provision for sliding (motorized if required), rotating and/or tilting and for taking 6.6" square filters are optional. Panavision can also supply special sliding diffusers, diopters and all manner of image control filters, etc., to use in their matte boxes.

Camera Motor: A 24-volt motor runs the camera at any speed from 4-30 fps. Camera speed is crystal-controlled at all frame rates and may be adjusted at 1 fps increments. Special sync boxes are available to synchronize the camera with a mains power supply, computers, video signals, or process projectors in shutter phase synchronization. Internal heaters ensure that cameras may be used at sub-zero temperatures without special preparation.

DBA Rating: Less than 25db with film and lens, measured 3 feet from image plane.

Magazines: 1000' and 500' magazines are available. Both can be used on the top of the camera for minimum camera length or at the rear for minimum camera height.

Optical accessories: Almost all Panaflex 35mm front-of-lens optical accessories and filters, etc., can be used on the System-65 cameras.

Batteries: Camera, magazines, heaters and accessories all operate off a single 24V Ni-Cad battery.

Camera support equipment: "Super Panahead" geared head incorporates a 60° tilt range with a built-in wedge system to allow the operator to select where that range is, anywhere between the camera pointing directly up or directly down, and three gear ratios in both the pan and tilt movements. A sliding base unit enables a camera to be quickly attached and detached and to be slid backwards and forwards on the head for optimum balance. "Panapod" tripods, with carbon fiber legs, are available in a range of sizes.

Video Assist Systems: State-of-the-art CCD video systems are available in B & W or color.

Environmental protection equipment: All System-65 cameras and magazines have built-in heaters for operation in any temperature. Heated covers are available to give additional protection to lenses, especially zoom lenses. Other covers are available to protect the camera, magazines and lenses. Spinning-glass rain deflectors are available for use in storm conditions. An autobase is available to secure the camera in conditions of vibration, high "g" forces and other stressful and dangerous conditions. A water-box is available to protect the camera in shallow water conditions; a hazard box protects the camera from explosions, collisions and other dangerous situations.

Panavision Panaflex System-65 Hand-holdable

Movement: Dual pilot pin registration ensures process-plate image steadiness. Pilot pins register in the same perforation holes (immediately below the bottom frame line) as optical printers. Four pull-down claws. Entire movement may be removed for servicing.

Aperture plate: Removable for checking and cleaning.

Shutter: 170° Fixed-opening focal plane shutter.

Reflex System: Two models are available — one has a rotating mirror, the other a semi-silvered fixed reflex mirror for flicker-free viewing, which is especially suitable for Panaglide, Steadicam, Louma and remote camera operation.

Optical viewfinder system: High magnification optical system. The viewfinder tube is orientatable and gives a constantly upright image through 360°; short and long viewfinder tubes are available for handheld and tripod usage. System incorporates an optical magnifier for critical focusing and picture composition, a contrast viewing filter and a light-proof shutter. Wide-range ocular adjustment with marker bezel to note individual settings. A built-in "Panaclear" eyepiece heater ensures mist-free viewing. Adjustable leveler link arm supplied with every Panahead to keep eyepiece position constant while tilting the camera up or down. An eyepiece diopter to suit the operator's own eyesight can be provided on request.

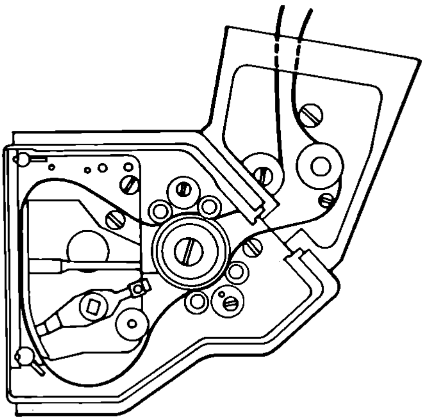
Ground Glasses: Interchangeable ground glasses available with any marking, or combination of markings. "Panaglow" illuminated reticle system with brightness control is standard. Ground glasses with finer or coarser texture available on request.

Lens Mounting System: Panavision positive clamp lens mount for maintaining critical flange focal depth setting. All lenses are pinned to ensure proper rotational orientation.

Lenses: Lenses are interchangeable with the System-65 Studio Camera.

Lens Control: Focus control which can be used from either side of the camera. Zoom lenses are supplied with an electronic zoom control unit as standard.

Matte Boxes: A standard matte box incorporating a sunshade, provision for two 4 x 5.650" filters which can be individually slid up and down. Special matte boxes incor-



(Note: The extension unit is used only for top-magazine configuration.)

porating more filter stages, with provision for sliding (motorized if required), rotating and/or tilting and for taking 6.6" square filters are optional. Panavision can also supply special sliding diffusers, diopters and all manner of image control filters, etc., to use in their matte boxes.

Camera motor: A 24-volt motor is used to run the camera at any speed from 4-72 fps. The motor is crystal controlled at all speeds and may be adjusted in 1 fps increments. Special sync boxes are available to synchronize the camera with a main power supply, with computers, with video signals and with process projectors in shutter phase synchronization. Internal heaters ensure that the cameras may be used at sub-zero temperatures without special preparation.

Magazines: 1000' and 500' magazines are available. 1000' reverse running magazines available on request.

Magazine loading: Same as Panavision PSR 200° camera.

Optical accessories: Interchangeable with System-65 Studio camera.

Batteries: The camera, heaters and accessories all operate off a single 24V Ni-Cad battery. Belt batteries are available for hand-holding.

Camera support equipment: Lightweight System-65 Hand-holdable cameras are ideal for use with Panaglide and Steadicam floating camera rigs and on remotely controlled camera cranes. They can also be used with a "Panatate" 360° turn-over rig.

Video Assist Systems: State-of-the-art, CCD video systems are available in B & W or color. Flicker-free images are possible with the pellicle reflex system.

Environmental protection equipment: Same as System-65 above.

35mm Cameras

Aaton 35mm Handholdable

This extremely compact camera -- 7 kg (15.4 lbs.) with 120 meters (400 feet) of film -- is designed for handheld small-camera situations where traditional 35mm cameras would be too bulky or awkward. The film channel is adjustable: Academy, 1.85:1, or Techniscope.

Movement: The movement of the Aaton 35 is a linear stroke, with the in/out movement controlled by a cam coaxial with the claw shaft (U.S. patent no. 3806016). The security provided by the claw's linear pull-down, followed by non-shifting withdrawal from the perforation at the dead point, makes a registration pin system unnecessary — the claw tip itself ensures this function. The vertical steadiness of this pull-down movement is enhanced by the perfect lateral film positioning ensured by a spring-loaded side pressure guide.

Shutter: Reflex mirror shutter, single blade, 180° opening.

Focusing: Through-the-lens viewing and focusing, 6X magnification. Auto erect image. Swiveling viewfinder for perfect eye-to-shoulder distance adjustment.

Lenses: Panavision, Arri PL or Aaton mounted lenses can be installed. The Aaton mount, because it has the shortest flange focal distance of the industry, can receive almost all the best still-photography lenses, like the Leica R, Nikon and Canon-AF.

Motors: A small direct-drive brushless motor (1500 rpm) runs the mechanism. Automatic stop in viewing position. A second motor in the camera body drives the magazine through an independent magnetic clutch. The Aaton battery (12V, 1.8 Ah) fits directly onto the camera body.

Magazine: 400' displacement-type magazine is prethreaded and allows quick changing. It is automatically locked into position when placed on the camera body and is released by lifting a lever on the motor side of the camera. The feed and take-up rolls compensate for each other in size, while the shaft of each roll shifts position as the film is exposed. The electronic counter registers in feet and meters.

Video Assist: A small high-resolution CCD video camera attached to the side of the camera only bleeds off 30% of the light from the viewfinder.

Aaton 35-II

Movement: Linear-stroke single claw; self registering (U.S. patent no. 3806016). The vertical steadiness of this movement is enhanced by the perfect lateral film positioning ensured by a spring-loaded side pressure guide. Hair-free gate has air circulation channel to keep hair out.

Shutter: True 180-degree front surface mirror facilitates 60Hz HMI and video monitor roll-bar elimination. Stops in viewing position. May be inched for aperture inspection.

Viewfinder: Reflex from shutter, 6X magnification, auto erect image, interchangeable ground glass. Swiveling viewfinder for perfect eye-to-shoulder distance adjustment.

Lens Mount: Panavision, Arri PL or Nikon interchangeable mounts. 35mm to Super 35 format conversion in five minutes in the field.

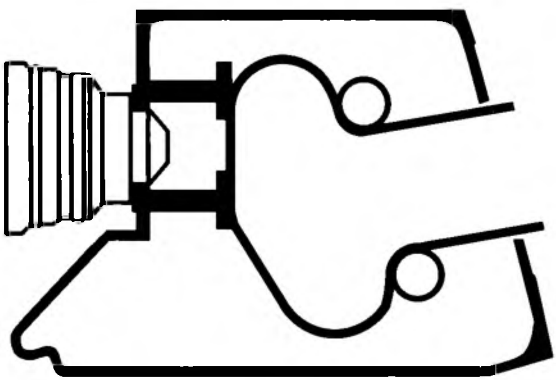
Drive: Brushless crystal sync 12V motor for 24, 25, and 29.97 or 30 fps. Variable control 6 to 54 fps. Maximum speed with external control is 32 fps. Circuit board and motor may be removed and replaced in two minutes. Slim battery (12V 1.8Ah) fits directly onto the camera body. A second motor in the camera body drives the magazine through an independent magnetic clutch.

Magazines: 122m (400') pre-threaded displacement-type magazine for instant changing. The feed and take-up rolls compensate for each other in size, while the shaft of each roll shifts position as the film is exposed. The electronic counter transmits feet or meters to the camera body.

Features: Digital control display: footage, voltage, speed, ISO, magazine footage, low battery and out-of-sync warnings. The key-code compatible, AatonCode time recording system prints large and rugged time matrixes on the edge of the film, ensuring perfect sync with SMPTE time of audio recorders. 1 ppm TCXO internal clock, initialized with RS232 or SMPTE signals. Negatives from the Aaton 35-II are fully mixable with Panavision, Moviecam and Arri BL AatonCode-equipped cameras.

Accessories: Lightweight wide-format swing-away matte-box; two 4 x 5.6 and one 138mm rotating stages. Also accommodates Panavision mattes. Lightweight and zero-backlash follow-focus system. CCD video assist with manual iris control delivers extremely sharp images.

Arriflex 535



The Arriflex 535 is a completely integrated camera system. Its microprocessor control technology permits shutter angle and speed changes while running — at the camera or remotely.

Movement: Multi-link film transport with dual-pin registration conforming to optical printer standards, and dual pull-down claws. Easily removed for changing to a 3-perforation pull-down. Adjustable pitch control. Universal aperture plate has both interchangeable format masks and a behind-the-lens gel filter holder. Ground glasses and fiber-optic focus screens for all aspect ratios available.

Shutter: Microprocessor-controlled variable mirror shutter. Continuously adjustable from 11° to 180° while running, in .01° increments, at any camera speed. Exposure is 1/48 of a second at 24 fps with a 180° shutter. The 535's program also permits simultaneous frame rate/shutter angle effects, such as programmed speed changes with precise exposure compensation.

Viewfinder: Swingover Viewfinder fully operational from either camera left or camera right. Permits omni-directional reflex viewing with constant image correction side-to-side and upright. Programmable ArriGlow for low-light filming. Nine pre-programmed illuminated formats, an optional customized format module and fiber-optic focus screens. Switchable ND.3 and ND.6 contrast viewing glasses, a variety of in-finder information LEDs, and a 12"-15" variable finder.

Lens Mount: PL (Positive Lock) lens mount, 54mm diameter, with relocatable optical center for easy conversion to the Super 35 format. Flange focal distance is 52mm, and image sharpness is guaranteed due to the rigid mechanical connection between lens mount and film plane. Both Super Speed and Standard lenses with PL mounts may be used. PL zoom and telephoto lenses should be used with a bridgeplate system.

Lenses: The 535 utilizes the full range of: Zeiss Superspeed — 18mm, 25mm, 35mm, 50mm, 65mm, and 85mm T-1.3s; Zeiss Standard — 10mm, 12mm, 14mm, 16mm, 20mm, 24mm, 28mm, 32mm, 40mm, 50mm, 85mm, 100mm, 135mm T-2.1s; and 60mm, 180mm, and 300mm T-3.0s; Arri Anamorphic — 32mm, 40mm, 50mm and 75mm T-2.3s, and 100mm and 135mm T-3.0s; Arri Macro — 16mm, 24mm, 32mm, and 40mm T-2.1s; 50mm and 100mm T-3.0s and 200mm T-4.3. RTH Cooke and Angenieux zoom lenses.

Motor: Microprocessor-controlled 24V DC motor that operates with quartz accuracy at 24/25/29.97/30 fps on-board, and at 3-50 fps with the Camera Control Unit (CCU), Remote Unit (RU), or the Variable Speed Unit (VSU). It also operates at 24/25 fps reverse with the CCU, and at 1 fps crystal accurate with its phase button. 50/60 Hz is standard. External Sync Unit (ESU) is designed for multi-camera, video, or projector interlock. Power input is through a 3-pin connector: Pin 1 is (-), and Pin 2 is +24V. Operating temperature range is -4°F to +122°F (-20°C to + 50°C).

Magazines: 400' and 1000' coaxial, each with two microprocessor-controlled torque motors. Microprocessor samples and adjusts feed/take-up tension and all other functions continuously. Mechanical and digital LCD counters are built-in.

Matte Boxes: The 535 utilizes a 19mm diameter rod Camera Support System. The Support System includes a full range of matte boxes, bridgeplate, 2-speed follow focus, and lens supports. 15mm rod adapters are available upon request.

1. 6.6 x 6.6 Production Matte Box: covers lenses 12mm and up, as well as most presently used zooms. Interchangeable two, four, or six filter stages, rotatable 360 degrees, swing-away for changing lenses. Geared filter frames.

2. 5 x 6 Production Matte Box: covers fixed lenses 14mm on up, as well as most presently used zooms. Two filter stages, swing-away for changing lenses. Geared filter frame.

3. 4 x 4 Production Matte Box: covers lenses 16mm and up. Two and four filter stages, rotatable 360 degrees, swing-away for changing lenses. Geared filter frames.

4. 4 x 4 Matte Box: (for use with 35-3 and 16SR systems only) covers lenses 16mm and up. Two filter stages, mounts on Arri lightweight support.

5. 4 x 4 Lightweight Matte Box: mounts directly to the front of any 80mm front diameter lens. Two filter stage with removable rubber lens shade.

Indicators: In-finder Displays: LEDs in the viewfinder allow the operator to monitor various camera functions, battery status, and programmable film-end warning. Digital LCD Tachometer and Footage Displays: camera left/right; audible and visible out-of-sync warning; visible film jam; film-end; error codes; improper movement position; improper magazine mounting; and disengaged rear film guide indicators.

Electronic Accessories: Variable Speed Unit (VSU) module mounts directly to the 535, and permits camera speed changes between 3 and 50 fps, non-crystal. Shutter Control Unit (SCU): mounts directly to the camera and permits camera shutter angle changes between 11° and 180°. Remote Unit (RU): operational remotely from up to 60', provides an VSU/SCU (variable shutter/variable speed) combination. The RU links the SCU and VSU to permit manual adjustment of the frame rate while the 535's microprocessor varies the shutter angle — all to ensure a constant depth-of-field and exposure. Video Optics Module (VOM): provides flicker reduction and iris control. With Selectable Beam Splitter, facilitates video viewing under difficult conditions. SMPTE Time Code Module plugs in to utilize on-board time code generator, and provides full SMPTE 80-bit time code capability. Electronic Sync Unit (ESU): The ESU, operational remotely from up to 60', provides synchronization with an external PAL or NTSC video signal (50/60 Hz), another camera or a projector, or computer or video monitor via a monitor pick-up. It also contains a phase shifter, pilotone generator, and selectable division ratio between an external source and the camera's frame rate. Camera Control Unit (CCU): provides integrated control over all electronic functions.

Accessories: 2-Speed follow focus with 1:1 or 1:.06 ratios; bridgeplate support system for CG balance and mount for matte box, follow focus, servo zoom drive, and heavy lenses; hand-held rig for shoulder operation of the camera; finder extender and leveling rod; barney and heated barney; Arri Geared Head; and director's viewfinder with PL mount.

Arriflex 535B

The Arriflex 535B is the lightweight version of the 535, designed for handheld and Steadicam cinematography. (Refer to the Arriflex 535 section for full 535 specs.)

Movement: The 535B has the same multi-link film transport, with dual-pin registration that conforms to optical printer standards, and dual-pin pull-down claws as the 535. It has an adjustable pitch control. The 535B operates at crystal-accurate speeds from 3 to 60 fps.

Shutter: The 535B has a manually adjustable mirror shutter, variable from 11° to 180° in 15° steps, and 144° and 172.8°.

Lens Mount: The Arri 54mm PL lens mount, with a relocatable optical center for easy conversion to Super 35. Flange focal distance is 51.98 - 0.01mm.

Lenses: Same as 535.

Motor: The 535B has a microprocessor-controlled 24V DC motor that operates from 3-60 fps, variable in 0.001 increments at crystal accuracy. It features on-board programmable speeds of 24, 25, 29.97 and 30 fps, and variable crystal speeds from 3-60 fps. Speeds are continuously variable when the Remote Unit (RU-1) is used. Speeds can be programmed from the on-board LCD, with the Remote Unit (RU-1), and with the Camera Control Unit (CCU), Arri's standard off-camera programming unit. The 535B's power input is through a 3-pin connector: Pin 1 is (-), and Pin 2 is +24V. Operating temperature range is -4°F to +122°F (-20°C to +50°C).

Viewfinder: The 535B has a lightweight Swingover Viewfinder that pivots on two axes, with full left or right side viewing, and a fully upright image no matter where it is placed. It can be used with the new Arri flicker-reduced CCD black & white and color video assists, and be easily set up for anamorphic use. Adaptable for left- or right-eyed viewing with a built-in telescopic extender, and has quick-change beam splitters for B & W or color CCD video, and slide-in masks for illuminated in-finder format markings. The entire finder is easily removed without tools, and accepts a 100% video module for Steadicam use.

Magazines: Standard 535 400' and 1000' coaxial magazines.

Electronic Features: At the LCD, the user can pre-set camera speed and time code information, and display frame rate, film stock, battery voltage, and time code and user bits. The CCU (Camera Control Unit) can be used to set and run these 535B camera functions. An additional LCD display can be added on camera right. The LCD also indicates film jam, film end, improper movement position, magazine improperly mounted, and rear film guides disengaged. If the 535B is not ready for operation, its running control lamp illuminates red. Time Code: The 535B utilizes the same plug-in TC module as the 535. It records SMPTE RP 136 Form C, and has an 80-bit integrated TC generator. TC crystal accuracy is plus/minus 1ppm (0-50 degrees C).

Electronic Accessories: VSU, RU, and time code module (see 535); Video Optics Module (VOM) -- Video monitoring is an integral part of the 535B's design. The 535B can accommodate both B & W and color CCD cameras, and attached to the VOM both provide flicker reduction and iris control.

Matte Boxes: See 535.

Additional accessories: 2-Speed follow focus; bridgeplate support system for CG balance and mount for matte box, follow focus, servo zoom drive, and heavy lenses; hand-held rig for shoulder operation of the camera; finder extender and leveling rod; barney and heated barney; Arri Geared Head and Arri Geared Head 2; and director's viewfinder with PL mount.

Arriflex 35-3 High Speed MOS

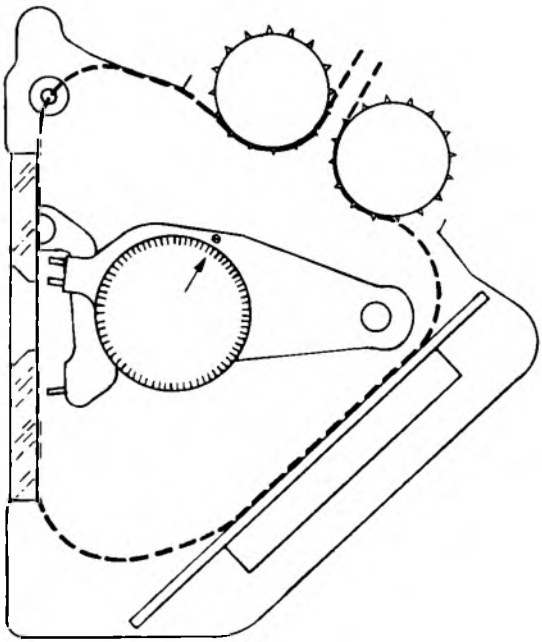
Movement: One registration pin and dual-pin pulldown claw. Film channel incorporates a pressure pad at the back of aperture area. Aperture plates and ground glasses for all aspect ratios are interchangeable.

Shutter: Rotating, front surface coated mirror shutter system, with variable shutter: 180°, 172.8°, 144°, and 135°. Variable shutter from 15° to 135° in 15° increments is available for earlier cameras, and is standard on 35-3 130 fps models. The 15° to 180° shutter is constructed of lightweight silicon crystal. Exposure is 1/48th of a second at 24 fps with 180° shutter.

Reflex Viewfinder: Four interchangeable doors with viewfinders are available: Standard door with fixed viewfinder and mount for video tap; offset finder door for use with 400' coaxial shoulder magazine; pivoting finder door, pivots 210°; new pivoting finder door with optical adapter to attach video camera. All have adjustable Super Wide Angle eyepiece with manual iris closure. Finder extenders available are 9" standard, 9" anamorphic, and 12.2" standard with ND.6 contrast viewing glass.

Lens Mounts: 54mm diameter PL mount. Flange focal distance is 52mm. Super Speed and Standard lenses with PL mount, those with Arri Bayonet (41mm diameter), and Arri Standard lens mounts with PL adapter may be used. PL and non-PL zoom and telephoto lenses should be used with Bridgeplate Support System.

Motor Drive: 12/24V DC motor, with quartz-controlled sync at 24/25/30 fps, 50/60 Hz. An on-board variable speed dial may be used to adjust camera speed from



4 to 50 fps at 12V DC. The camera is continuously variable from 4 to 100 fps (130 fps on the 35-3 130 fps camera) at 24V DC with a Variable Speed Unit. The 50/60Hz EXB-2 External Sync Control may be used to interlock the 35-3 with a video source, projector or another camera. A 4-pin power

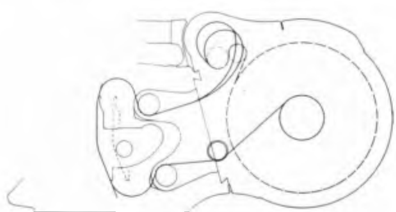
connector is located in the rear of the electronics housing. Pin 1 is (-); Pin 4 is 12V (+). Operating temperature range is -13°F to +122°F (-25°C to +50°C).

Displays: An electronic tachometer and footage counter. An external red LED located below the counter indicates when a low memory battery condition exists. A red LED to indicate an out-of-sync condition and a green LED to indicate variable speed mode are visible in the viewfinder

Magazines: 200', 400', and 1000' displacement mags; 400' low profile, coaxial shoulder magazine for handholding.

Lenses: Full range of Zeiss Superspeed, Zeiss standard, Arri Anamorphic, Arri Macro, RTH Cooke and Angenieux zoom lenses. See Arriflex 535 Lenses section for details.

Arriflex 35BL-4s



Movement: 35BL-1 through BL-4 cameras feature dual-pin registration and dual pull-down claws that advance the film through a fixed-gap film channel. The 35BL-4s has a technologically advanced movement that includes an adjustable pitch control. Aperture plates and ground glasses for all aspect ratios are interchangeable between all 35BL models.

Shutter: Rotating, front surface coated mirror shutter system, with variable shutter: 180°, 172.8°, 144°. Exposure is 1/48 of a second at 24 fps with 180° shutter. 35BL-1 and 35BL-2 cameras have 180° fixed shutter.

Reflex Viewfinder: 35BL-4s and BL-4 viewfinders are a full stop faster and brighter than earlier 35BL cameras, and feature a larger exit pupil, ArriGlow illuminated frame lines, and a high aperture 12.5" finder extender with swing-in contrast viewing filter and variable magnification up to 2X. The finder rotates 90° above, and 90° below level with the image always upright. An adjustable Super Wide Angle eyepiece with manual iris closure and 6.5X magnification is standard on 35BL-4s and BL-4 cameras. An adjustable eyecup allows the operator to select the optimum eye-to-exit pupil distance. Finder extenders available for the 35BL-4s and 35BL-4 include a 12.5" standard with switchable contrast viewing filter, and for the 35BL-3, 35BL-2, and 35BL-1, a 9" standard, and 9" Anamorphic.

Lens Mount: 54mm diameter PL mount, switchable to Super 35 format. Flange focal distance is 52mm. Super Speed and Standard lenses with PL mount, those with Arri Bayonet (41mm diameter), and Arri Standard lens mounts with PL adapter may be used. Both PL and non-PL zoom and telephoto lenses should be used with a bridgeplate system. Early 35BL cameras have Arri bayonet mount. BNC mount available for 35BL-3 only. 35BL-2 and BL-1 cameras require lens blimps for silent operation.

Motor Drive: 12V DC motor with quartz-controlled sync at 24/25/30 fps, 50 or 60 Hz for all 35BL models. A Variable Speed Control accessory extends the recommended speed range from 5 to 40 fps on the 35BL-4s, 35BL-4, 35BL-3, and 5 to 50 fps on the 35BL-2. The 35BL-1 will operate up to 100 fps with the HSU-100 speed control, specially modified magazines, and two 14.4V batteries. Multi-camera interlock is achieved with the EXS-2 50/60Hz External Sync Unit. Power input through a 4-pin connector. Pin 1 is (-); Pin 4 is +12V. Operating temperature range is -4°F to +122°F (-20°C to + 50°C).

Indicators: An LED electronic tachometer and footage indicator and an audible out-of-sync warning are built-in. A red LED near the footage counter indicates low footage, memory, battery.

Magazines: 400' and 1000' coaxial. The 35BL can be handheld with either magazine. Mechanical footage counters are integral, and 35BL-4s magazines have an adjustable pitch control.

Lenses: Full range of Zeiss Superspeed, Zeiss standard, Arri Anamorphic, Arri Macro, RTH Cooke and Angenieux zoom lenses. See 535.

Accessories: 2-Speed follow focus; bridgeplate support system for CG balance and mount for matte box, follow focus, servo zoom drive, and heavy lenses; video adapter for simultaneous optical and video viewing; SMPTE time code; finder extender and leveling rod; barney and heated barney; Arri Geared Head; director's viewfinder with PL mount.

Arriflex 35-3C

Movement: Single pin claw with extended dwell-time to assure accurate film positioning during exposure. Film gate components are precision finished steel, and hard chrome plated. Full aperture is standard, with other formats available.

Shutter: Rotating reflex mirror shutter system, variable from 0° to 165°, in 15° increments. Exposure is 1/52nd of a second at 24 fps with a 165° shutter.

Reflex Viewfinder: 6.5X Super Wide Angle eyepiece for increased side-to-side viewing; interchangeable doors include fixed viewfinder with mount for videotap, 210° pivoting viewfinder with or without video, and offset viewfinder door for use with 400-ft. shoulder magazine.

Lens Mount: 54mm diameter PL mount. Flange focal distance is 52mm. Super Speed and Standard lenses with

PL mount, those with Arri Bayonet (41mm diameter), and Arri Standard lens mounts with PL adapter, may be used. Both PL and non-PL zoom and telephoto lenses should be used with a special 3-C Bridgeplate Support System.

Motor Drive: Forward or reverse running 12V DC handgrip motor with quartz-accurate sync at 24/25 fps, with EXB variable speed accessory to adjust speed range from 5 to 50 fps. Multi-camera interlock is achieved with the 50/60 Hz EXB sync control accessory. Power input through a 4-pin connector. Pin 1 is (-); Pin 4 is 12 V (+). Operating temperature range is -13 F to +122 F (-24 C to +50 C).

Magazines: 200' forward operation only, 400' forward or reverse; and 400' modified 35-3 shoulder magazines available.

Lenses: Full range of Zeiss Superspeed, Zeiss standard, Arri Anamorphic, Arri Macro, RTH Cooke and Angenieux zoom lenses (see Arriflex 535 Lenses Section for details).

Accessories: Finder extenders including 9" and 12.2" non-anamorphic, and 9" anamorphic; leveling rod; 2-speed follow-focus; special 35-3C bridgeplate support system for CG balance and mount for matte box, follow focus, servo zoom drive, and heavy lenses; video adapter for simultaneous optical and video viewing; Pilotone generator for 24/25 fps, 50/60 Hz shooting; director's viewfinder with PL mount.

Arriflex 35-2C

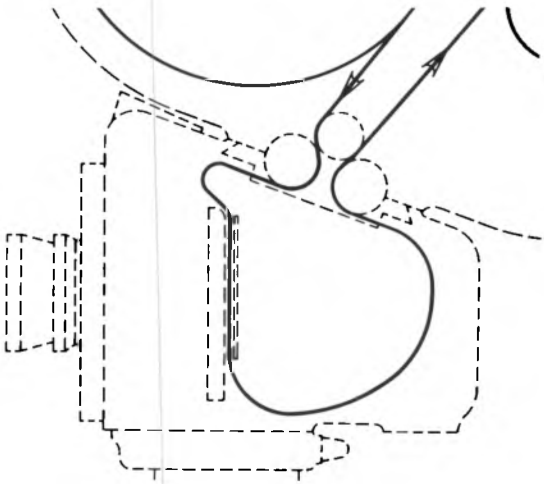
Description: The 35-2C series consists of multipurpose 35mm cameras. They are used handheld, and with appropriate accessories, for almost every type of motion picture production application.

35-2C/B: Standard 2C featuring the Arri parallax-free viewfinder system, a precision film transport system with a maximum speed of 48 fps, a three-lens mount turret, and an interchangeable motor-drive system.

35-2CGS/B: Standard 2C features plus Pilotone output and startmarking system.

35-2CV/B: Standard 2C features plus variable shutter, adjustable from 0° to 165°.

35-2CHS/B: High-speed model with 80 fps movement and tachometer. A 32V DC motor with variable speed control is included with the camera.



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35-2CT/B: Standard 2C with Techniscope gate and two-perforation pulldown film transport system.

Movement: Single-claw with extended dwell-time to assure accurate film positioning during exposure. Academy aperture is standard, with other formats available.

Shutter: Rotating reflex mirror shutter system with 180° opening. Exposure is 1/48th of a second at 24 fps.

Reflex Viewfinder: 6.5X Wide Angle eyepiece and parallax-free viewing.

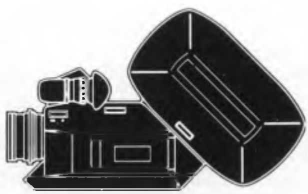
Lens Mount: Three-lens turret with two Arri Standard and one Arri Bayonet mount. All Arri Standard and Bayonet lenses that cover the full 35mm format can be used. Zoom and telephoto lenses should be used with a special 2C Bridgeplate Support System.

Motor Drive: 32V DC highspeed handgrip motor for 20 to 80 fps operation is standard; other motors include 16V DC governor motor for 24/25 fps operation, 24-28V DC variable motor for 20 to 64 fps; 16V DC variable motor for 8 to 32 fps. Operating temperature range is -13 F to +122 F (-24 C to +50 C). Magazines: 200' forward operation only, 400' forward or reverse.

Lenses: Full range of Zeiss Superspeed, Zeiss standard, RTH Cooke and Angenieux zoom lenses with Bayonet or Standard mounts. Matte Boxes: Bellows and lightweight versions.

Accessories: Servo zoom drive; camera door (Anamorphic available); periscope finder; finder extender; and flat motor base to convert camera to flat-base configuration for mounting on flat surface or inside blimp housing.

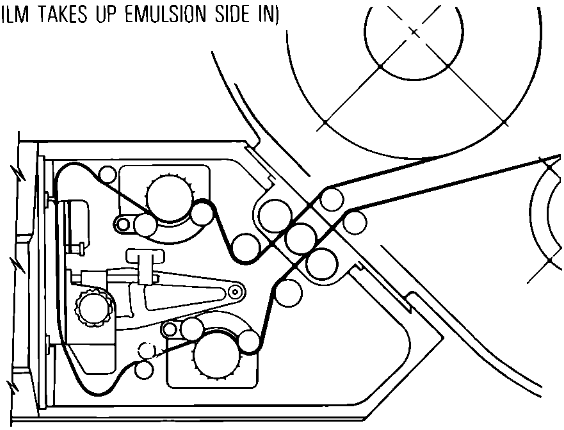
Cinema Products FX35



Special effects camera featuring pin-registered steadiness to 120 fps and computer control interface. Can be handheld.

Movement: Cam-driven dual-pin pull-down. Dual-pin registration in Mitchell position. Adjustable stroke length and entry position. Exit and entry buckle trips. Forward and reverse operation, .980" X .735" standard aperture with provision for hard mattes.

Shutter: Butterfly reflex with focal plane cup. Adjustable 180°/172.8°/144°/90°/45°/0°. Stops in viewing position. Internal phasing control to sync with TV equipment.



Reflex Viewfinder: Erect, bright image, orientable. Fine-grain interchangeable viewing screens. Precision register pins for matte alignment. Three viewing filters. 360° adjustable eye piece; extender available. Optional video assist.

Lens Mount: BNCR standard, PL optional; anamorphic locating pin. Optional adapter for Arri standard or bayonet-mounted lenses.

Drive: Self-contained, 12 to 32V DC motor; synthesized crystal control from 1 to 120 fps in 0.01 fps steps. (Requires 24 to 32V for over 64 fps). One fps button for threading. Audible/visible out-of-sync indicator.

Magazines: FX 35 QUAD (quick acting displacement) 400' (forward/reverse), 1000' (forward only). Feature steel toe, single latch cover, footage indicator, anti-spill brake, easily cleaned light trap. Adapter for Mitchell magazines.

Features: Can be run from personal computer. Feedback: status information, alarms. Shutter and digital shaft coder quadrature and all control functions. Designed to be as steady as an optical printer. Display module over viewfinder swivels for operator or assistant; shows speed, footage, camera mode, battery voltage, current, and low battery alarm. Optional 10-foot extension cable.

Accessories: Matte boxes, filters, lens control systems, video assist, time code, viewfinder exposure meter, computer interface module.

Cinema Products XR35 Lightweight Studio Camera

Lightweight blimped silent studio camera.

Movement: Standard Mitchell pin-registered compensating link; Cinema Products' independent adjustment of stroke length and entry position. Removable aperture plate with built-in matte slide for various formats. Timing marks for reassembly after cleaning. Inching knob.

Shutter: Focal plane, continuously variable 5° to 180°; control and lock on rear panel.

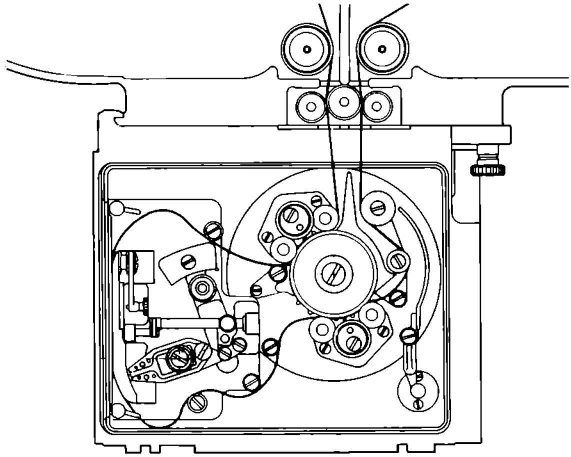
Reflex Viewfinder: Rotating mirror, stops in viewing position. Fine-grain interchangeable screens. Standard or de-anamorphic optics. High-low magnification relay lens, two contrast filters, built-in closure. Large eyepiece with diopter adjustment and lock.

Lens Mount: BNCR with anamorphic locating pin.

Drive: Internal crystal-controlled motor assembly continuously variable 4 to 32 fps. Fps indicator and control knob. Pushbutton for sync speed, selector switch for 24 or 25 fps ±15 ppm in 0°-140° F temperature range. Visible/audible out-of-sync warning. Circuit breaker, power indicator, running indicator lights, 30V battery pack.

Magazines: 1000' QUAD (quick acting displacement). Lightweight, steel toe plate, velvet rollers, snap latch mounting, single latch cover. Footage indicator, anti-spill brake. Magazines are installed on the camera through a "clamshell" opening in the blimp housing which provides maximum access without requiring side or headroom clearance.

Features: Built-in focus control system with right and left side knobs, magnetic calibration discs, brake, auxiliary drive; mounted on front housing. Six station filter wheels accepting standard gelatin filters. Lightweight swingaway



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matte box. Illuminated level, lens light and interior threading lights. LED footage counter in feet or meters. Built-in carrying handles. Complete camera system (less lens and film) weighs 93 pounds.

Accessories: Matte boxes, filters, viewfinder and aperture mattes, video assist, time code.

Feathercam CM35

Lightweight (10 pounds) handheld pin-registered camera with snap-on magazines.

Movement: Cam-driven dual pull-down, dual-register pins. Six-inch-long film gate. Loop-forming threading system. Simple maintenance.

Shutter: Rotating mirror, 180°, stops in viewing position.

Reflex Viewfinder: Right or left eye. Extension available.

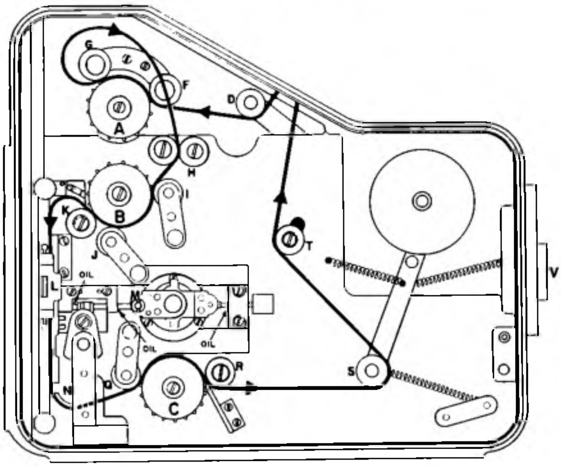
Lens Mount: Optional and interchangeable BNCR, Nikon, Arri (new or old).

Drive: Variable 4 to 48 fps built-in 24V motor; 24/25 fps crystal sync, soft start-up to eliminate slack. Optional single-frame drive. 24V battery, on-board or external. LED fps/footage (or meters) counter with memory.

Magazines: 500' coaxial snap-on. Does not require prethreading. Mechanical footage counter.

Accessories: Video assist, bridge plate, matte box, pistol grip.

IMAGE 300 35mm



35mm highspeed (300 fps) pin-registered reflex camera.

Movement: Epicyclic; six pulldown claws; two register pins in Mitchell position. Dynamically balanced. Frame-to-frame register 0.0005" or better. Full (silent) aperture.

Shutter: Beryllium rotating two-blade mirror; 120°.

Reflex Viewfinder: Bright upright image; interchangeable ground glasses; variable magnification; video tap; light trap prevents accidental fogging.

Lens Mount: BNCR; Panavision available.

Drive: Built-in motor and circuitry; maximum speed in three seconds. Self-braking; will stop in five feet from 300 fps. Requires 115V AC, 50/60 Hz, 30A starting, 18A running. Ten pushbutton-actuated speeds, 24 to 300 fps.

Magazines: Coaxial 1000' feed and takeup magazines are identical and separately mounted; takeup can be removed without removing the feed magazine. Gear driven, differentially controlled. Automatic drive engagement and supply overrun brake. Footage-used counter for acetate or polyester base.

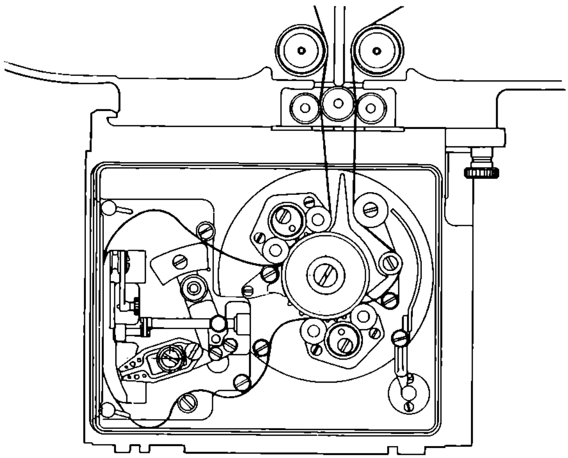
Features: Sync pulse for strobe light, sync at all operating speeds. Matte box iris rods compatible with Arriflex. Footage counter with memory. Remote control input jack.

Mitchell NC, NCR, BNC, BNCR (35mm); FC, BFC (65mm)

The NC camera differs from the "standard" model in that it uses a mechanically different and quieter movement and has other features which make it quieter. NC, BNC, FC, BFC are rack-over models. NCR, BNCR are reflex models. NC model has a four-lens turret, the others a single lens mount. B models are blimped versions.

Movement: Dual-register pins, four-prong pull-down; adjustable stroke. Timing marks on shutter and movement facilitate removal and reassembly. Removable aperture plate with built-in matte slot. 35mm full .980" x .735" aperture. Speed range: single frame to 32 fps. Slot for dual gel filters.

Shutter: Focal plane 175° maximum variable to 0° in 10° increments. Phase and opening indicator on back of



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camera. Some models have automatic four-foot fade in or out.

Reflex Viewfinder: Rotating mirror. Viewing tube same on rack-over and reflex. Interchangeable ground glasses, variable magnification, film clip/matte slot, contrast viewing filters. Adjustable focusing eyepiece.

Viewfinder: External large screen erecting finder. Parallax correction coupled by cam to lens focus knob.

Lens Mount: Four-lens turret, NC only; flange depth 1.695". Single mount all others: 35mm flange depth 2.420"; lenses can be centered on full or Academy aperture.

Magazines: 400', 1000', 1200' double compartment sound insulated. NC magazines will not fit standard camera but standard magazines may be used on NC models with adapter; not recommended for sound shooting.

Drive: Demountable motors for all types of shooting; synchronous motors are sound insulated. Crystal sync 30V DC with 50/60 Hz signal, mirror positioning circuit and audible offspeed indicator.

Accessories: Film matte punch. Matte boxes for rotating and sliding diffusion and filters. Director's finder which takes camera lens mounts.

which camera body racks over for focusing and critical lineup.

Note: There are several versions of modifications available for special applications.

Movement: High Speed: Dual registration pins. Dual forked pull-down claws engage four perforations simultaneously. Removable aperture plate has built-in matte slot. Full Aperture: .980" x .735" Academy Aperture Mask: 868" x 631". Speed range: Single frame to 120 fps (160 fps can be achieved but is not recommended). Standard movement cannot be used for high-speed work. Not possible to convert standard to high-speed camera by interchanging movements.

Shutter: 170° maximum. Variable in 10° calibrated segments to 0° manually, forward or reverse.

Focusing: Variable magnification erect image focusing telescope built into the camera. Through-the-lens ground glass critical focus and viewing when camera is racked over. Built-in contrast viewing filters for color and monochrome emulsions. Interchangeable ground glasses. Any aspect ratio outline available. Camera focus tube has built-in matte slot and permits the making of perfect match dissolves.

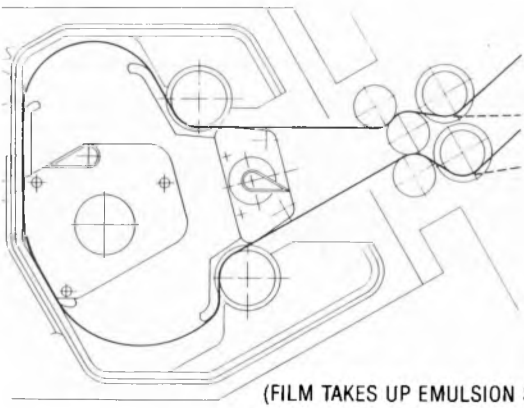
Lenses: Four-lens turret. Positive index type, with rising and falling front. Mitchell-designed heavy-duty rotary-type lens mounts. Flange depth: 1.695". Standard and wide-angle matte boxes provide for use of glass mattes, gauzes, hard mattes, glass filters, Pola screen, diffusers, variable diffuser attachment, etc.

Motors: Variable (wild) motors: 12V DC (8 to 24 fps), 110V AC or DC (8 to 24 fps), High Speed. 110V AC or DC rheostat controlled (24 to 128 fps). Synchronous (sound) motors: 110V, 60-cycle, 1 phase AC; 220V, 60-cycle, 3-phase AC; 220V, 3-phase interlocking AC; 220V, 3-phase AC/96V DC Multi-duty (Synchronous at 220V AC only). 50-cycle motors available on request. Animation motor: Stop-motion, 110V AC.

Magazines: 400', 1000' and 1200' double compartment-type magazines.

Viewfinder: Large erect viewfinder calibrated for different focal-length lenses. Available with dual calibrations for any two aspect ratios. Parallax-free follow-focus attachment available.

Moviecam Super 35mm



Movement: Compensating link with dual pilot pin registration and dual pull-down. Interchangeable aperture plates for all standard aspect ratios.

Shutter: 180° rotating mirror variable to 45°. Calibrated at 90°, 144°, 172.8°. Stops in viewing position.

Reflex Viewfinder: Rotatable 360° maintaining erect image. 12" extension tube with built-in 2.4X magnification available. Large exit pupil has heated rear element. Eyepiece adjustable. Anamorphic viewing available. Illuminated frame lines. Integral video assist; external video power unit includes 1 ½" monitor.

Lens Mount: BNCR.

Drive: Microprocessor-controlled motor, 12 to 32 fps in one-frame increments. Crystal sync. 24V DC or 110/220V AC.

Magazines: 500' and 1000' displacement-type torque motor drive. Built-in heater.

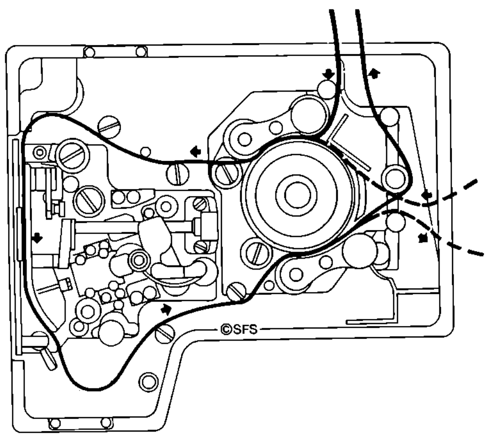
Features: Below 20 dBa sound level. Built-in automatic slate. Plug-in circuit boards field replaceable. Built-in camera heaters. Footage and frame rate digital display forward and reverse. Handheld and studio follow-focus for all lenses.

Weight: 29 pounds with 500' of film and 50mm lens.

Accessories: "Moviespeed" attachment allows programmable speed changes from 1 to 50 fps forward and 12 to 32 fps reverse during shooting, with fully automatic exposure compensation. Time base code attachment. Synchronizer for flicker-free HMI shooting, filming from TV monitors or process photography. Computer diagnosis attachment for troubleshooting circuit boards. Matte boxes.

Panavision Platinum Panaflex 35mm

Movement: Dual pilot pin registration ensures process-plate image steadiness. Pilot pins register in the same perforation holes (immediately below the bottom frame line) as optical printers. Double pull-down claws. Pitch and stroke controls for optimizing camera quietness. 4-perf movement is standard, 3-perf is available. Movement may be removed for servicing.



Aperture Plate: Removable for checking and cleaning. Full-frame aperture is standard, aperture mattes are used for all other frame sizes. A special perforation locating pin above the aperture ensures trouble-free and rapid film threading.

Aperture Mattes: Interchangeable aperture mattes are available for Academy, Anamorphic, Super 35, 1.85:1, 1.66:1, and any other as required. Special hard mattes are available on request.

Shutter: Focal plane shutter, infinitely variable and adjustable in-shot. Maximum opening: 200°, minimum: 50° with adjustable maximum and minimum opening stops. A digital display allows adjustments in 1/10° increments. Micrometer adjustment allows critical synchronization with computers, TV monitors and HMI lighting at unusual frame rates. Manual and electronic remote control units available.

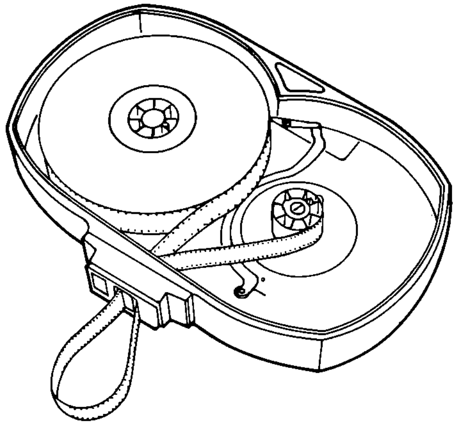
Behind-the-lens Filtering: Behind-the-lens gel filter holder.

Reflex System: Reflex rotating mirror is standard and is independent of the light shutter system. Interchangeable semi-silvered fixed reflex mirror for flicker-free viewing is optional.

Optical Viewfinder System: High magnification optical system. The viewfinder tube is orientable and gives a constantly upright image through 360°. Short, Intermediate and Long viewfinder tubes are available. System incorporates an optical magnifier for critical focusing and picture composition, a de-anamorphoser, a contrast viewing filter and a light-proof shutter. Wide-range ocular adjustment with marker bezel to note individual settings. A built-in "Panaclear" eyepiece heater ensures mist-free viewing. Adjustable eyepiece leveling link-arm is supplied with every Panahead to keep the eyepiece position constant while tilting the camera. Entire optical viewfinder system may be removed and replaced with a video viewfinder display for lightweight camera configuration (e.g., for Panaglide, Steadicam, Louma, remote camera usage). An eyepiece diopter to suit the operator's own eyesight can be provided on request.

Ground Glasses: Interchangeable ground glasses available with any marking, or combination of markings. "Panaglow" illuminated reticle system with brightness control is standard. Ground glasses with finer or coarser texture available on request. Provision for a cut frame to be placed in the viewfinder system for optical image matching. Frame cutters are available to suit negative or positive perforations.

Lens Mounting System: Panavision positive clamp lens mount for maintaining critical flange focal depth setting. All lenses are pinned to ensure proper rotational ori-



entation. (Note: this is particularly important with anamorphic lenses.) Iris-rod support is supplied.

Lenses: Exceptionally wide range of spherical, anamorphic and specialty lenses is available. All are checked and calibrated by MTF. Primo lenses are all color matched and range from a distortion-free 10mm to 150mm. Primo zoom lenses are equal to Primo lenses in image-look and optical performance. All Primo lenses have widely spaced lens focus calibrations and have been especially designed for low veiling glare. Physically long lenses are supplied with adequate length iris rods for matte box and filter support, ultra wide-angle lenses are supplied with a suitable sun-shade and matte box.

Lens Control: A lightweight focus control which can be used from either side of the camera is standard; an interchangeable "Studio" focus control unit is optional, as are electronic remote focus and aperture controls. Zoom lenses are supplied with an electronic zoom control unit as standard.

Matte Boxes: A standard matte box incorporating a sunshade, with provision for two 4 x 5.650" filters which can be individually slid up and down. Special matte boxes incorporating more filter stages, with provision for sliding (motorized if required), rotating and/or tilting and for taking 6.6" square filters are optional. Panavision can also supply special sliding diffusers, diopters and all manner of image control filters, etc, to use in their matte boxes.

Camera Motor: A 24-volt motor is used to run the camera at any speed from 4-36 fps and is crystal controlled at all speeds and may be adjusted in 1/10th fps increments. Special sync boxes are available to synchronize the camera with a mains power supply, with computers and video signals and with process projectors to run in shutter phase synchronization. Panaflex cameras may be used at sub-zero temperatures without special preparation.

DBA Rating: Less than 20 dB with film and lens, measured 3' from the image plane.

Magazines: 2000', 1000', 500' and 250' magazines are all available. All can be used on the top of the camera for minimum camera length or at the rear for minimum camera height and for good balance when hand-holding (2000' magazines can be used in the top position only). 1000' reverse running magazines available on request.

Magazine Loading: See diagram.

Hand-holdability: Handles and a shoulder-rest are provided for hand-holding the camera. In this configuration the camera is best used with a 500' or 250' magazine fitted at the rear. The weight of the camera in hand-held mode, with a 500' magazine and film, is approximately 27 lbs.

Image Contrast Control: "Panaflasher" light overlay unit an optional accessory.

Optical Accessories: Front-of-lens optical accessories include an exceptionally wide range of color control filters, diffusion filters, fog filters, low-contrast filters, black, white and colored nets, full-cover and split diopters, low/high angle inclining prisms.

Batteries: Camera, magazines, heaters and accessories all operate off a single 24V Ni-Cad battery. The normal battery complement is two x cased units with built-in chargers. Belt batteries are optional.

Camera Support Equipment: "Panahead" geared head, incorporates a 60° tilt range with a built-in wedge system to allow the operator to select where that range is, anywhere between the camera pointing directly up or directly down, and three gear ratios in both the pan and tilt movements. A sliding base unit enables a camera to be quickly attached and detached and to be slid backwards and forwards on the head for optimum balance. "Panatate" turn-over mount allows 360° camera rotation about the lens axis while at the same time permitting nodal pan and tilt movements. Nodal adapter available to mount a Panaflex nodally on a Panahead. "Panapod" tripods with carbon fiber legs are available in a range of sizes.

Video Assist Systems: State-of-the-art, CCD video systems are available in B &W or color.

Environmental Protection Equipment: All Panaflex cameras and magazines have built-in heaters to enable them to be operated in any ambient temperature. Heated covers are available to give additional protection to lenses, especially zoom lenses, to keep their operation smooth in intensely cold conditions. Other covers are available to protect the camera, magazines and lenses from heat and dust and from rain and water. Spinning-glass rain deflectors are available for use in storm conditions. An autobase is available to secure the camera in conditions of vibration high "g-forces" and other stressful and dangerous conditions. A water-box is available to protect the camera in shallow water conditions, a hazard box to protect the camera from explosions, collisions and other dangerous situations.

Time Code: The AatonCode code system encodes every frame with a SMPTE time code which is readable by both computer and human.

Panavision GII Golden Panaflex

Very similar to the Platinum Panaflex. Incorporates most of the features and operates with most of the accessories listed for that camera.

Panavision Panaflex-X

Similar to the GII Golden Panaflex but has a fixed viewfinder system and is not hand-holdable.

Panaflex Panastar High-Speed

Movement: Dual pilot pin registration ensures process-plate image steadiness. Pilot pins register in the same perforation holes (immediately below the bottom frame line) as optical printers. Four pull-down claws. Entire movement may be removed for servicing.

Threading Diagram: See below.

Aperture Plate: Same as Platinum Panaflex.

Aperture Mattes: Same as Platinum Panaflex.

Shutter: Focal plane shutter with infinitely variable opening and adjustable in-shot. Maximum-opening: 180°, minimum: 40° with adjustable maximum and minimum opening stops. A digital display allows adjustments in ⅒°

increments. Micrometer adjustment allow critical synchronization with computers, TV monitors and HMI lighting at unusual frame rates. Manual and electronic remote control units available.

Reflex System: Same as Platinum Panaflex.

Optical Viewfinder System: Same as Platinum Panaflex.

Ground Glasses: Same as Platinum Panaflex.

Lens Mounting System: Same as Platinum Panaflex.

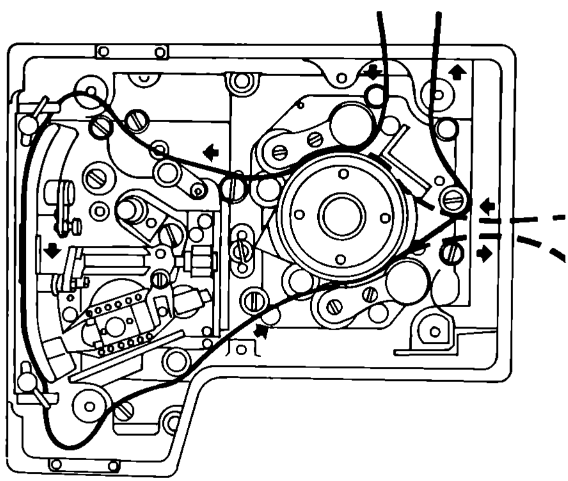
Lenses: Same as Platinum Panaflex.

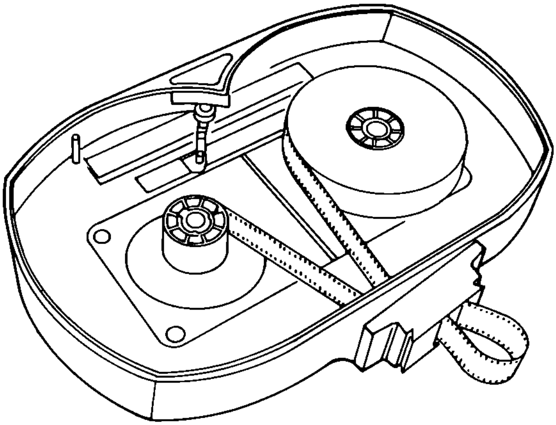
Lens Control: Same as Platinum Panaflex.

Matte Boxes: Same as Platinum Panaflex.

Camera Motor: A 24-volt motor is used to run the camera at any speed from 4-120 fps and is crystal-controlled at all speeds and may be adjusted in 1 fps increments. Special sync boxes are available to synchronize the camera with a main power supply, with computers, with video signals and with process projectors in shutter phase synchronization. Panastar cameras have internal heaters and may be used at sub-zero temperatures.

Magazines: 1000' and 500' magazines are available. Either can be used on the top of the camera for minimum camera length or at the rear for minimum camera height





Panastar reverse running type magazine threading

and for good balance when hand-holding; 1000' reverse running magazines available on request.

Hand-holdability: Handles and a shoulder-rest are provided for hand-holding the camera. In this configuration the camera is best used with a 500' magazine fitted at the rear. The weight of the camera in hand-held mode, with a 500' magazine and film, is approximately 26 lbs.

Image Contrast Control: Same as Platinum Panaflex.

Optical Accessories: Same as Platinum Panaflex.

Batteries: Same as Platinum Panaflex.

Camera Support Equipment: Same as Platinum Panaflex.

Video Assist Systems: Same as Platinum Panaflex.

Environmental Protection Equipment: Same as Platinum Panaflex.

Panavision Super R-200° 35mm

Movement: Dual pilot pin registration. Double pull-down claws. Pitch control to optimize camera quietness. Entire movement may be removed for servicing.

Aperture Plate: Removable for checking and cleaning. Full-frame aperture is standard, aperture mattes are used for all other frame sizes. A special perforation locating pin above the aperture ensures trouble-free and rapid film threading.

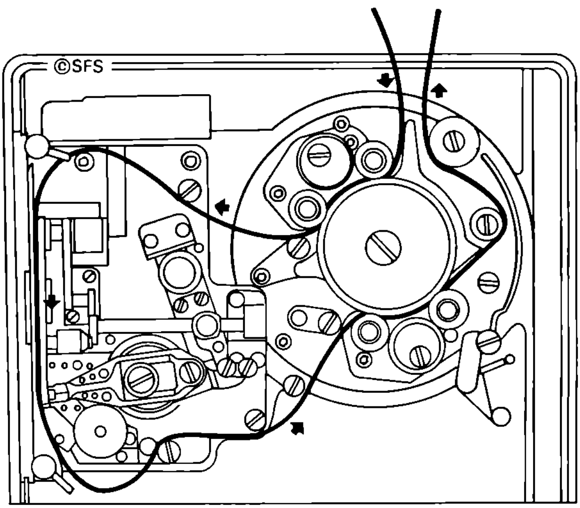
Aperture Mattes: Interchangeable aperture mattes are available for Academy, Anamorphic, Super-35, 1.85:1,1.66:1, TV transmitted and any other aperture required. Special hard mattes are available on request.

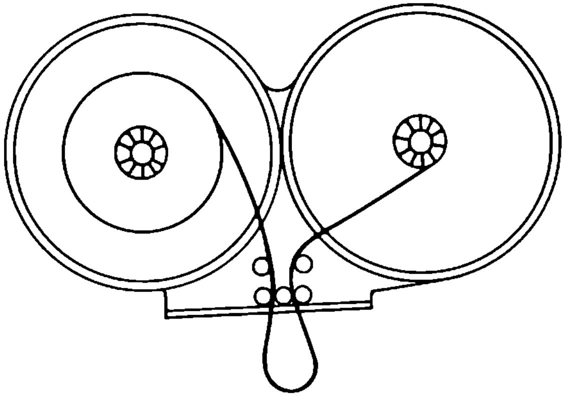
Shutter: Focal plane shutter with infinitely variable opening and adjustable in-shot. Maximum opening: 200°; minimum: 50° with adjustable maximum and minimum opening stops. A digital display allows adjustments in ⅒° increments. Micrometer adjustment allows critical synchronization with computers, TV monitors and HMI lighting at unusual frame-rates. Manual and electronic remote control units available.

Reflex System: Reflex rotating mirror is standard and is independent of the light shutter system. Interchangeable semi-silvered fixed reflex mirror for flicker-free viewing is optional.

Behind-the-lens Filtering: Provision for a behind-the-lens filter gel.

Optical Viewfinder System: Fixed optical system. System incorporates an optical magnifier for critical focusing and picture composition, a de-anamorphoser, a contrast viewing filter and a light-proof shutter. Wide-range ocular adjustment with marker bezel to note individual settings. A built-in "Panaclear" eyepiece heater ensures mist-





free viewing. An eyepiece diopter to suit the operator's own eyesight can be provided on request.

Ground Glasses: Same as Platinum Panaflex.

Lens Mounting System: Same as Platinum Panaflex.

Lenses: Same as Platinum Panaflex.

Lens Control: Same as Platinum Panaflex.

Matte Boxes: Same as Platinum Panaflex.

Camera Motor: 24 or 36V motors are used to run the camera at any speed from 4-36 fps with crystal control at 24 and 25 fps. Special sync boxes are available to synchronize the camera with a main power supply, with computers and video signals and with process projectors in shutter phase synchronization. May be used at sub-zero temperatures without special preparation.

DBA Rating: Less than 24 dB with film and lens, measured 3' from the image plane. Magazines: 1000' and 400' magazines are available. The 400' magazine can be used, together with a special low-profile magazine cover, for minimum camera height.

Optical Accessories: Same as Platinum Panaflex; see page 70.

Batteries: Camera, heaters and accessories all operate on either a 24V or a 36V Ni-Cad battery. The normal battery complement is two x cased units with built-in chargers.

Camera Support Equipment: "Super Panahead" geared head incorporates a 60° tilt range with a built-in wedge system to allow the operator to select where that range is, anywhere between the camera pointing directly up or directly down, and three gear ratios in both the pan and tilt movements. A sliding base unit enables a camera to be quickly attached and detached and to be slid backwards and forwards on the head for optimum balanced "Panapod" tripods, with carbon fiber legs, are available in a range of sizes.

Video Assist Systems: State-of-the-art, CCD video systems are available in B & W or color.

Photo-Sonics 35mm 4B/4C

Rotary prism recording camera designed for high speed full format 35mm photography.

Film Transport: Continuous.

Frame Rate: High-speed system: 500 to 2500 fps in 500-frame intervals. Low-speed system: 250 to 1250 fps in 250-frame increments. Special low-speed motor, 125 fps-625 fps, available on request.

Aperture Size: Full-frame 35 mm.

Film Specifications: B & H .1866" perforations.

Shutter: Rotary disc, 72° fixed shutter. 36°, 18° or 9° shutter available on request.

Viewfinder: Fries orientable. Boresighting is accomplished through the taking lens using ground film.

Lens Mount: Nikon or BNCR.

Drive: High-speed 208 VAC, 3 phase, 60 Hz, Y-connected synchronous speed motor. Surge at maximum frame rate 60 amps/each phase; running 30 amps/each phase. Low speed 115VAC, single phase, 60 Hz, synchronous speed motor. Surge at maximum frame rate 40 amps; running 20 amps.

Magazine: 1000'.

Film Cores: Film must be wound on dynamically-balanced aluminum film cores prior to use in this camera.

Accessories: Video assist on-axis, parallax-free, shuttered video camera or off-axis side mounted.

Photo-Sonics 35mm-4ER

High speed, (6 to 360 f.p.s.) pin register studio recording camera.

Movement: Intermittent with 12 pull-down arms, four registration pins and a vacuum back.

Shutter: Adjustable rotary disk type with increments: 5° between 5° and 50°; 10° between 50° and 120°.

Reflex Viewfinder: 4ER incorporates a reflex viewing system in conjunction with a Jurgens/Arriflex orientable viewfinder system and shuttered CCD video tap.

Lens Mount: BNCR, Panavision or Photo-Sonics.

Drive: Built-in motor and circuitry. Requires 208 VAC, single phase, 60 Hz, SCR, solid state. Surge at maximum frame rate 35 amps; running 20 amps.

Magazines: 1000-foot capacity with built-in light traps.

Features: 200-watt heater. Sync pulse for strobe light synchronization. Ground glass with Academy, TV safe action and 1.85:1.

Weight: 125 pounds with 1000-foot magazine loaded.

Accessories: Arriflex 5 x 6 Matte Box with Hard Matte set. Arriflex 6x6 Matte Box with Hard Matte set. Diopters for close focus: + 1/2, +1, +2, +3 set.

Ultracam 35mm

Sound level 20±1 dB at three feet with film and 50mm lens.

Movement: Full aperture: .985" x .736". Single claw, dual registration pin, compensating link, using tungsten counter-balance for minimum possible vibration. Automatic film location by spring-loaded pin. Pitch adjustment compensated for 3X more change in stroke length at end of stroke than at start. Entire movement can be removed for cleaning; coupling is keyed for correct alignment on replacement.

Shutter: Focal plane 175° on same shaft with mirror.

Reflex Viewfinder: Rotating two-blade half-speed mirror. 41°30' to permit short back focus lenses. Eyepiece rotates 360° using prism to provide erect image. All surfaces high efficiency for bright image, exit pupil 10mm. 6X to 9X true zoom magnification. Anamorphic correction available. Interchangeable ground glasses. Internal diopter accommodation. Right or left eye operation. Video assist on bayonet mount.

Lens Mount: SBNCR.

Drive: Internal 28V DC optically encoded. 8, 12, 16, 18, 20, 24, 25, 30, and 32 fps and by a 10V P-P external pulse of 60X frame rate. Crystal sync ±15 ppm over 0° to 130° F range. 50/60 Hz and frame rate output pulse.

Weight: 31 lbs. with 400' of film and 50mm lens.

Magazines: 500' and 1000' displacement. Built-in torque motor and electric brake. Either size will mount on camera top or rear.

Features: Quick-release balance plate. Built-in follow-focus. LED counter feet/meters may be preset to any reading; battery operated memory. Built-in heater. Swing-away matte box; rotating feature accepts various size filters with two stationary stages and two rotating stages.

VistaVision Cameras

MSM Model 8812 35mm/8-perf VistaVision

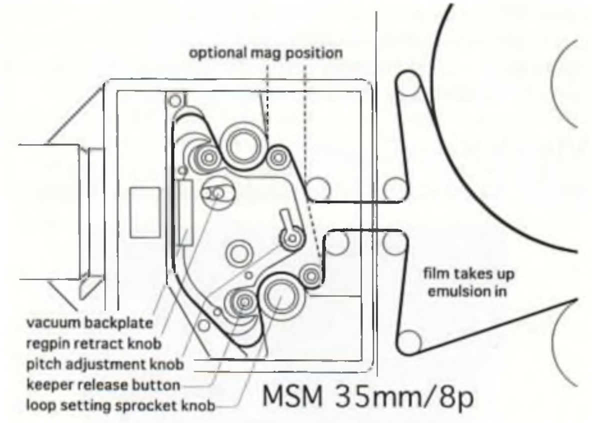
Movement: MSM Monoblock high-speed, triple register pins, claw engages four perfs. Shrinkage adjustment changes both stroke and entry position. Indexable loop-setting sprockets have independent locking keeper rollers. Vacuum backplate assures film plane accuracy, removes without tools for cleaning. Aperture and movement remove easily for cleaning and lubrication. Aperture size 1.485" wide x .992" high. Frame-rates from time-lapse to 72 fps forward, to 30 fps reverse.

Shutter: Focal plane shutter, manually variable from 172.8° to 55° with stops at 144° and 108°.

Viewfinder: Spinning mirror reflex. Interchangeable ground glasses with register pins for film clips. Finder rotates 360° with erect image, image can be manually rotated for unusual setups. Finder shows 105% of frame, magnifier allows critical focusing at center of interest. Single lever controls internal filter and douser. Heated eyepiece has large exit pupil and long eye relief. High-resolution B & W CCD videotap is built into camera door with swingaway 50/50 beamsplitter. Viewfinder removes completely for aerial or underwater housing use.

Lens Mount: BNC lens mount. 15mm matte rods are on Arri BL centers for accessory compatibility.

Magazines: 1000' and 400' displacement magazines operate bidirectionally at all camera speeds. A positive



camlock secures the mag in running position and switches power to the motor and heater contacts in the magfoot. Expanding core hubs have integral DC servomotors controlled by film tension in both directions, with soft startup to eliminate slack. Tightwind rollers guide film winding for smooth solid rolls at any camera angle. Non-contact light traps feature infrared end-of-film sensors.

Features: Crystal sync from 5 to 72 fps in .001 increments. Status LEDs for power, heat, low battery, mag ready, buckle, and speed sync. Two illuminated LCD footage counters. Digital battery volt/amp meter. Circuit breakers for camera, mag, heat, and accessories. Control port allows operation from handheld remote or interface with computers and external accessories.

Wilcam W-7 VistaVision High Speed

VistaVision, 8-perforation 35mm designed for operation at 200 frames per second.

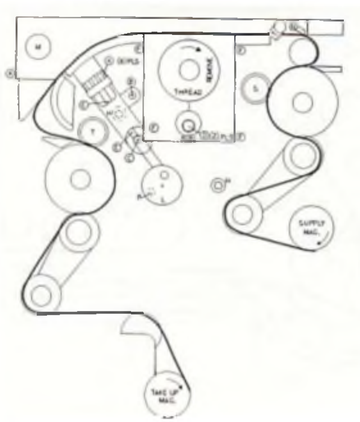
Registration: 3 dual-register pins.

Film Transport: 2 claw pins. Transport claws never enter the registration pin perforations.

Shutter: Beryllium mirror with tungsten counter weights.

Viewfinder: Rotating mirror. Uses servo motors for constant erect image while the eyepiece is being rotated.

Lens Mount: BNCR



Lenses: 14mm f/2.8 Canon, 19mm f/2.8 Leitz, 24mm T-1.4 Canon, 28mm T-1.8 Zeiss, 35mm T-1.4 Zeiss, 50mm T-1.4 Zeiss, 85mm T-1.4 Zeiss, 135mm T-1.8 Zeiss, 35-140 f/1.4 Vivitar zoom. Also 200mm, 400mm, and 600mm.

Magazines: 1000-foot.

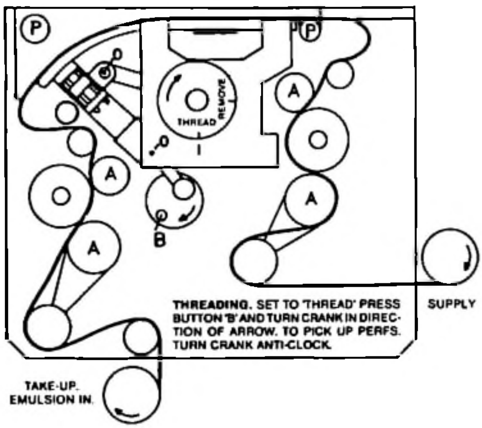
Magazine Drive: Gear-driven through torque motors permanently mounted on the camera body.

Matte Box: Wilcam 4 x 5.65 also standard Arriflex 6 x 6.

Weight: 110 pounds with 50mm lens and film.

Wilcam W-9 VistaVision Lightweight

VistaVision, 8-perforation 35mm designed for general purpose use. Maximum speed 100 frames per second.



Registration: 3 dual-register pins.

Film Transport: 2 claw pins. Transport claws never enter the registration pin perforations.

Shutter: 180° Beryllium mirror with tungsten counterweights.

Viewfinder: Rotating mirror. Uses servo motors for constant erect image while the eyepiece is being rotated.

Lens Mount: BNCR.

Lenses: 14mm f/2.8 Canon, 19mm f/2.8 Leitz, 24mm T-1.4 Canon, 28mm T-1.8 Zeiss, 35mm T-1.4 Zeiss, 50mm T-1.4 Zeiss, 85mm T-1.4 Zeiss, 135mm T-1.8 Zeiss, 35-140 f/1.4 Vivitar zoom. Also 200mm, 400mm, and 600mm.

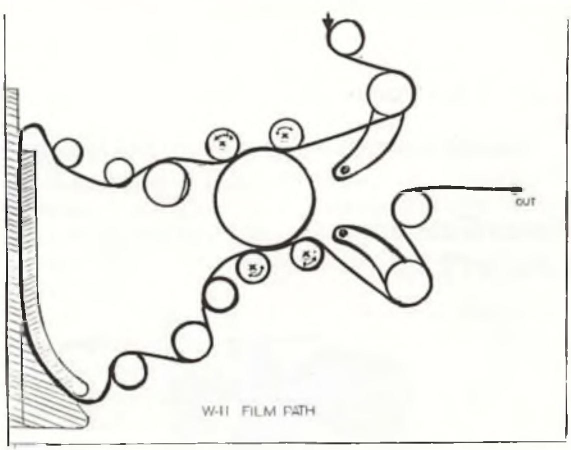
Magazines: 1000-foot.

Magazine Drive: Torque motors mounted on each

Matte Box: Wilcam 4 x 5.65 also standard Arriflex 6 x 6.

Weight: 37 pounds with 50mm lens and film.

Wilcam W-11 VistaVision Sound Speed



VistaVision 8-perforation 35mm. Designed for soundstage production shooting. Runs at 24, 25, and 30 frames per second, all crystal sync. Virtually silent in operation without relying on extensive blimping. Noise level in operating condition with a prime lens is 25 dB at 3 feet in front of the camera lens.

Registration: 3 dual-register pins. 2 pairs in conventional location, 1 pair .050 wide perforations trailing.

Film Transport: 2 claw pins. Transport claws never enter the registration pin perforations.

Shutter: Half-speed, 144 degrees. Beryllium mirror driven by second motor, phase-locked to camera motor.

Viewfinder: High-efficiency ground glass with locating pins for film clip. Automatic image erection with manual override for odd-angle viewing. 10X magnifier for critical focusing. Built-in Sony CCD video camera.

Lens Mount: BNCR.

Lenses: Available BNCR lenses: 14mm f/2.8 Canon, 19mm f/2.8, Leitz, 24mm T-1.4 Canon, 28mm T-1.8 Zeiss, 35mm T-1.4 Zeiss, 50mm T-1.4 Zeiss, 85mm T-1.4 Zeiss, 135mm T-1.8 Zeiss, 35-140 f/1.4 Vivitar zoom. Also 200mm, 400mm and 600mm.

Magazines: 1000-foot. Supply on right side of camera, take up on rear.

Magazine Drive: Hysteresis clutch with sensing arms in camera body for correct film tension.

Battery Voltage: 36 volts.

Current: 3 amperes.

Follow focus: On left side of camera. Detachable.

Matte Box: Wilcam 4 x 5.65 also standard Arriflex 6 x 6.

Weight: 60 pounds with 50mm lens and 1000 feet of film.

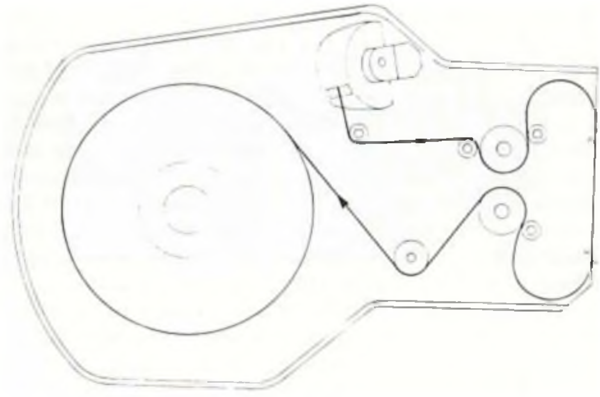
16mm Cameras

Aaton XTRplus

Ergonomically designed standard 16 and Super 16 camera for studio and documentary use, featuring time code and video assist. Sound level 19dB. *(Aaton XTRplus specific features appear in italics.)*

Movement: Linear-stroke single claw; self registering. Lateral and vertical registration system ensures a positioning of the film better than 2.5mm in all three axes. Hair-free gate with air circulation channel pulls hair out.

Shutter: True 180-degree front surface mirror facilitates 60Hz HMI and video-monitor roll-bar elimination.



Stops in viewing position. May be inched for aperture inspection.

Viewfinder: Reflex from shutter. Ultra-bright viewfinder. Fiberoptic imaging finder field is 120% of standard 16mm frame. Swiveling auto erect image eyepiece with 10X magnification. 20cm or 40cm extensions and left-eye extender available. Field interchangeable St16/Super 16 ground glass with Aatonite markings available on option. Built-in light meter display in viewfinder also indicates low battery, out-of-sync and before-the-end and end-of-film warnings.

Lens Mount: Aaton positive lock ring mount, Arri PL or Panavision Primo mounts. Aaton mount also accepts Arri Bayonet or any reflex-type lens with Aaton adapter. Standard to Super 16 format conversion in five minutes.

Drive: Brushless crystal sync 12V motor for 23.98, 24, 25, 29.97 & 30 fps. Variable control form 3 to 60 fps crystal controlled to $^1/_{1000}$ fps. Built-in TV bar eliminator. *(24, 25, 30 fps plus 6 to 54 fps in 12 steps, no built-in TV bar eliminator on XTRplus.)* Electronic base and motor may be removed and replaced in two minutes. Slim battery (12V 1.8 Ah) fits directly onto the camera body.

Magazines: 122m (400ft) coaxial. Feed chamber loaded in dark and loop threaded in daylight. Fourteen to fifteen-perforation loop length. Twistless film threading and hair-free gate eliminates pressure marks and emulsion pile-up. Magnetically driven takeup with electronic and mechanical counters. Memo-mag indexes for magazine ID recognition.

Features: Back-lighted digital control display: footage, speed, voltage, ISO, time code, magazine elapsed time *(no back-light nor elapsed time on XTRplus display)*. Memo-mag allows magnetic recognition by the camera body of 7 different magazines *(3 on XTRplus)*. Counter in camera provides LCD display of remaining footage — for short-ends load or multi-emulsion shoot. Keycode compatible and frame-accurate time code marking in SMPTE matrixes and human readable numbers. 1ppm TCXO internal clock for 8-hour autonomy. Bottom of camera-to-lens optical axis distance is 105mm to make the XTRplus compatible with 35mm camera accessories *(109.2mm on XTRplus)*.

Accessories: Lightweight wide-format swing-away matte box: two 4 x 5.6 and one 138mm rotating stages. Also accommodates Panavision mattes. Lightweight and without play follow-focus system. Totally incorporated black & white or color CCD video assist: the combination of concave viewing screen and exclusive relay lens with manual iris control delivers the clearest and sharpest images — requires no set-up time. LTR Model: superseded by XTRs, LTRs are differentiated by the magazine mechanical drive, no LCD counter and no CCD video-assist compatibility.

Arriflex 16SR-2

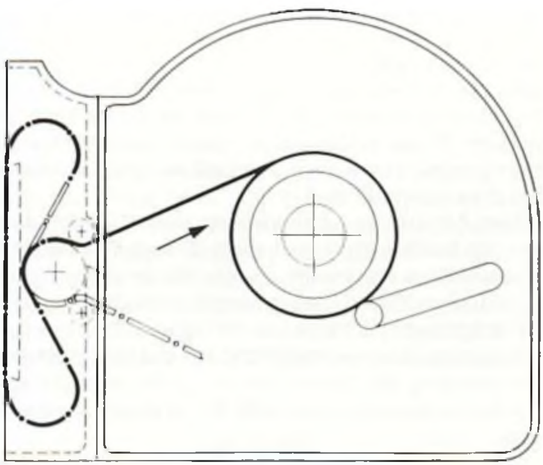
Description: The Arriflex 16SR-2 is a silent 16mm production camera, featuring a narrow, symmetrical body design and a unique, patented swing-over viewfinder. The 16SR-2's unique design allows the user to operate from either side of the camera. The 16SR-2 features a pin-registered film transport and fixed-gap channel, a fiberoptic viewing screen, patented orientable swingover viewfinder, APEC TTL metering system, auto shutter stop, and preset iris activator. It is widely used internationally for feature films, television production, TV commercials, music videos, nature and wildlife films, documentaries, and for industrial and scientific film production.

Versions:

1. 16SR-2E: Standard 16SR without APEC, preset lens activator or automatic exposure control. These features may be retrofitted.

2. 16SR-2: Standard 16SR, with APEC (Arri Precision Exposure Control).

3. 16SR-2 Automatic: Same as Standard 16SR with APEC, but also includes servo-activated, fully automatic



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exposure control. Exposure is adjusted automatically at any speed from 5 to 75 fps.

4/5. 16HSR-2 Highspeed Automatic, and 16HSR-2E Highspeed (w/o APEC): Operate up to 150 fps and require gray finish 16SR Highspeed magazines. On the Automatic version, exposure is adjusted automatically from 10 to 150 fps with lenses equipped with auto-iris capability.

6/7. Super 16 16SR-2 and Super 16 16HSR-2 Highspeed Standard and Highspeed 16SR cameras: All Arri accessories may be used without modification. Highspeed camera requires grey finish highspeed magazines.

Movement: Pin-registered, compensating link film transport, with fixed-gap film channel. The 16SR-2 operates from 5 to 75 fps with external variable speed control. The 16HSR-2 Highspeed (and the 16HSR-1 Highspeed version) operates from 10 to 150 fps with external variable speed control. The movement does not require threading as the loop is preset when the magazine is loaded. Switches located in the camera base of early versions lock in crystal speeds of 24 and 25 fps, 50 and 60 Hz, and in later SR cameras, 30 fps, 72 Hz. All 16SRs can be modified with a 30 fps kit.

Swingover Viewfinder: Rotating mirror-shutter system with 180° opening (1/48 sec at 24 fps), with high aperture/parallax-free viewing, and 10X magnification at the eyepiece. The swingover reflex viewfinder is centrally located, and swings within a 190° arc to either side of the camera for left- and right-side operation. The finder also rotates 360° parallel to the camera on either side, and swings out 25° for additional operator comfort. It features a fiber-optic viewing screen, a red out-of-sync LED, and an APEC exposure indicator.

Lens Mount: Steel bayonet lens mount (41mm diameter), with built-in auto-iris facility. Flange focal distance is 52mm. When used with an auto-iris lens, the iris will open to full aperture when camera is turned off and close down to a preset aperture when the camera is activated. All Arri 16mm or 35mm format standard and bayonet mount lenses covering the 16mm format can be used. Long or heavy lenses must be used with the bridgeplate support system.

APEC: Through-the-lens Arri Precision Exposure Control system. Provides continuous exposure information (match-needle mode) on a 4-stop indicator displayed in viewfinder. For film speeds ASA 16-1000. An optional servo-operated automatic exposure control system (with manual override) for complete automatic exposure control with auto-iris lenses is available.

Motor Drive: Quartz-controlled 12V DC motor for 24/25/30 fps, 50/60/72 Hz operation. A variable-speed accessory extends the speed range from 5 to 75 fps (on the 16HSR Highspeed, from 10 to 150 fps). Multi-camera interlock is achieved with the FSZ-II sync control accessory. Power input through a 4-pin connector. Pin 1 is (-); pin 4 is +12V. Modular plug-in electronics boards contain circuitry controlling all electronic functions, including a built-in start-marking system, out-of-sync light, Pilotone output and prewiring for SMPTE 80-bit time code. Operating temperature range is -4° F to +122° F (-20° C to +50° C).

Magazines: 400' coaxial; normally accepts 100' and 200' daylight loads; 400' daylight reels may be used if 1/8" is milled off the reel's edge. Loop is formed during loading for quick magazine change. Grey finish Highspeed magazines must be used on 16HSR, 16HSR-2 Highspeed and 16SR Super 16 Highspeed cameras.

Super 16: Both 16SR-2 and 16HSR-2 Highspeed cameras are available in Super 16. The wider Super 16 format (7.5mm x 12.3mm) required repositioning the optical axis 1mm to the left. The lens mount, fiber screen, viewfinder, tripod mounting hole and accessory shoe were moved accordingly. The shutter opening of the Super 16 camera is 172.8°. The APEC exposure system is standard on both cameras, but auto-iris exposure control is not available. The following bayonet-mounted lenses will work in the Super 16 format: Zeiss 16 format Superspeed primes 12mm, 16mm, and 25mm T-1.3; Zeiss 35 format Superspeed primes 18mm, 25mm, 35mm, 50mm, and 85mm T-1.3 and 135mm T-2.1; Zeiss 35mm Standard primes 10mm, 16mm, 20mm, 24mm, 28mm, 32mm, 40mm, 50mm, 85mm, 100mm, and 135mm T-2.1; and 60mm, 180mm, and 300mm T-3.0. Angenieux 16-44mm T-1.3 and 15-150mm T-2.3; RTH Cooke 10.2-54mm T-2.8. All 35mm format zoom lenses will cover Super 16.

Matte Boxes: See Arriflex 535 Matte Box section for details. Accessories: 2-speed follow-focus with 1:1 or 1:.06 ratios; bridgeplate support system for CG balance and mount for matte box, follow focus, servo zoom drive, and heavy lenses; lightweight support, on-board batteries, left and right grips for handheld operation of the camera; finder extender; SMPTE time code generator; High-speed unit for operation of Standard 16SRs up to 75 fps or 16HSR Highspeed up to 150 fps; Arri Geared Head; and director's viewfinder with PL mount.

Arriflex Super 16

Two versions of the 16SR-2 camera are available in the Super 16 format: the 16SR-2 (5-75 fps) and the 16HSR-2 Highspeed (10-150 fps). Normal operation and functions of both are virtually the same as with standard 16SR-2 cameras.

The height of the Super 16 aperture in the 16SR-2 is identical to that in regular 16SRs, but the aperture is 2mm wider, pushing into the left perf area on the negative. The Super 16 aperture is 7.5 X 12.3mm, and the aperture of regular SRs is 7.5 X 10.3 mm. This necessitates the repositioning of the optical middle axis of lens mount, viewfinder, tripod thread and accessory holder by 1mm to the left. Single-perf film must be used.

The 16SR-2's spinning mirror shutter has a 172.8° shutter opening. Super 16 SRs have the same exposure meter system as in regular 16SRs, but the automatic exposure control feature cannot be installed.

Because of the wider aperture area covered, some standard 16mm lenses will vignette. The following 41mm Steel Bayonet Mount lenses can be used for Super 16 production:

16mm Format	
Superspeed Primes	
12mm	Zeiss Distagon T-1.3
16mm	Zeiss Distagon T-1.3
25mm	Zeiss Distagon T-1.3
50mm	Zeiss Planar T-1.3
Zoom Lenses	
11-66mm	Angenieux T-2.6
11.5-138mm	Angenieux T-2.3
15-150mm	Angenieux T-2.3
16-44mm	Angenieux T-1.3
10.4-52mm	Cooke Varokinetal T-2.8
10-30mm	Cooke Varokinetal T-1.5
35mm Format	
Superspeed Primes	
18mm	Zeiss Distagon T-1.3
25mm	Zeiss Distagon T-1.3
35mm	Zeiss Distagon T-1.3
50mm	Zeiss Planar T-1.3
65mm	Zeiss Planar T-1.3
85mm	Zeiss Planar T-1.3
Standard Primes	
16mm	Zeiss Distagon T-2.1
20mm	Zeiss Distagon T-2.1
24mm	Zeiss Distagon T-2.1
28mm	Zeiss Distagon T-2.1
32mm	Zeiss Planar T-2.1
40mm	Zeiss Planar T-2.1

50mm	Zeiss Planar T-2.1
60mm	Zeiss Macro Planar T-3.0
85mm	Zeiss Planar T-2.1
100mm	Zeiss Planar T-2.1
135mm	Zeiss Planar T-2.1
180mm	Zeiss Sonnar T-3.0
300mm	Zeiss Tele-Apotessar T-3.0 (with 2X range extender becomes 600mm T-6.0)

Zoom Lenses: All 35mm format zoom lenses with 41mm steel bayonet mount will cover Super 16.

Time Code Note: 16SR-2 Super 16 cameras are time code compatible.

Arriflex 16SR-3

Silent 16mm production camera system for both Standard 16 and Super 16 production. In two versions:

1. 16SR-3 Standard (Standard 16 and Super 16)
2. 16HSR-3 Highspeed (Standard 16 and Super 16)

Movement: Pin-registered compensating link, with fixed-gap film channel. 5-75 fps Standard; 10-150 fps Highspeed.

Shutter: Variable (manually) rotating mirror shutter; 90°, 135°, 144°, 172.8°, 180° shutter openings. Shutter opening indicated on LCD display during electronic inching mode.

Reflex Viewfinder: Swingover Viewfinder swings in a 190° arc for full left- or right-side operation, with fully upright image in any position. With CCD video assist and flicker-reduction electronics attached, viewfinder swings in a 120° arc. Finder is equipped with ArriGlow — steplessly adjustable illuminated frame lines for both Standard 16 and Super 16. The finder also has warning indications for asynchronous camera speed, film-end and low battery. NOTE: the 16SR-3 Super 16 aperture can be masked for the Standard 16mm frame. No additional aperture is needed.

Lens Mount: Standard 54mm Arri PL mount will take any 35mm format PL mount lens. Adapters available for 41mm bayonet and standard mount lenses.

Drive: Built-in crystal-controlled 24V DC motor. Onboard programmable speeds of 24, 25, 29.97 and 30 fps, and variable crystal speeds from 5-75 fps in the Standard camera, or 10-150 fps in the Highspeed 16SR-3, variable in 0.001 increments at crystal accuracy. Speeds are continuously variable when the Remote Unit (RU-1) is used. Speeds can be programmed from the 16SR-3's on-board LCD, with the Remote Unit (RU-1) or with the Camera Control Unit (CCU), Arri's standard off-camera programming unit.

Magazines: 400-foot coaxial. Standard 80-bit SMPTE time code module built in. Existing 16SR-2 magazines can be used. 16SR-3 magazines without time code are available.

Time Code: Integral 80-bit SMPTE time code. Recording module built into 16SR-3 magazines. Fully complies with SMPTE RP 114 standard.

Video Assist: Takes Arri ½" black & white or color CCD video assist, and Arri AFP-2 flicker reduction electronics for bright, flicker reduced images. Adjustable for Standard 16 and Super 16, with the full image of either format on the monitor. Changing beam splitter ratio for color or B & W is easy, and requires no adjustment.

LCD Display:

a. set/display frame rates

b. set/display film counter

c. display mirror shutter opening (during electronic inching mode)

d. set/display time code and user bits

e. display TC sensitivity readout

f. battery voltage and low-battery warning

g. film-end and asynchronous camera speed

The CCU can be used to control or set most of the above functions.

System Compatibility: A wide variety of Arriflex 35mm accessories can be used with the 16SR-3, such as: ESU-1, External Synchronizing Unit; RU-1, Remote Unit; RS-3, Remote Switch; HE-3, Heated Eye Cup; the standard camera handgrip; CCU-1, Camera Control Unit; and the AFP-2 Anti-Flicker Processor.

Lenses: With its 54mm PL lens mount, the 16SR-3 utilizes the full range of 35mm format and 16mm format Zeiss Superspeed, Zeiss Standard, Arri Anamorphic and Arri Macro lenses, and RHT Cooke and Angenieux zoom lenses.

Matte Boxes: The 16SR-3 uses the Arri 19mm rod Camera Support System. The Support System includes a full range of matte boxes (6.6x6.6, 5x5, and a variety of 4x4), bridgeplates, 2-speed follow-focus, and lens supports. 15mm rod adapters are available on request. The 4x4 Production Matte Box is ideal for the 16SR-3. Its swingaway design covers lenses 16mm and up, has interchangeable two- and four-frame geared filter stages, is fully rotatable, and accepts most Support System accessories.

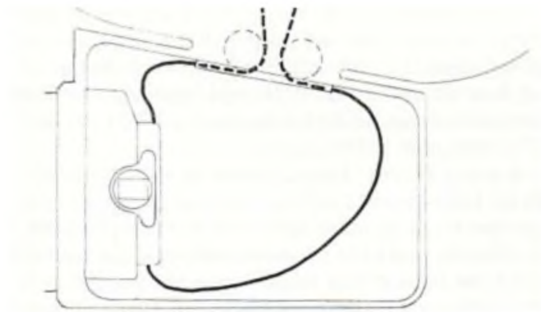
Geared Heads: The 16SR-3 works with both the Arri Geared Head, and the Arri Geared Head 2.

Arriflex 16BL

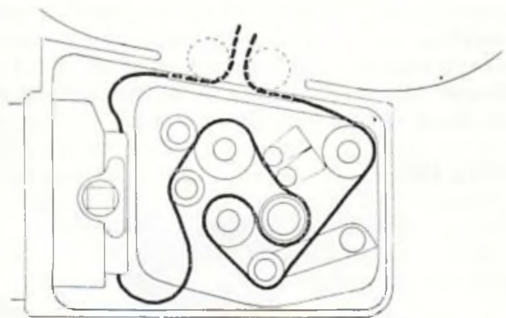
Movement: Registration pin operates through a variable speed range of 5 to 50 fps, forward or reverse, when used with appropriate motor and speed controls.

Reflex Viewfinder: Rotating mirror-shutter system with fixed 180° opening (1/48 sec at 25 fps), high-aperture/parallax-free viewing, 10X magnification at the eyepiece. An offset finder accessory is available for handheld camera applications for additional operator comfort.

Lens Mount: Steel Arri Bayonet mount (lens housings are required to maintain minimal camera operating sound levels). All Arriflex Standard or Bayonet mount lenses that cover the 16mm format can be used with lens housings.



16mm ARRIFLEX 16BL
DOUBLE-SYSTEM
(FILM TAKES UP EMULSION SIDE IN)



16mm ARRIFLEX MODEL 16BL
SINGLE-SYSTEM SOUND
(FILM TAKES UP EMULSION SIDE IN)

Standard zoom and telephoto lenses should be used with the Bridgeplate Support System.

APEC: Exposure control system, meters behind the lens and displays continuous exposure information (match-needle mode) in the viewfinder.

Motor Drive: Two motor-drive systems are available. The quartz-controlled motor provides cordless sync-control and automatically stops the shutter in viewing position. Its speed range is 6, 12, 24 (quartz-controlled) and 48 fps. The Universal motor is transistorized and governor controlled. A Variable Speed Control accessory will drive the

Universal motor from 10 fps to 40 fps. Magazines: 200', 400' (forward and reverse), and 1200' (forward only) magazines.

Lenses: Fixed focal length Standard and Zeiss Superspeed lenses. Zeiss, Angenieux and Cooke zoom lenses.

Matte Box: Bellows type; available for all 16BL lens housings.

Accessories: Universal Lens Housing for use with fixed focal length lenses when minimal camera operating sound level is required (accepts 3x3 or a 94mm diameter filter); interchangable TV ground-glass; fiber-optic screen available; offset finder; finder extender; zoom drive; 12V DC quartz motor for 6, 12, 24 and 48 fps; Variable Speed Control for 10 to 40 fps operation with universal motor; plug-in Single-System Sound Module; and Single-System Record Amplifier.

Arriflex 16S/B; 16S/B-GS; 16M/B

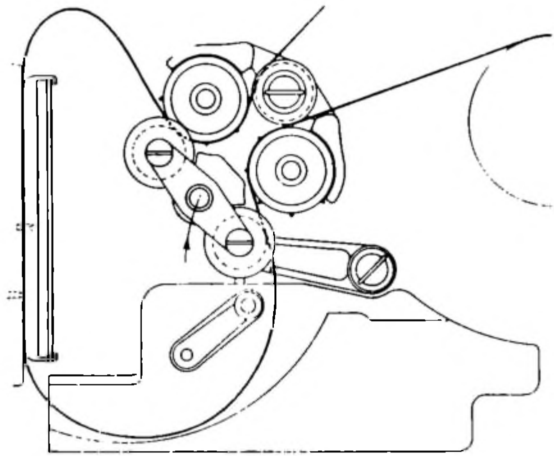
Arriflex 16S/B: Features pin-registered film transport system operating to 75 fps, 100-foot internal daylight film spool loading, with top-loading 400-foot magazine, reflex viewfinder system, divergent three lens-mount turret, and motor interchangeability.

Arriflex 16 S/B-GS: Pilotone sync-generator and start-marking system built-in.

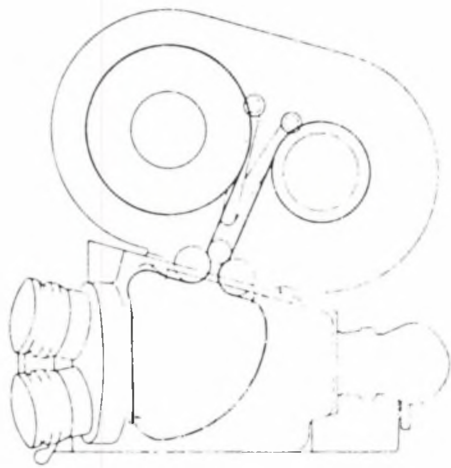
Arriflex 16M/B: The 16M camera is configured differently and has no internal daylight spool film load capacity. 200-, 400- and 1200-ft. 16M magazines are available for this camera. It accepts all of the accessories in the 16S system except the magazines and power-cables.

Movement: Registration pin, operates through a variable speed range of 75 fps (with appropriate tachometer), forward or reverse. The 16S, 16M and 16BL movements are identical.

Reflex Viewfinder: Rotating mirror-shutter system with 180° opening (1/48 sec at 24 fps), high-aperture/paral-



16mm ARRIFLEX S/B SERIES
(FILM TAKES UP EMULSION SIDE IN)



16mm ARRIFLEX 16M
(FILM TAKES UP EMULSION SIDE IN)

lax-free viewing, 10X image magnification at the eyepiece. An interchangeable ground glass or fiber-optic screen, and an optional APEC exposure control indicator, are located within the viewfinder system.

Lens Mount: The 16S and M cameras have divergent three lens-mount turrets with two standard and one steel bayonet-lock mounts. Any Arriflex standard or bayonet-mount lens that covers the full 16mm format may be used. Zoom and telephoto lenses require use of the Bridgeplate Support System.

APEC: Exposure control system, meters behind the lens and displays continuous exposure information (match-needle mode in the viewfinder, 16S only).

Motor Drives: Quartz-regulated, governor-controlled, synchronous, and variable-speed motors are available for 16S and M cameras. Motor specifications are listed in the accessory column.

16S Magazines: 200- and 400-ft. torque motor-driven magazines are available for 16S cameras. The torque motor drive is essential with 16S magazines, and is interchangeable with all 16S magazines of the same film capacity.

16M Film Magazines: 200-, 400- and 1200-foot magazines are available for the 16M cameras. These magazines are gear-driven and do not require torque motor drives. The 1200-foot magazine operates in forward direction only.

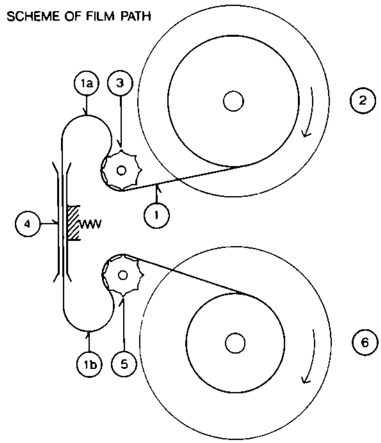
Lenses: Fixed focal length Standard and Zeiss Superspeed lenses. Zeiss, Angenieux, and Taylor Hobson Cooke zoom lenses in Arri Standard or Bayonet mount.

Matte Box: (16S/M) with adjustable bellows, one rotating and one stationary filter stage. Accepts 3x3, 3x4, and 4 x 4 glass filters. A 94mm round Polarizing screen can also be used. Lightweight sunshade and filter holder (rubber) for 16S or 16M, accepts 3 x 3 filters.

Accessories: Fiber-optic screen; periscope viewfinder; finder extender; 12V DC quartz-motor for 24/25 fps 50/60Hz, variable speeds 5 to 75 fps, and single-frame forward and reverse capability and pilotone output; 8V and 12V DC governor motor for 24 fps forward operation only; 8V or 12V DC variable motor for 5 to 40 fps forward or reverse operation; 110V AC/60 Hz synchronous motor and in-line power supply for 12V, 24 fps operation; bridgeplate support system; adapter for microscope stand and microscope optical link.

Bolex 16mm (All Models)

Movement: Single-claw pull-down. Trailing claw system assuring maximum picture steadiness without need for registration pin. Aperture plate made from hard chromed steel. Gate has automatic threading device that loops the film and inserts it into gate and around sprockets. Rear pressure plate can be removed for cleaning gate. Automatic loop former prevents loss of loop.



Shutter: Bolex spring-driven cameras (H-16 Rex 5 and H-16 SBM) have 135° variable shutter which can be opened or closed while camera is running. It can be locked at ¼, ½ and can be opened and closed automatically with Rexofader accessory. Shutter speeds 12-64 fps, single-frame. Bolex electrically driven cameras (H-16 EBM and H-16 EL) have fixed 170° shutter. Shutter speeds electronically controlled 10-50 fps.

Focusing: All cameras have flickerless focusing and parallax-free viewing through prism reflex finder. Image is magnified 14X in eye-level finder and may be continuously viewed in filming or stopped position.

Lenses: H-16-Rex 5 has 3-lens turret for C-mount lenses, other models have large Bolex bayonet mount suitable for heavy zoom and telephoto lenses. Adapter for C-mount lenses and accessories available. Full line of Switar, Vario Switar and Angenieux zoom and standard lenses, matte box, extension tubes, Aspheron wide-angle adapters etc, available.

Drive: Spring-driven cameras will expose 16 ½' of film on one winding. Variable-speed motor and electronically stabilized motor suitable for sync pulse and crystal sync available for spring-driven cameras. H-16 EBM and H-16 EL have 10-50 fps electronically regulated motors built in. H-16 EL has single-frame and electric rewind, instant start and stop. All models accept 400' magazine with take-up motor.

Magazines: All cameras accept 100' Daylight Loading Spools, which can be ejected with built-in lever device. 400' magazine with self-contained take-up motor available.

Features: Footage and frame counters add and subtract. Spring motor may be disengaged. Full 100' film rewind. Audible scene-length signal clicks every 28 frames. Single-frame exposure button for instantaneous or time exposures. All cameras have filter slot behind the lens. H-16 EL has built-in through-the-lens silicon light meter with shock-proof LED indicators in the VF.

Accessories: Automatic Rexofader fading device for H-16 REX and SBM available for 40-frame fades. Camera grip, barney blimp, extension tubes for macrocinematography. Underwater housing for EL and EBM, matte box, cable releases, tripods, monopod, shoulder brace.

Note: Many other accessories, such as animation motors, microscope attachments and time-lapse units, are available from other firms.

Bell & Howell 16mm Filmo 70

Compact, spring-wound 100' daylight loading 16mm camera. Accessory 400' magazine and electrical motor for models 70HR and 70SR.

Movement: Cam-operated single claw. Spring-loaded edge guide and pressure plate. Relieved aperture plate.

Shutter: 204° (models before SN 154, 601: 216°)

Viewfinder: Outside finder tube, 3-lens turret, parallax correcting eyepiece.

Focusing: Magnified central image on ground glass when objective lens turret is rotated 180°. Safety latch prevents camera running when in focusing mode.

Lens Mount: Three-lens turret, geared to finder lens turret. C mount.

Drive: Spring-driven, governor-controlled drive exposes 22' per wind at 8 fps-64 fps (model 70SR at 128 fps only). Models 70SR and 70HR have optional battery or AC motors.

Magazines: Model 70SR and HR use optional 400' compartment-type magazines (electric motor should be used for magazine operation).

Features and Accessories: Hand backwind for dissolves. Standard dial footage indicator, optional digital Veeder. Single-frame drive. Replacement shutter for less than 204°. Filter slot modification. External large image viewfinder.

Minicam 16mm (GSAP)

Movement: Intermittent, single pull-down claw, cam actuated.

Shutter: 133° fixed.

Focusing: Boresight alignment tool available as optional accessory.

Lens Mount: Supplied to accept lenses in "C" mount or Arriflex Mount configuration.

Motor: Integral, 24V DC. Adjusted for 24 or 48 fps.

Magazine: Uses pre-loaded Eastman Kodak magazines, 16mm x 50', in all popular emulsions.

Other Features: Light weight (less than 2½ lbs). Ideal "point-of-view" camera. Widely used for skiing, auto racing, sky diving or installations hazardous to camera equipment.

Accessories: "C" mount front plate; Arriflex Mount front plate; Battery, Ni-Cad, rechargeable; adjustable camera tool; boresight alignment tool; power plug; power cable; carrying case; underwater housing; battery charger.

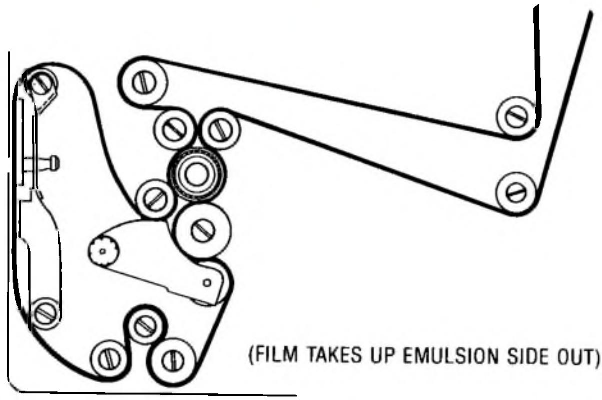
Cinema Products CP-16 & CP-16A

16mm news/documentary/single/double system sound cameras.

Movement: Sinusoidal, intermittent movement. Self-engaging single-claw film pull-down with precision lapped surfaces for quiet, long-life reliability. Film accurately guided over a series of stainless steel balls to guarantee in-focus, scratch-free pictures (with no emulsion pickup). Stainless steel pressure plate, ground lapped with recessed center area, easily removable for cleaning.

Shutter: 173°; (optional 144°).

Viewfinder: The CP-16 was designed for specific use with Angenieux zoom lenses with built-in reflex viewfinders. Viewfinders are available in various lengths for shoulder or tripod operation, and provide ground spot focusing in the center of the clear viewing area. TV reticle markings define safe action area. Horizontal, 22½° & 45° angle eyepiece position.



Lens Mount: Type "C".

Drive: Plug-in 20V battery drives crystal sync built-in motor. 24 fps ± 15 ppm over 0°-140° F; interchangeable pulley for 25.

Magazines: 400' snap latch. Adapter for Mitchell 400' and 1200' magazines.

Sound Recording System: CP-16 and CP-16/A cameras operate with 3XL-type record/playback head assemblies. The CP-16/A features the Crystasound built-in amplifier system, a self-contained recording system complete with two low-impedance dynamic microphone inputs, one 600-ohm line input, VU meter, headphone monitoring, switchable AGC and auxiliary mixer input. A provision for wireless receiving is also available. An auxiliary mixer, model 6C, provides 6 channels of microphone input. The auxiliary mixer is complete with VU meter, switchable AGC, and headphone monitoring. The mixer, built-in amplifier and wireless units are all powered from the camera's Ni-Cad battery (model NC-4).

Features: Weighs 15.8 lbs. with 400' film and 12-120mm zoom. 16.8 lbs. with sound amplifier. Out-of-sync warning light and battery indicator. Filter slot.

Accessories: An AC power supply, single and multiple chargers, sound preamplifier, microphones, front-mounted VU meter, mike/lite bracket, lighting kits, fluid head tripods, quick-release shoulder and tripod mount, plus a line of Angenieux zoom lenses and a wide range of carrying cases.

Cinema Products CP-16R & CP-16R/A

Reflex 16mm news/documentary/studio single/double system sound cameras.

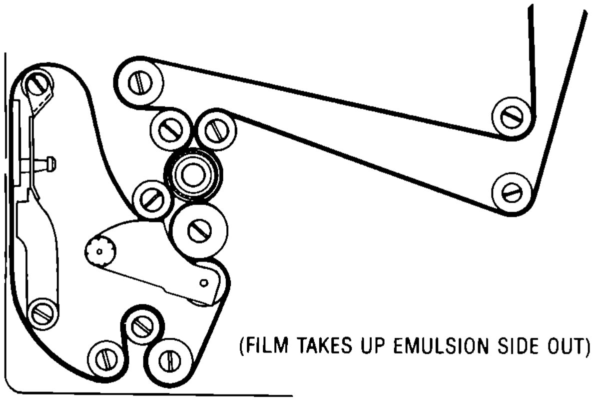
Movement: Sinusoidal, intermittent movement, self-engaging single-claw film pull-down. Film accurately guided over a series of stainless-steel balls to guarantee in-focus, scratch-free pictures (with no emulsion pickup). Stainless-steel pressure plate, ground lapped with recessed center area, easily removable for cleaning.

Shutter: Focal plane 170° (optional 144°).

Reflex Viewfinder: Rotating mirror integral with focal plane shutter. Stops in viewing position. Fiberoptics screen marked with TV safe action, projection, and 35mm blow-up lines. Adjustable focusing eyepiece 12X magnification, 90° click stop rotation; optional 360° rotatable right or left eyepiece. Erect image.

Lens Mount: Thread-locking bayonet. Adapters for Arri or Nikon mounts.

Drive: 20V plug-in battery drives built-in crystal-controlled motor 24 or 25 fps sync speed ± 15 ppm over 0-140° F. Standard speeds 12, 16, 20, 24, 28, 32 and 36 fps. Pulley change 24 to 25 makes range 12.5, 16.5, 21, 25, 29, 33.5 and 37.5 fps.



Magazines: 400' snap latch. Adapter for Mitchell 400' and 1200' magazines.

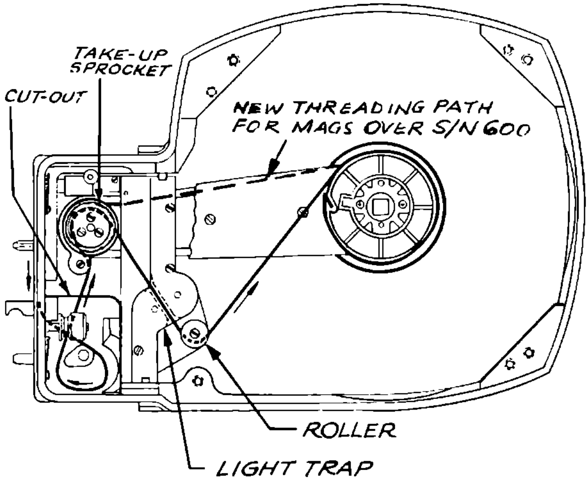
Sound Recording System: The CP-16R and CP-16R/A cameras have been designed to accept Crystasound 3XL-type magnetic record/playback heads. The CP-16R/A features the Crystasound built-in amplifier system, a self-contained recording system complete with two low-impedance dynamic microphone inputs, one 600-ohm line input, VU meter, headphone monitoring, switchable AGC and auxiliary mixer input. A provision for wireless receiving is also available. An auxiliary mixer, model 6C, provides 6 channels of microphone input. The auxiliary mixer is complete with VU meter, switchable AGC, and headphone monitoring. The mixer, built-in amplifier and wireless units are all powered from the camera's Ni-Cad battery (model NC-4).

Features: Filter slot. Battery test. Viewfinder indicator LED for battery, out-of-sync, film runout, sound VU. Weight with 10-150mm zoom, 400' film, battery: 17.4 lbs.

Accessories: Finder 7" extension. Cinevid-16 video assist, bayonet mounted. Automatic or semi-automatic exposure system with viewfinder display. Zoom control system. Power supply/charger. Shoulder and tripod mounts.

Cinema Products GSMO 16mm

Movement: A high-precision, single-claw, sinusoidal registration movement with a curved film gate for minimum pull-down time. The interchangeable film gate assembly with its floating pressure plate and hard chrome-edge film guides is located in the cassette-type coaxial magazine.



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Shutter: Rotating mirror 180° stops in viewing position. (144° shutter for TV filming applications optional.)

Reflex Viewfinder: Fiberoptic viewing screen marked with TV safe action, 16mm projection, and 35mm blow-up lines. Two viewfinder options; both have 12X magnification, high-efficiency optics, focusing eyepieces. Dual-purpose viewfinder provides 32 adjustable viewing positions; may be extended 7" for tripod operation. Optional viewfinder pivots for left or right eye and provides 360° rotation. Erect image. Optional 7" extender.

Lens Mount: Single-thread locking bayonet with locating pin. Optional adapters for Arri and Nikon mounted lenses.

Drive: 20V plug-in battery drives crystal-controlled motor; speeds of 12, 16, 24, 25, 32, 48 and 64 fps or alternate speeds of 12, 20, 24, 25, 30, 48 and 64 fps. Accuracy + 30 ppm over 0°-140° F.

Magazines: Quick-change, rugged, cassette-type coaxial magazine contains interchangeable film-gate assembly. Automatic loop forming device. (Preloaded magazines can be changed instantly without touching film.) 100' and

400' capacities. 400' magazine features "film remaining" manual indicator.

Features: Illuminated digital film counter (feet or meters) with memory. Full-frame auto slating. External battery test. LED out-of-sync and low-battery indicator in viewfinder. Weight with 400' load and 17.5-70mm zoom lens: 12.44 lbs.

Accessories: Exposure control system with display in viewfinder. Remote speed control with continuously variable speed from 12-64 fps. Zoom control system. AC power supply, battery charger. Quick-release shoulder and tripod mounts. Video assist.

Eclair ACL 16mm

Movement: The claw movement is a wedge-shaped claw controlled by an eccentric and a fixed cam and rendered positive by the use of a counter cam. The steadiness of the image is excellent, with a tolerance of less than one-thousandth of frame height. Lateral steadiness is assured in the gate by a fixed side bar and a spring-loaded guide. Image sharpness is ensured by a spring-loaded pressure plate which forms part of the front of the ACL magazine and which maintains the film perfectly against the aperture during the exposure.

Shutter: Focal plane 175°.

Reflex Viewfinder: Oscillating mirror, low-loss optical system, fine-grain ground glass. Image magnification 12X. Focusing eyepiece will rotate through 360° parallel to the camera.

Lens Mount: Universal Type C. Outside thread for various adapters.

Drive: 12V DC crystal-controlled motor at 24 or 25 fps directly on shutter shaft. Variable-speed capability 12 to 40 fps. Optional 115V sync motor.

Magazines: Snap-on 200' coaxial. Prethreaded for quick change; as soon as core load film or daylight spools are inserted in feed side of magazine and film is passed through light trap to takeup side, the remainder of loading operation may be carried on in daylight. Film remainder dial.

Features: Automatic start mark. Pilotone output 50 or 60 Hz. Weight: 7.7 lbs.

Eclair CM-3 16/35mm

Movement: Pull-down claws are mounted on sliding cam-driven plate. Movement has two sets of ratchet-type pull-down claws; one on each side for 35mm and a centered claw for 16mm. Ease of adjusting claw stroke permits adapting camera to either normal four-perforation pull-down or two-perforation pull-down for Techniscope, or single-perforation pull-down for 16mm operation. Claw movement stroke may be changed by sliding cam, which is reached through opening in aperture plate. No disassembly or special tools required. Registration and steadiness achieved by double rear pressure plate and very long side rails. Top plate keeps film flat in focal plane, bottom plate holds film at edges only, to keep it properly aligned for pull-down claws. Aperture plate is made of one piece of steel, hand-polished and undercut to prevent scratching. Aperture plate is part of camera body proper, pressure plates are built into magazine. Raised area in center of aperture portion of pressure plate eliminates breathing.

Shutter: 200° variable front-surfaced mirror reflex shutter rotates at 45° angle between lens and film plane. Center of shutter is below aperture, thus describing a horizontal wiping motion across film. Shutter may be varied to 35° by turning knob on left side of camera body.

Reflex Viewfinder: Through-the-lens focusing and viewing. Lens may be follow-focused while viewing. Extra fine-grained ground glass presents brilliant image even under low-light levels or when lens is stopped-down. 360° rotatable eyepiece for right or left eye. Adjustable mattes for various aspect ratios.

Lenses: Three-lens divergent cam-lock turret with Camerette CA-1 lens mounts. CA-1 lens mount is large diameter brass bayonet-type. Divergent turret permits mounting 5.7mm focal length and longest telephoto lenses without optical or physical interference.

Drive: Motors are mounted on side of camera and may be changed in a few seconds. Basic motor is 6-8V DC rheostat-controlled variable speed type (also available for 24V power). Other motors: 6, 12 and 24V DC transistor-controlled regulated motors with variable-speed or constant-speed operation with 50 or 60 Hz sync pulse outputs. 115V 60 Hz and 220V three-phase, 60 Hz AC motors for synchronous sound shooting. Hand-drive also available for 1, 8 or 16 pictures per turn.

Magazines: 200', 400' and 1000' displacement-type magazines allow rapid changing. Magazines are pre-loaded with a fixed loop (which may be set from outside at any time). Automatic footage counter. Removal of magazine allows inspection and cleaning of aperture plate and film channel. For Techniscope operation, T-Type magazine operates at either 45' per minute or 90' per minute by merely changing gears.

Features: Built-in tachometer. Sliding mattes for film aperture and viewfinder for 16mm. Techniscope or other wide-screen ratios. Dovetail adapter for instant tripod clamping has twin matte-box rods for mounting metal matte box. Two filter stages, one rotatable and removable, for use with extra-wide-angle lenses. Additional mattes may be positioned in front of matte box to protect the lens from being struck by back-light.

Accessories: Lightweight magnesium tripod. Entire tripod bowl and movements can be lifted from legs and clamped to table edges, doors, ladders, etc. Sound blimp. One door allows sliding camera out on rails for instant magazine change, and automatically connects follow-focus, lens diaphragm and external eyepiece. Camera may be used with all anamorphic and zoom lenses, in or out of blimp. Full instrumentation capabilities available with single-frame pulse and intervalometer operation. Aquaflex underwater housing for both 35mm Techniscope and 16mm.

Eclair NPR 16mm

Blimpless, silenced camera.

Movement: Film is advanced by desmodrimic cam movement. Quiet movement is achieved by wedge-shaped claw which slides into perforation with a wedging motion. Film is pulled down and registered upon bench-type registration pin which begins moving into position before film has stopped. Extra-long rear pressure plates and side guide rails steady film. Raised areas in center of aperture portion of pressure plate eliminate possibility of breathing or focal shift.

Shutter: 180° high reflectance front-surfaced mirror reflex shutter, centered on motor shaft below aperture, rotates at 45° angle between lens and film plane. Shutter rotation delivers horizontal exposure action and lessens "skipping" problems on fast-moving subject matter or fast horizontal camera movement.

Focusing: Parallax-free through-the-lens focusing and viewing. Image magnified 12X. Critical focusing possible even at low light levels, or with stop-down lens, because of extremely fine-grain ground glass and high-gain mirror and low-loss optical system.

Lenses: Standard two-position turret has one Camerette CA-1 lens mount and one "C" mount. Turrets available with two CA-1 mounts, or with two "C" mounts. Any lens from 5.7mm focal length may be used without affecting sound level of camera. CA-1 is a bayonet mount without springs or other loose-fitting adjustments. Lenses by Angenieux, Kinoptik, Taylor Hobson Cooke and some Berthiot optics can be supplied in CA-1 mount.

Motor Drive: Standard motor is 12V DC transistor-controlled regulated 24 fps type. Motor generates 60-cycle sync pulse when operating exactly at 24 fps and maintains speed accuracy within 2/10 of 1% (indicated by running light). Motor has high torque and operates at 1440 rpm to turn shutter shaft directly, so that no noise is caused by gearing down. Also available: variable speed (wild) 12V DC motor (0-40 fps); synchronous (sound) 110V AC, 220V AC single or three-phase motors for operation from mains or from crystal-controlled power packs for cordless synchronous operation. All sync motors are available for 25 fps 50 cycle (European TV) operation. Motors are interchangeable without tools.

Magazines: 400' instant changing coaxial magazine has prethreaded loop and may be snapped on and off instantly. Entire film aperture and film channel may be inspected and cleaned when magazine is removed. No torque motors required for takeup. Each magazine takes either core loads or daylight spools of 100', 200' or 400' capacity. Separate footage counters provided for core and daylight spool loads. As soon as core load film is engaged in sprocket wheel of magazine feed chamber, remainder of threading operation may be carried on in daylight. Magazine has noisemaking clutches and loop guards to disengage drive and warn of malfunction.

Viewfinder: Double 360° swiveling viewfinder; shows more area than film aperture. Inside inner rectangle outlines full aperture. Inaccuracies in alignment of viewfinder do not affect accuracy of ground glass positioning. Eyepiece adjusts for either left- or right-eye operation and has full diopter compensation with automatic opening and closing light-trap.

Features: Built-in automatic clapper for start-marks with bloop modification for use with Nagra ¼" magnetic tape recorder and other oscillator markers. Camera may be used with any tape recorder with sync pulse recording facility. Matte box with adjustable bellows and two-stage filter holder with rod and long lens supports. Noise Level: 29.5 dB at 3'.

Mitchell 16mm Professional, HS & HSC

Movement: Dual pilot pins. Dual claw pull-down assures optimum registration. Removable aperture plate has built-in filter slot. Pressure plate removable. Timing marks on shutter and movement permit easy removal of entire mechanism for cleaning, eliminating danger of improper insertion. Speed range: Professional Model single-frame to 128 fps; HS & HSC single-frame to 400 fps. All models will run 1200' roll of film at maximum frame rates.

Shutter: Professional Model: 0° to 235°. HS and HSC: 0° to 140°. Both adjustable while running (not recommended above 150 fps on HS and HSC models).

Focusing: Professional and HS Models: variable magnification, erect image focusing telescope built into camera door. Through-the-lens ground glass critical focus and viewing when camera is racked over. Built-in contrast viewing filters for color and monochrome film. Interchangeable ground glasses with different aspect ratios available. HSC model: uses 10X prismatic boresight looking through aperture plate opening in register plate.

Lenses: Professional and HS Model: Four-lens turret, positive index type. Flange depth 0.900", Mitchell-designed heavy-duty precision rotary-type lens mounts with built-in follow-focus gear ring. "C" type Mitchell adapter available, permits use of "C" mounted lenses on 16 Mitchell turret. HSC: has single-hole lens board on camera body. Uses lenses in Mitchell mounts. Mitchell "C" mount adapter for lenses in standard "C" mounts available.

Motors: Professional, HS and HSC Models: up to 128 fps. Variable (wild) motors: 12V DC, 110V AC or DC. High-speed motors: 110V AC or DC (48 to 128 fps), 24V DC (16 to 64 fps). Synchronous (sound) motors: 110V, 60-cycle. 1-phase AC; 220V, 60-cycle, 3-phase AC; 220V AC/96V DC Multi-Duty (synchronous at 220V only). 50-cycle motors available on request. Animation motor: Stop-motion 110V AC. HS & HSC: 115V 60-cycle AC (12 fps to 400 fps). Has solid-state variable speed control.

Magazines: Professional, HS & HSC Models: 400' and 1200' double compartment-type magazines. Magazines accept 100' or 200' daylight spools or 400' or 1200' lab loads. Brake recommended on feed side when running high speed.

Viewfinder: Professional, HS Model: Large, erect viewfinder calibrated for different focal length lenses provides sharp, bright image and accurate field for ease of composition. Parallax-free follow-focus attachment available. Special tracking and monocular finders available for sports and instrumentation filming. HSC: 10X prismatic boresight.

Special Features: Professional and HS Model: Veeder footage and frame counters. Camera base has incorporated spirit level. Calibrated tachometer built into back of camera. Built-in buckle trip operates if film fails to take-up. HS & HSC: Have end-of-run switch.

Accessories: Complete line of accessories available, including sound blimp (400' or 1200' magazine top), follow-focus attachment, matte box, sports finders, close-up devices, tripods, pip timers, dual timing light, cases.

Mitchell 16mm Reflex, SSR-16 Single System, DSR-16 Double System Sound Cameras

Movement: Single claw, single (or double for double system sound) registration pin. Adjustable stroke. Three sprockets. Removable aperture plate has built-in filter slot. Movement removable without losing timing. Speed range 16-64 fps. Alternate non-metallic and steel gears for quietness. Guides and locks interlocked with compartment door.

Shutter: Focal plane 170° separate from mirror.

Reflex Viewfinder: Rotating mirror. Ground glass tinted outside film aperture area. Interchangeable ground glasses. Dovetail on camera for outside finder.

Lens Mount: 3-lens divergent turret. Flange depth 2.047".

Drive: Variety of demountable motors, no tools required.

Magazines: 400' and 1200' double compartment, designed for quietness.

Sound Recording Features: The SSR-16 contains a sound head for magnetic recording on pre-striped film. Record and playback head is contained internally in the camera box behind the movement. Extremely high quality of the recording system and camera allows wow and flutter characteristics of less than 0.3% and 0.4%, respectively. The mixer-amplifier allows the use of two low-impedance microphones. System is all solid-state, contains VU meter, bias adjustment, individual and master monitoring control for microphones; power supply is self-contained, using alkaline nickel cadmium batteries with a built-in charger. It produces 30 volts DC and charger operates on 115 volts

AC 50/60 Hz. Recording heads and mixer-amplifier made by RCA. The SSR-16 also contains a pic-sync generator for recording double-system lip-sync sound. The DSR 16 is for double system lip-sync sound work. Has same features as the SSR-16 except RCA recording system is deleted and pic-sync generator is used. Both models available for use on 50 Hz power. Operating noise: 36 dB at 3'.

Blimp: An extremely versatile blimp is available for soundstage work. Through-the-lens reflex viewing is extended through the blimp door. (Same as S35R blimp.) Flat front door with removable sunshade for use with fixed focal length lenses is easily exchanged for extension housing when using zoom lens. External focus and zoom knobs on both sides, viewing windows for lens scales, footage counter and tachometer dials. Five internal lights at strategic points. Threading knob for motor. Electrical panel has lighted switch. Buckle trip will turn out light.

Panavision Panaflex 16mm Camera System

Movement: Pilot pin registration ensures optimum image steadiness. Entire movement may be removed for servicing.

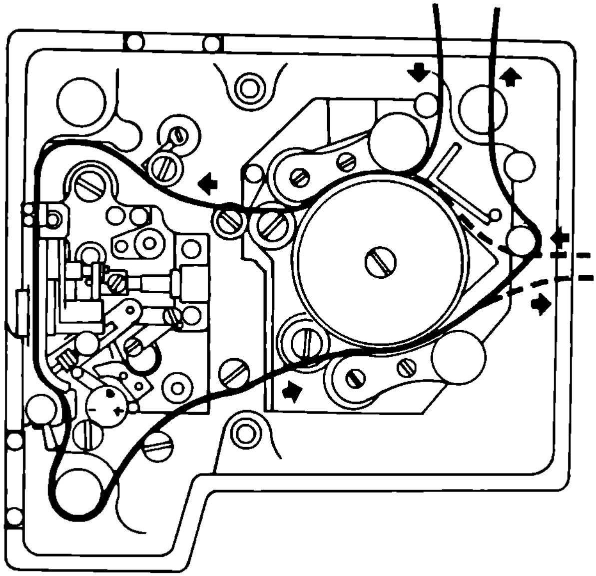
Aperture Plate: Removable for checking and cleaning. Normal 16mm aperture plate is standard, Super 16 is available.

Shutter: Focal-plane shutter with infinitely variable opening and adjustable in-shot. Maximum opening 200°, minimum 50° with adjustable maximum and minimum opening stops. A digital display allows adjustments in ⅒° increments. Micrometer adjustment allows critical synchronization with computers, TV monitors and HMI lighting at unusual frame-rates. Manual and electronic remote-control units available.

Reflex System: Reflex rotating mirror is standard and is independent of the light shutter system. Interchangeable semi-silvered fixed reflex mirror for flicker-free viewing is optional.

Behind-the-lens Filtering: Provision for a behind-the-lens filter gel.

Optical Viewfinder System: High magnification optical system. The viewfinder tube is orientable and gives a constantly upright image through 360°. A short viewfinder tube is provided for hand-holding operation and a normal length for tripod mounted use. Viewfinder tubes may be

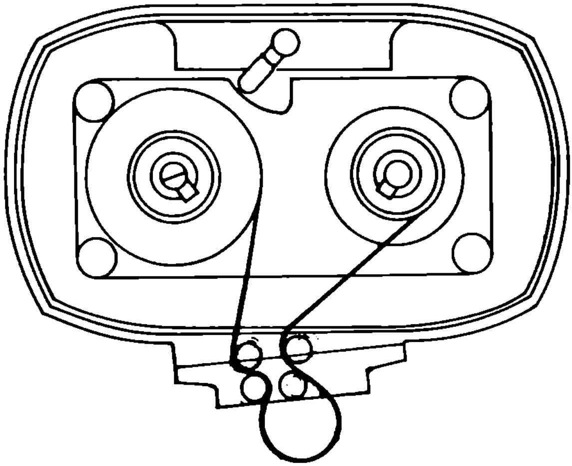


swung out to suit left- or right-eye viewing. System incorporates an optical magnifier for critical focusing and picture composition, a contrast viewing filter and a light-proof shutter. Wide-range ocular adjustment with marker bezel to note individual settings. A built-in "Panaclear" eyepiece heater ensures mist-free viewing. Adjustable leveler link arm supplied with every Panahead to keep eyepiece position constant while tilting the camera up or down. An eyepiece diopter to suit the operator's own eyesight can be provided on request.

Ground Glasses: "Panaglow" illuminated reticle system with brightness control is standard. Ground glasses with finer or coarser texture available on request.

Lens Mounting System: Panavision positive clamp lens mount for maintaining critical flange focal depth setting. All lenses are pinned to ensure proper rotational orientation.

Lenses: Specially designed and manufactured Panavision-16 lenses to suit the 16mm image format. All lenses checked and calibrated by MTF. Panavision 16mm lenses are all color-matched and range from a distortion-



free 8mm to 135mm (lists are available). A wide range of Panavision-engineered long-focus and zoom lenses by other manufacturers are also available. All lenses have widely spaced lens focus calibrations and exceptionally low image veiling glare. Physically long lenses are supplied with adequate-length iris rods for matte box and filter support.

Lens Control: A lightweight focus control which can be used from either side of the camera is standard; an interchangeable "Studio" focus control unit is optional, as are electronic remote focus and aperture controls. Zoom lenses are supplied with an electronic zoom control unit as standard.

Matte Boxes: A standard matte box incorporating a sunshade, provision for two 4 X 5.650 filters which can be individually slid up and down. Special matte boxes incorporating more filter stages, with provision for sliding (motorized if required), rotating and tilting — and to take 6.6" square filters — are optional. Panavision can also supply special sliding diffusers, diopters and all manner of image control filters, etc., to use in their matte boxes.

Camera motor: A 24-volt motor is used to run the camera at any speed from 4-36 fps, is crystal-controlled at all speeds and may be adjusted in 1/10 fps increments. Special sync boxes are available to synchronize the camera with a main power supply, with computers, with video signals and with process projectors in shutter phase sync. Panaflex-16 cameras may be used at sub-zero temperatures with little special preparation.

Camera noise: Less than 20 dB with film and lens, measured 3' from the image plane.

Magazines: 1200' and 400' film magazines are available. Either can be for minimum camera height and for good balance when hand-holding.

Hand-holdability: Handles and a shoulder-rest are provided for hand-holding the camera. In this configuration the camera is best used with a 400' magazine fitted on the rear.

Optical Accessories: Front-of-lens optical accessories include an exceptionally wide range of color control filters, diffusion filters, fog filters, low-contrast filters, black, white and colored nets, full-cover and split diopters, low/high angle inclining prisms.

Batteries: Camera, magazines, heaters and accessories all operate off a single 24V Ni-Cad battery. The normal battery complement is two x cased units with in-built chargers. Belt batteries for hand-holding are optional.

Camera Support Equipment: A special 16mm version of the "Panahead"geared head is available for the Panaflex-16. A sliding base unit enables a camera to be quickly attached and detached and to be slid backwards and forwards on the head for optimum balance. "Panatate" turnover mount allows 360° camera rotation about the lens axis while at the same time permitting nodal pan and tilt movements. "Panapod" tripods, with carbon-fiber legs, are available in a range of sizes.

Video Assist Systems: State-of-the-art, CCD video systems are available in B & W or color.

Environmental Protection Equipment: All Panaflex-16 cameras and magazines have built-in heaters to enable them to be operated in any ambient temperature. Heated covers are available to give additional protection to lenses, especially zoom lenses, to keep their operation smooth in intensely cold conditions. Other covers are available to protect the camera, magazines and lenses from heat and dust and from rain and water. Spinning-glass rain deflectors are available for use in storm conditions. An autobase is available to secure the camera in conditions of vibration, high "g" forces and other stressful and dangerous forces. A water-box is available to protect the camera in shallow water conditions, and a hazard box can be used to protect the camera from explosions, collisions and other dangerous situations.

Time Code: The AatonCode system encodes every frame with a SMPTE time code which is readable by both computer and human being.

Film

Color

Since the Sixth Edition of this manual was published, several important advances in color film technology have been made by all manufacturers marketing in the United States. A major breakthrough in emulsion technology has resulted in the development of new films with increased sensitivity, greater exposure latitude, improved speed-to-grain ratio, better definition and improved storage life. The cinematographer now has a choice of a variety of negative and reversal camera films balanced for both daylight and tungsten light sources.

Except for direct projection of the processed camera film, color negative is the preferred camera film for original cinematography in all formats except Super 8mm. Instances of films used for "direct projection" are travel lecture photography, instrumentation photography and some documentary photography (availability of laboratory facilities for processing the film chosen may also be a factor in film selection). Although the use of negative film means more care in handling the original camera film, better color quality due to the incorporation of color masking in the negative emulsions is the reward. Color negative film is available in low, medium and high-speed emulsions balanced for tungsten (3200°K) light sources and in low-and high-speed emulsions balanced for daylight. If tungsten-balanced film is used in daylight a Kodak Wratten 85 or Fuji LBA-12 or equivalent filter should be on the camera and the exposure index reduced by ⅔ of a stop. If daylight balanced film is used in tungsten light, a Kodak Wratten #80A should be used, but this practice is not recommended because it requires the exposure index to be reduced by two stops.

Color reversal camera films, which when processed result in a positive image on the original film, are also supplied in emulsion types balanced for tungsten or daylight light sources. The same conversion filters recommended for use with color negative can be used with the same adjustment in exposure index. If single-system sound is desired, check with the film manufacturer. Some of these films can be supplied with magnetic striping.

Black & White

A variety of black & white emulsion types are available from the film manufacturers. Many are special-purpose films designed for scientific or instrumentation use. The cinematographer should be aware of these films and the possibility of using one or more of them if a desired effect cannot be achieved with conventional motion-picture emulsions. For pictorial use, panchromatic emulsions in several speed ranges are available in 35 and 16mm negative and 16mm reversal films. The reproduction of colored objects in terms of shades of gray varies with different types of film.

The cinematographer can control tonal values to get a technically correct rendition of the subject or to exaggerate or suppress the tonal differences for brightness, contrast or other effects by the use of filters. B & W negative films of low or medium speed are most desirable for sharpness and fine grain, and have ample sensitivity for general use. High-speed film is useful for low "available light" situations or for high-frame-rate photography. Because of the current low frequency of use of black & white as compared to color, it is especially important to establish working exposure indexes relative to the processing laboratory. B & W processing is not as standardized as color processing, differences in chemistry, developing time, and temperature result in changes of contrast as well as exposure index.

ASA: Exposure Indexes

While ASA film speeds do not apply directly to motion-picture films, exposure meters calibrated to ASA, ANSI, or ISO standards specify exposure indexes (EI) related to film speeds (film speeds are calculated mathematically from sensitometric exposures; exposure indexes are numbers useful to the cinematographer in determining or specifying exposure in a given instance). All film manufacturers furnish EI numbers related to commercial exposure meters as a recommendation for a starting point in determining optimum exposure.

Film Selection: Color Negative

For normal high key cinematography select the film with an ASA number most consistent with the light level and f-stop to be utilized; in general, slower films are sharper and less grainy than faster films. If economy in illumination or small f-stop for depth of field is a factor, use of a faster (higher EI) film is indicated.

For any special "look" or low-key cinematography, experimentation or experience is needed. Generally, use of an EI lower than the manufacturer's recommendation will produce finer grain, higher color saturation, and a slight increase in sharpness at the expense of loss of highlight detail and flattening of whites; use of a higher EI than recommended will show more grain, lower color saturation, loss of sharpness and loss of shadow detail. Relative position on a particular laboratory printer scale is also a factor to be considered when determining an EI.

Color Reversal Film

Since color reversal films are intended for direct projection, there is less exposure latitude (compared to negative film) for a usable film, both for actual density/exposure range and lack of opportunity to shift densities in transferring to a print.

Selection of an EI should therefore be made based on the use to which the film will be put. If an EI higher than the manufacturer's recommendation is required, forced development may be used with a compromise in image quality.

Edge Numbers

These numbers, also referred to as footage or key numbers, are sequentially printed by the film manufacturer along one edge of the film outside the perforations. The numbers on 35mm film manufactured prior to 1990 are located every 16 frames (12 inches apart); on 16mm film they are every 20 frames (6 inches apart) or every 40 frames (12 inches apart). The numbers are applied during manufacture either by photographic exposure (visible only after processing) or printed with a visible ink on the base side of the film. All 16mm and 35mm camera original color film is latent-image edge-numbered. B & W 16mm and 35mm camera original film is ink edge-numbered.

Several changes in the format for edge numbers were introduced during the latter part of 1990. In conformance with SMPTE standard SMPTE 254, 35mm film now

COMPARISON of FILM SPEEDS

ASA/EI	BSI/JSA	DIN	GOST	SCHEINER
3	3	6	2.8	16°
4	3	7	3.6	17°
5	5	8	4.5	18°
6	6	9	5.8	19°
8	8	10	7.2	20°
10	10	11	9	21°
12	12	12	11	22°
16	16	13	14	23°
20	20	14	18	24°
25	25	15	23	25°
32	32	16	29	26°
40	40	17	36	27°
50	50	18	45	28°
64	64	19	58	29°
80	80	20	72	30°
100	100	21	90	31°
125	125	22	112	32°
160	160	23	144	33°
200	200	24	180	34°
250	250	25	225	35°
320	320	26	288	36°
400	400	27	360	37°
500	500	28	450	38°
650	650	29	576	39°
800	800	30	720	40°
1000	1000	31	900	41°
1250	1250	32	1125	42°
1600	1600	33	1440	43°
2000	2000	34	1800	44°
2500	2500	35	2250	45°
3200	3200	36	2880	46°

For all practical purposes ASA/BSA/JSA/EI are the same.
The DIN system is calculated Log 10. In the past
DIN speeds were written with the speed number followed by /10. (example: 2/10)
The Scheiner system is obsolete. It was distiguished by ° following the number.
The GOST System was used in the USSR.

has both human-readable edge numbers and machine-readable information printed as a latent image on its edge at the time of manufacture. In addition to an incrementing number, a zero-frame reference mark, consisting of a filled circle approximately 0.025 to 0.030 inches (0.64 to 0.76 mm), is printed adjacent to the digit of the human-readable edge number that is closest to the tail of the film. The frame immediately above the zero-frame reference mark is the one referenced by that edge number. The numbers are printed so that the center line of the zero-frame reference is aligned with the center-line of a perforation. The spacing from one key number to the next is 64 perforations. A mid-foot human readable and a mid-foot machine-readable edge number is printed halfway between each key number. The mid-foot human-readable edge number consists of a zero-frame reference mark and the adjacent edge number that is nearer the head end of the roll plus an offset in perforations that is always 32 perforations. All characters of the mid-foot edge number are approximately ½ size. A similar system currently under study by a SMPTE standards committee has been proposed for 16mm.

Film Perforations

Pitch

Pitch is the distance from the leading edge of one perforation to the leading edge of the next and is expressed in decimal inches. Motion picture perforations are commonly referred to as having either "long" or "short" pitch. When films are being printed, the original camera film and the unexposed print film pass together over a curved printing sprocket for exposure. Since the print film is on the outside, the difference in diameter is accommodated by giving a shorter pitch to the camera original on the inside.

16mm Films

16mm camera films are supplied with either a row of perforations along one edge or with a row along both edges. Most 16mm camera films are furnished with two rows of perforations for use in "silent" type cameras. Those with one row are intended for use in single-system cameras where sound and picture are simultaneously recorded, either optically or by means of magnetic striping on the film.

Reversal-type 16mm camera films intended for projection are usually supplied in long pitch (.3000). Negative or reversal type film intended for subsequent release printing is usually supplied with short pitch (.2994).

Standard 16mm perforations
SMPTE 109-1986-2R-.2994
110-1986-1R-.2994
SMPTE 109-1986-2R-.3000
110-1986-1R-.3000

35mm Films

35mm motion picture films are supplied with perforations of two basic shapes and with either long or short pitch. Bell & Howell or BH indicates negative and Kodak Standard or KS indicates positive. Negative perforations are designed to insure a steady image during exposure in a camera-type pull-down and registration mechanism. Positive perforations have a shape intended to reduce cracking with repeated projection. "Negative" or "positive" perforations describe the shape of the perforation and not the type of film involved.

Standard 35mm perforations
SMPTE 93-1992- BH-.1866
93-1992- BH-.1870
139-1986- KS-.1866
139-1986- KS-.1870

65mm Films

65mm film used for original photography and duplicating is perforated KS-.1866. When first introduced this film was perforated long pitch because only step-printing was available. With the advent of continuous contact printing facilities, the negative and duplicating films are now perforated with short pitch.

Standard 65mm
SMPTE 145-1988-KS-.1866

70mm Films

Release printing from 65mm negative or intermediate is on 70mm film which is perforated the same as 65mm but is an additional 5mm wide. The additional width is equally divided on each side of the perforations to accommodate magnetic sound tracks. In addition to the standard 70mm film format two other formats are available for special venue processes.

Standard 70mm
SMPTE 119-1988-KS-.1870

70mm Type I
ANSI PH 1.20-1963- 0.234

Perforations for this standard are 0.13 x 0.08 in size with a pitch of 0.234.

70mm Type II
ANSI PH 1.20-1963 -KS-.1870

Perforations for this standard are the same size and pitch as SMPTE 119 but with an "E" dimension of 0.079 ± 0.004 instead of 0.215 ± 0.003.

Film Handling and Storage

Film raw stock is sensitive to heat, radiation and moisture, and may be contaminated by gases or dirt. The following precautions are suggested when handling or storing raw stock.

1. Store in a cool (55° F/13° C or lower), clean area for short periods and in a deep freeze (0° F/-18° C) for periods longer than six months. Relative humidity should be 50 percent or less to avoid rusting of cans and or possible damage to labels and cartons.

2. Do not store where chemical contamination is present, either gas or liquid. Fumes, such as those from ammonia, formaldehyde, hydrogen sulfide, illuminating gas, mercury, motor exhaust, solvents, sulfur dioxide, can damage photographic emulsions.

3. Avoid X-rays or radiation of any kind. Raw stock should not be stored or shipped near radioactive materials. For example, Eastman Kodak states "to protect film stored 25 feet away from 100 milligrams of radium, 3½ inches of lead must be placed around the radium."

4. Film should not be stored near exhaust or heating pipes, or in direct sunlight coming through a window even if the room is air-conditioned.

5. Allow time for film to reach loading-room temperature before opening container to avoid condensation.

6. Keep the loading room and/or changing bag clean.

7. Clean magazines outside the loading room and be sure the outsides of film cans are clean before taking them into the loading room.

8. Bag and seal exposed film in original or similar containers.

9. Process exposed film as soon as possible. If it must be held more than a day before processing or shipping, seal the film from moisture and store as cold as possible. (A deep freeze is appropriate.)

10. If raw stock or exposed film is to be shipped by commercial carrier, it should be tightly wound on cores. The outside shipping container should be labeled conspicuously: "Keep away from heat or X-ray." Stock labels are available for this purpose.

Processed Film Storage

Though this is not usually the responsibility of the cinematographer, the following information may be useful:

1. Condition the film at 20 to 30 percent relative humidity at room temperature (optimum relative humidity is 25 percent).

2. Wind film emulsion in on cores or reels. (Do not use PVC containers, cores, or reels.)

3. Store flat.

4. Store at temperature of 50° F/10° C or lower.

(Ref: ANSI IT9.11, SMPTE RP 131 Eastman Kodak Co. publication H-1.)

FILM DATA CHART

	Balance		Emulsion Type		Edge	ASA/ISO			
						Tungsten		Daylight	
Color Negative Films	Day	Tung	35mm	16mm	ID	EI	Filter	EI	Filter
Agfa XT 100		X	XT100	XT100	N	100	-	80	85
Agfa XT 320 High Speed		X	XT320	XT320	H	320	-	200	85
Agfa XTS 400 High Speed		X	XTS400	XTS400	S	400	-	250	85
Eastman EXR 50 D	X		5245	7245	K	12	80A	50	-
Eastman EXR 100 T		X	5248	7248	M	100	-	64	85
Eastman EXR 200 T		X	5293	7293		200	-	125	85
Eastman EXR 500 T		X	5296	7296	J	500	-	320	85
Eastman HS Day	X		5297	7297	C	80	80B	250	-
Fujicolor F-64		X	8510	8610	N10	64	-	40	*
Fujicolor F-64 D	X		8520	8620	N20		-	64	-
Fujicolor F-125		X	8530	8630	N30	125	-	80	*
Fujicolor F-250		X	8550	8650	N50	250	-	160	*
Fujicolor F-250 D	X		8560	8660	N60	64	**	250	-
Fujicolor F-500		X	8570	8670	N70	500	-	320	*
* LBA-12 or 85									
** LBB-12 or 80A									
Color Reversal Films									
Eastman Ektachrome Day	X		5239	7239	VND	40	80A	160	-
Eastman Ektachrome Tung		X		7240	VNF	125	-	80	85B
Eastman Ektachrome HS Day	X			7251	VXD	100	80A	400	-
Eastman Ektachrome HS Tung		X		7250	VNX	400	-	250	85B
Kodachrome 25 Movie Film	X			7267		6	80A	25	-
Kodachrome 40 Movie Film		X		7270		40	-	25	85
Black and White Negative Films									
Agfa Pan 250					H	200	*	250	*
Eastman Plus-X			5231		H	64	*	80	*
Eastman Plus-X				7231	PXN	64	*	80	*
Eastman Double-X			5222		C	200	*	250	*
Eastman Double-X				7222	DXN	200	*	250	*
Fuji FG			71112		FG	64	*	80	*
Fuji RP				72161	RP	64	*	80	*
* See filter section for B&W Photography.									
Black and White Reversal Films									
Eastman Plus X Reversal				7276	PXR	40	-	50	-
Eastman Tri-X Reversal				7278	TXR	100	-	125	-

Super 8 Films
B&W Kodak Plus-X & Tri-X Reversal as above. Color Kodachrome 25 & Kodachrome 40 as above.

Agfa FILMS

AGFA XT-100 COLOR NEGATIVE FILM (35mm/16mm)

DESCRIPTION

DAY	FILTER	EXPOSURE INDEX TUNG.	FILTER	ID
64	**84**	**100**	**–**	**M**

This is a medium-speed color negative film with very fine grain, wide exposure latitude, high sharpness and faithful color rendition. Designed for general cinematography, this film lends itself to both indoor and outdoor use.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	25	50	100	200	400	800	1600

AGFA XT-320 HIGH SPEED COLOR NEGATIVE FILM XT 320 (35mm / 16mm)

DESCRIPTION

DAY	FILTER	EXPOSURE INDEX TUNG.	FILTER	ID
200	**85**	**320**	**–**	**H**

This is a high-speed color negative film with excellent speed-to-grain ratio, wide exposure latitude, high sharpness and faithful color rendition, that is intended for use in cinematography at low light level conditions.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	10	20	40	80	160	320	640

Agfa FILMS

AGFA XTS-400 HIGH SPEED COLOR NEGATIVE FILM (35mm/16mm)

DESCRIPTION	DAY	EXPOSURE FILTER	INDEX TUNG.	FILTER	ID
	250	85	400	–	S

This is a high-speed color negative film with excellent speed-to-grain ratio, wide exposure latitude, high sharpness and faithful color rendition that is intended for use in cinematography at low light level conditions.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	1/5.6	f/8.0	f/11
Footcandles required	6	12	25	50	100	200	400

AGFA PAN 250 NEGATIVE FILM (35mm/16mm)

DESCRIPTION	DAY	EXPOSURE FILTER	INDEX TUNG.	FILTER	ID
	250	*	200	*	H

This is a high-speed panchromatic negative film with fine grain, high resolving power and wide exposure latitude. Designed for general cinematography, this film lends itself to both indoor and outdoor use.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	12	25	50	100	200	400	800

*See filter section for B&W photography.

EASTMAN FILMS

EASTMAN EXR COLOR NEGATIVE FILM 5245 (35mm/65mm) 7245 (16mm)

DESCRIPTION

EXPOSURE INDEX				
DAY	FILTER	TUNG.	FILTER	ID
50	**-**	**12**	**80A**	**K**

This is a low speed, daylight-balanced color negative film with wide exposure latitude, micro-fine grain, very high sharpness, and high resolving power.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11	f/16
Footcandles required	50	100	200	400	800	1600	3200	6400

EASTMAN EXR COLOR NEGATIVE FILM 5248 (35mm/65mm) 7248 (16mm)

DESCRIPTION

EXPOSURE INDEX				
DAY	FILTER	TUNG	FILTER	ID
64	**85**	**100**	**-**	**M**

This is a medium speed color negative film with wide exposure latitude, micro-fine grain, very high sharpness, and high resolving power.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11.0	f/16.0
Footcandles required	25	50	100	200	400	800	1600	3200

EASTMAN FILMS

EASTMAN EXR 200T FILM 5293 (35mm/65mm) 7293 (16mm)

DESCRIPTION

EXPOSURE INDEX

DAY	FILTER	TUNG.	FILTER	ID
125	**85**	**200**	**–**	**L**

This is a color negative film with optimum speed for grain extended latitude, reduced contrast, micro-fine grain, very high sharpness, high resolving power, and superior color.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11	f/16
Footcandles required	5	25	50	100	200	400	800	1600

EASTMAN EXR 500T FILM 5296 (35mm/65mm) 7296 (16mm)

DESCRIPTION

EXPOSURE INDEX

DAY	FILTER	TUNG.	FILTER	ID
320	**85**	**500**	**-**	**J**

This is a high-speed color negative film with wide exposure latitude, micro-fine grain, very high sharpness and high resolving power.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11	f/16
Footcandles required	5	10	20	40	80	160	320	640

EASTMAN FILMS
HIGH SPEED DAYLIGHT COLOR NEGATIVE 5297 (35mm/65mm) 7297 (16mm)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
	250	–	60	80B	C

This is a high-speed color negative film with wide exposure latitude that is intended for use without filters in daylight, with HMI lights, or with mixtures of natural and artificial light.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11	f/16
Footcandles required	10	20	40	80	160	320	640	1280

EASTMAN EKTACHROME FILM (DAYLIGHT) 5239 (35mm) 7239 (16mm)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
	160	–	40	80A	VND

This is a moderate speed daylight-balanced color reversal film designed for use under low-level illumination or for high speed photographic applications. The processed film is balanced for direct projection or television display.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	16	32	63	125	250	500	1000

EASTMAN FILMS

EASTMAN EKTACHROME FILM (Tungsten) 7240 (16mm)

DESCRIPTION

EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
80	**85B**	**125**	**-**	**VNF**

This is a moderate speed color reversal film designed for news and documentary applications. The processed film is balanced for direct projection or television display.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	20	40	80	160	320	640	1250

EASTMAN EKTACHROME HIGH SPEED FILM (Daylight) 7251 (16mm)

DESCRIPTION

EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
400	**-**	**100**	**80A**	**VXD**

This is a high-speed daylight-balanced color reversal film designed for use under daylight illumination or a variety of HMI, xenon and mercury discharge lamps without filtration. The exposure index of this film can be increased to EI 800 (daylight) or higher by extended time of development. The processed film is balanced for direct projection or television display.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	6.3	12.5	25	50	100	200	400

EASTMAN FILMS

EASTMAN EKTACHROME High Speed Film (Tungsten) 7250 (16mm)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
	250	**85B**	**400**	-	**VNX**

This is a high-speed color reversal film designed for use under low-level illumination when supplemental lighting is unavailable or undesirable. The exposure index of this film can be increased to EI 800 (tungsten) or higher by extended time of development. The processed film is balanced for direct projection or television display.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	6.3	12.5	25	50	100	200	400

EASTMAN FILMS

EASTMAN PLUS-X NEGATIVE FILM 5231 (35mm) 7231 (16mm)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID (35mm)	ID (16mm)
	80	*	**64**	*	**H**	**PXN**

This is a medium-speed panchromatic film designed for general production use, both outdoors and in the studio.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	40	80	160	320	630	1250	2500

*See filter section for B&W photography.

EASTMAN DOUBLE-X NEGATIVE FILM 5222 (35mm) 7222 (16mm)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID (35mm)	ID (16mm)
	250	*	**200**	*	**C**	**DXN**

This is a high-speed panchromatic negative film designed for use under adverse lighting conditions and where greater depth of field is required without increasing the illumination. This film has medium graininess. As with other negative, the granularity increases with the density of the image resulting in increased graininess in the projected print. Avoid overexposing, especially when using in the 16mm format.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	13	25	50	100	200	400	800

*See filter section for B&W photography.

EASTMAN FILMS

EASTMAN PLUS-X REVERSAL FILM 7276 (16mm/Super 8mm)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
	50	*	**40**	*	**PXR**

This is a low-speed panchromatic reversal film designed for general production use both outdoors and in the studio when sufficient light is available.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	63	125	250	500	1000	2000	4000

* See filter section for B&W photography.

EASTMAN TRI-X REVERSAL FILM 7278 (16mm/Super 8mm)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG	FILTER	ID
	200	*	**160**	*	**TXR**

This is a high-speed panchromatic reversal film suitable for general motion picture photography.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	16	32	63	125	250	500	1000

EASTMAN FILMS

KODACHROME 25 MOVIE FILM (DAYLIGHT) 7267 (16mm/Super 8mm)

DESCRIPTION

EXPOSURE INDEX DAY	FILTER	TUNG	FILTER	ID
25	–	6	80A	

This is a low-speed, daylight-balanced color reversal film designed for general motion picture photography outdoors. The processed film is balanced for direct projection.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	100	200	400	800	1600	3200	6400

KODACHROME 40 MOVIE FILM (Tungsten) 7268 (16mm/Super 8mm)

DESCRIPTION

EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
25	85	40	–	

This is a moderate speed, color reversal film designed for news and documentary applications. The processed film is balanced for direct projection or television display.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	60	125	250	500	1000	2000	4000

FUJI FILMS

FUJICOLOR F-64 COLOR NEGATIVE FILM 8510 (35mm) 8610 (16mm)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
	40	**LBA-12 or 85**	**64**	-	**N10**

This is a low-speed color negative film with fine grain, very high sharpness and faithful color rendition.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	40	80	160	320	640	1250	2500

FUJICOLOR F-64 D DAYLIGHT COLOR NEGATIVE 8520 (35mm) 8620 (16MM)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
	64	-	-	-	**N 20**

This is a low-speed daylight color negative film with fine grain, very high sharpness and faithful color rendition that is intended for use in outdoor filming without filters in daylight, or with high level natural illumination-based indoor filming and artificial light.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	40	80	160	320	640	1250	2500

FUJI FILMS

FUJICOLOR F-125 COLOR NEGATIVE FILM 8530 (35mm) 8630 (16mm)

DESCRIPTION	EXPOSURE INDEX				
	DAY	FILTER	TUNG.	FILTER	ID
	80	**LBA-12 or 85**	**125**	-	**N30**

This is a medium-speed color negative film with fine grain, very high sharpness and faithful color rendition. Designed for general cinematography, this film lends itself to both indoor and outdoor use.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	20	40	80	160	320	640	1250

FUJICOLOR F-250 COLOR NEGATIVE FILM 8550 (35mm) 8650 (16mm)

DESCRIPTION	EXPOSURE INDEX				
	DAY	FILTER	TUNG.	FILTER	D
	160	**LBA-12 or 85**	**250**	-	**N50**

This is a high-speed color negative film with excellent speed-to-grain ratio, high sharpness and faithful color rendition that is intended for use in high speed photography as well as low light level conditions.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	10	20	40	80	160	320	640

FUJI FILMS

FUJICOLOR F-250 D COLOR NEGATIVE FILM 8560 (35mm) 8660 (16mm)

DESCRIPTION

EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
250	**-**	**64**	**LBB-12 or 80A**	**N60**

This is a high-speed, daylight-balanced color negative film with excellent speed-to-grain ratio, high sharpness and faithful color rendition. Designed for high-speed cinematography, underwater cinematography, low light level daylight filming and both indoor and outdoor filming with mixtures of natural and artificial daylight illumination.

EXPOSURE TABLE FOR DAYLIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	10	20	40	80	160	320	640

FUJICOLOR F-500 COLOR NEGATIVE FILM 8570 (35mm) 8670 (16mm)

DESCRIPTION

EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
320	**LBA-12 or 85**	**500**	**-**	**N70**

This is a high-speed color negative film that is intended for use in high speed and underwater *cinematography as well as both indoor and outdoor filming under low light level conditions.*

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	5	10	20	40	80	160	320

FUJI FILMS

FUJI FG PANCHROMATIC NEGATIVE FILM 71112 (35mm)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
	80	*	64	*	FG

This is a medium-speed panchromatic negative film with fine grain and high definition. Designed for general cinematography, both indoor and outdoor filming with mixtures of natural and artificial illumination.

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	40	80	160	320	640	1250	2500

*See filter section for B&W photography.

FUJI RP PANCHROMATIC NEGATIVE FILM 72161 (16mm)

DESCRIPTION	EXPOSURE INDEX DAY	FILTER	TUNG.	FILTER	ID
	80	-	64	-	RP

This is a medium-speed panchromatic negative film with fine grain and high definition, suitable for general cinematography. This film is designed for rapid processing where fast access is required. ,

EXPOSURE TABLE FOR TUNGSTEN LIGHT (24 frames per second 170° shutter opening)

Lens Aperture	f/1.4	f/2.0	f/2.8	f/4.0	f/5.6	f/8.0	f/11
Footcandles required	40	80	160	320	640	1250	2500

*See filter section for B&W photography.

Lenses

Lenses may be classified as normal, telephoto/ retrofocus, zoom, anamorphic and auxiliary.

Normal lenses are compactly mounted combinations of glasses, assembled so they may be mounted in a camera approximately one focal length from the image plane, or film. Normal lenses of long focal length tend to be bulky, therefore telephoto lenses are designed with negative glass elements arranged in a manner that permits the telephoto lens to be mounted closer to the image plane than its focal length would indicate. When camera design, because of beam splitters or reflex shutters, does not permit short focal length normal lenses to be mounted within one focal length of the film, the retrofocus or inverse telephoto lens design is used: a lens of short effective focal length but long back focus. Zoom lenses are a combination of the above, with the added feature that one or more elements may be moved in relation to the others. This provides not only a multiple number of focal lengths within one body, but permits changes of focal length, and therefore image size, during cinematography.

Anamorphic lenses are composed of the above types of lenses, in combination with either a cylindrical or prismatic element to compress the horizontal image, providing for a wider aspect ratio within the confines of the standard motion-picture frame. Nearly all present anamorphic lenses have a compression ratio, or squeeze ratio, of 2:1. (Other squeeze ratios have been used in the past, and there is at least one on the horizon contemplating the use of a different squeeze ratio.)

Auxiliary lenses are positive tele-extenders and negative wide-angle adapters, both of which alter the focal length of prime or zoom lenses, and simple elements usually referred to as "diopters" or "split-field diopters."

Selection of Lenses

Photographic and projection lenses are designed to compromise aberration and distortion to a minimum in a specific frame area. Lenses designed for cine use will not generally fill a still-camera frame, nor will still-camera lenses necessarily be as sharp as cine lenses in the smaller frame size. Likewise, design compromises are made to allow large diaphragm opening with acceptable but not necessarily optimum sharpness; better sharpness may be found if such a lens is stopped down a notch or two.

One widely quoted evaluation is Modulation Transfer Function (MTF), an objective measure of sharpness. While a useful means of comparison, it does not account for all distortions or aberrations (to be useful, MTF must be measured in the corners as well as in the center of the lens field). In simple terms, MTF compares the contrast of a lens with its resolving power. The resultant graph plots the MTF in percent versus the line frequency (lines per mm). The higher the curve and the flatter it is, the greater is the contrast of the resulting image and the more uniform the image quality.

Testing

Some suppliers and some independent agencies have test equipment and will help in evaluation. While it is beyond the scope of this manual to discuss lens design in greater depth, it should be pointed out that the cinematographer should take particular note of aberrations which are most evident at wide-open apertures and diffraction which limits the smallest useful aperture. Photographic testing is tedious, time-consuming and costly; the use of such a facility when available can be helpful. Qualities to be observed, preferably in comparison with a lens of known quality, include image sharpness at center and corners, contrast and flare, image distortion, and uniformity of exposure (vignetting).

Care and Maintenance

When not in use, lenses should be kept capped, and when transported, kept in a padded case. Shocks and vibration may jar the elements loose (this includes high-frequency vibration such as from an aircraft engine). When filming outdoors under dusty conditions, protect the lens with a filter. If no filter is required, use a clean optical glass or a UV filter (filters, of course, should be made of first-quality optical glass). It is less expensive to replace a scratched or marred filter than a front lens element.

Lenses should be inspected periodically for physical condition, including lens surface examination with a magnifying glass to look for fine scratches, loose glass elements, and loose mechanical elements such as focus scale rings, iris diaphragms, and zoom lens linkage and cams.

Never clean a lens with dry tissue or fabric. Tiny abrasive particles may cause scratches. The safest procedure is:

1. Blow off loose dust with "canned air." (If "air" is not available, a clean, very soft camel hair brush may be used; to remove all residual oil from the brush, first wash it in ether or pure grain alcohol and shake it out so that it is thoroughly dry. Keep the brush in an air-tight container. Under no circumstances should the brush ever touch skin. If it does so inadvertently, wash it again with ether or alcohol.) Do not blow dust off with the mouth. Next to dried fingerprints, saliva is the hardest thing to remove from a lens surface without scratching it.

2. If necessary to remove smears from the lens surface, fold a lens tissue and dampen the folded edge with lens-cleaning fluid. Carefully wipe the lens surface with a circular motion, starting at the center and working toward the edges. If this will not remove the smear, take a new, clean piece of lens tissue and repeat the procedure using pure xylene or pure grain alcohol (not rubbing alcohol). Be careful not to touch the lens mount with the xylene or alcohol. If you do, discard the lens tissue and start over. Xylene is particularly useful in removing oil or oily fingerprints from lenses. If it leaves a slight smear after removing an oily spot, repeat the action using alcohol.

Fingerprints, or any contacts with skin, leave a residue which may permanently etch the lens surface. Never clean camera lenses with silicone-coated lens tissue or cloth.

Removing Lens Retainer Rings

The cinematographer, unless skilled in lens repair, should avoid disassembly of lenses. If, in emergency, it is necessary to do so in the field, the ring may generally be easily unscrewed if the lightest fingertip grasp, with the least possible pressure, is applied. The more pressure applied, the greater the expansion of the ring on the sides opposite the fingers. Such pressure causes expansion of the ring and makes removal very difficult, if not impossible. A particularly stubborn ring may often be removed by applying a drop of carbon tetrachloride or a similar solvent. The same technique may be used in removing filter retaining rings.

Condensation

When equipment, including lenses, is taken from a cool, dry environment to a warm, moist environment, condensation will occur on the cold surfaces. This particularly applies when moving from an air-conditioned environment to the outdoors. A few minutes should be allowed for the equipment to warm up and the condensation to disappear before photographing. Visual inspection should suffice to determine when this takes place.

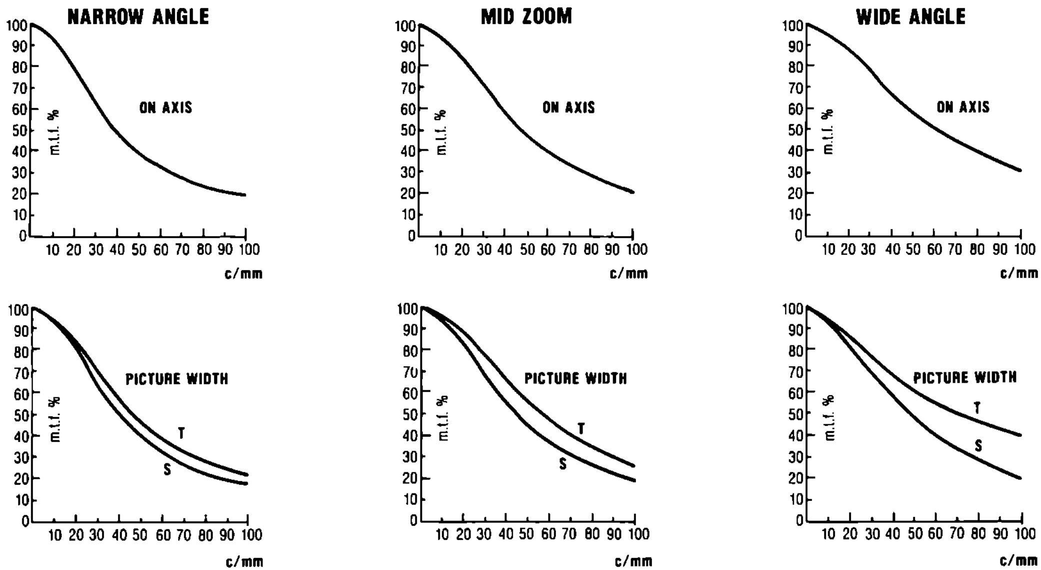
Understanding an MTF Chart

by Bern Levy

For many, evaluating a lens has usually been a matter of being aware of the manufacturer's past record and the experience of others who have used that type of lens. To those more technically inclined, the use of a test chart indicating resolving power, in lines per millimeter, may be considered a criterion of lens quality. However, resolving power value can be very subjective and does not necessarily indicate the true value of a lens. Resolving power alone, regardless of its accuracy, can be misleading. Lens manufacturers now utilize a method of lens testing that assesses the actual capability of a given lens.

This method is referred to as Modulation Transfer Function, or MTF. Scientifically, MTF is defined as a function that describes the modulation of a sinusoidal object as the frequency increases. In simpler terms, MTF compares the contrast of a lens with its resolving power. The relationship of sharpness, plus the ability to reproduce an image, gives a lens the property to produce a quality image. It is the result of this comparison that forms the MTF curve. As the spatial frequency (the distance of one black & white line pair) of the test chart increases, the image pattern is reduced in contrast. This change in contrast or "modulation" is the basis for the MTF method of evaluating a lens.

Since the Modulation Transfer Function is a method of quantitatively measuring the limits of resolution of a given area and the ability to reproduce an image of a given area, a single MTF curve only indicates the response for the specific conditions tested. The parameters for test data normally include focal length, aperture, object distance, light



TYPICAL M.T.F. OF 3:1 ZOOM LENS FOR 16 mm. FORMAT MEASUREMENT CONDITIONS: OBJECT AT ∞, FULL APERTURE, WHITE LIGHT color temperature and the image field radius as well as the spatial frequency of the test chart. In order to fully comprehend the performance of a lens, a number of MTF curves must be generated to cover a multitude of points within these test parameters.

To interpret the MTF curve, we must first understand that the horizontal axis of the chart normally indicates the spatial frequencies in cycles per millimeter and the vertical axis provides the modulation transfer factor or contrast values with a maximum of 100%. The basic criteria for interpreting an MTF curve are that the higher the curve and the straighter it is, the greater the contrast of the image and the more uniform the image quality. Whereas no lens can deliver 100% contrast, an MTF chart showing a relatively flat curve above 70% would indicate an excellent lens. Consideration must be made for the higher frequencies (right side of the horizontal axis) as even a high-quality lens cannot render an MTF (contrast) of more than 50% at a frequency of over 50 cycles.

Most MTF charts will show two curves: one for tangential lines (broken) and another for radial lines (continuous). Telephone lines can be considered tangential lines and telephone poles can be interpreted as radial lines. The optical aberration *astigmatism* shows up as sharp poles with out-of-focus wires. An MTF chart showing a marked distance between radial and tangential curves will clearly indicate that the lens suffers from astigmatism. Inversely, a chart indicating the two lines running very close will specify a lens with very slight astigmatism.

From the viewpoint of MTF, lenses can be roughly classified into two groups: high contrast with limited resolution, and lower contrast with greater resolution. What is appropriate for one is not necessarily correct for another. The film emulsion characteristics or the limiting frequency of a television camera tube will dictate the preferable type. The one with the best contrast properties in the frequency range to be recorded may be considered ideal.

Modern Telephoto Lenses

by William J. Turner
& Chris Condon

The term "telephoto lens" is generally used to describe any lens, regardless of its optical configuration, which magnifies the image at least 50% more than the normal lens on any specific camera. The term "true telephoto" refers to lenses designed for physical compactness, yet having an effective focal length (EFL) longer than the physical distance of the optics from the image plane. This type of lens employs a negative rear optical component. The term "telelens" is becoming more common than "telephoto" lens.

Many of the telephoto lenses in use today (over 180mm EFL) were originally designed for use with 35mm single-lens reflex still cameras. Several major still camera manufacturers, in efforts to satisfy the unique telephoto lens requirements of professional sports photographers, have designed superior quality, high-speed and zoom lenses using newly compounded, low dispersion optical glass (in some cases crystal substances such as fluorite). Through the use of state-of-the-art computer-aided optical design techniques, these lenses achieve a degree of color correction, sharpness and contrast far superior to those previously attainable in high-speed lenses.

Most of these lenses are very fast for their focal length. The Canon 300mm and 400mm f/2.8 lenses have become quite popular. The now discontinued Nikon 300mm f/2 has become an industry-standard lens. Aside from their traditional uses in the fields of documentary, news, sports, wildlife, and surveillance cinematography, telephoto lenses are used increasingly in the shooting of commercials and action films. Among the advantages of tele-lenses are dramatic close-ups, camera unobtrusiveness, greater safety, technical practicality, pictorial effect and novelty. Most of these lenses also feature internal focusing. Companies such as Century Precision Optics have modified these lenses for the exacting requirements of professional cinematography by converting the rear section and re-calibrating the iris in T-stops.

Some lenses are more extensively modified with larger, more visible footage scales, precision integral follow-focus gears, and special mounting brackets. The basic optics, however, are never changed.

Techniques

Tele-lenses tend to isolate the main subject from the background and foreground due to their inherently shallow depth-of-field. They also appear to compress objects at various distances from the camera, and may be employed to bring the background closer to the subject. A tele-lens also slows the apparent advance of a subject moving toward the camera. It is much easier to track an object moving laterally across a field with a tele-lens, because it will remain in view for a longer period of time and still retain a large image size. It is often advisable to move further back, use a long tele-lens and make a slow pan that films a large image for a greater length of time, rather than move in close to the subject's line of travel with a short focal length lens.

Several unique problems sometimes arise when shooting with tele-lenses. Increasing the image magnification also results in increased effect of camera vibration, thermal effects of atmospheric refraction (heat waves), atmospheric dust, vapors and ultraviolet radiation reflected from the same. However, new techniques have resulted in better image quality even under these adverse conditions. Following are a number of corrective tele-lens techniques that offer solutions to these problems. For example, camera vibration due to vibrating motor drive, unbalanced shutter or other mechanical characteristics can be minimized. While such vibration may have little or no detectable effects with wide-angle or normal lenses, it can be highly magnified when using long focal lengths. A solid tripod and a lens cradle should always be used. Most professional cameras have sufficient magnification in their reflex focusing systems so that any vibration effect can be observed in the viewfinder image. The tele-lens should first be focused in with the camera operating, and focus should be compared with the camera at rest to detect any adverse vibration effect.

Filters & Tele-lenses

Several types of filters can improve color in tele-lens shots. The most useful are Skylight 1A, 2A, 2B and 2C; also the UV 15, UV 16, UV 17 and others of comparable characteristics. Proper filtering of black & white films will greatly aid in minimizing atmospheric haze. Yellow, orange, and red filters improve definition and can increase contrast because they filter out violet and ultraviolet light. Dramatic haze penetration can be recorded with heavy red filters such as Wratten 25 and 29. The greatest haze penetration, far beyond visual rendition, can be produced with infrared sensitive film and any of the following Wratten filters: 72B, 87, 88A and 89A. (See "Infrared Cinematography.")

A word of caution regarding filters employed in front of long focal length, high-performance lenses: the filter's optical quality must match that of the lens on which it is used. Any lack of optical flatness will introduce aberrations which can ruin the image. For this reason, it is strongly recommended never to use any untested filter, especially with long focal length lenses.

It is becoming increasingly common to use glass filters at the back of telephoto lenses. In some cases, the filters are used via a filter holder that is inserted into a slot at the rear of the lens. In other cases, the filters are mounted in the camera adapter itself at the rear of the lens. There are many advantages to using the filter at the rear of the lens. Filters are much smaller and less costly. The most common sizes are 40.5 mm and 48 mm. Used behind the lens, the quality of the filter is not as critical as in front of the lens. Standard commercial filters are typically of more than sufficient quality for use behind the lens without causing degradation of the image. Recently, filter stages have been added behind many telephoto lenses. These stages allow rectangular filters to be rotated and translated, not only allowing the use polarizing filters, but hard-edge graduated filters as well. These filters are commonly used in two sizes: 2" x 3" and 45 x 70 mm.

To maintain the accuracy of the focus calibrations (and any focus marks that may be made during the course of the shot), the number and thickness of filters used behind the lens must remain constant. This means that clear filters must be used when no colored or effects filters are in place. The filters being used must also be of exact thickness to avoid shifting the predetermined focus of the lens. Both Tiffen and Harrison are currently manufacturing these rectangular filters to a consistent thickness.

The use of the multiple filters behind the lens can create another problem. Clear filters are normally not anti-reflection coated. The actual light loss caused by an uncoated clear filter is only ⅙ of a stop and, typically, can be ignored. Clear filters are said to cause "no light loss." However, using three (3) uncoated filters behind the lens results in three (3) losses of ⅙ each, adding up to at least ½ stop. This loss, therefore, must be taken into account when figuring the exposure (especially with multiple clear filters).

The best solution to the "heat wave" problem is to shoot during the early morning hours. A high downward camera angle will sometimes minimize heat waves by lessening the amount of ground level atmosphere that the lens must shoot through.

Focus collimation of long focus lenses can be affected significantly by temperature extremes. Lenses which are adjusted at room temperature may not be in focus in high desert temperatures due to thermal expansion of mount components. Focus should always be checked in the field under actual or simulated production conditions. In cold climates, condensation of moisture and cement separation can be minimized by gradual exposure to environmental extremes.

T-stop calibration of tele-lenses is the same as for short focal length lenses. However, it should be kept in mind that intervening haze actually lightens distant objects. The resulting aerial perspective (a gradual lightening of objects at increasing distances) will often result in an apparent overexposure when a distant object is isolated in a telephoto shot. Many cinematographers are, therefore, under the impression that tele-lenses are calibrated differently and require less exposure. Actually, the small portion of the distant scene being filmed is lighter in tone and lacks contrast because of atmospheric conditions.

To counterbalance the lack of contrast usually encountered in long-range filming, special emulsions may be chosen for use with high-power tele-lenses. Sometimes the film can be developed to a slightly higher gamma (if sufficient footage is involved to make this practical). Finally, because tele-lenses tend to magnify lateral image blur to an unnatural degree, it may be advisable to overcrank the camera somewhat.

Lens Extenders (Multipliers)

A lens extender, which consists of a multi-element optical attachment, may be positioned behind a prime lens to increase its focal length. These may be successfully used with many types of tele-lenses. It is a simple, inexpensive way to further extend the focal length of tele-lenses. Extenders of better quality can render acceptably sharp images; however, they should be stopped down for best definition.

Lens extenders have an exposure increase factor corresponding to their power. A 1.4X extender will increase the focal length of the lens 1.4X and require a 1-stop increase in exposure. Example: a 300mm f/2.8 lens becomes 420mm f/4 with a 1.4X extender. A 2X extender will double the focal length of the lens and require a 2-stop increase in exposure. Example: A 400mm f/2.8 lens becomes a 800mm f/5.6 with a 2X extender.

Since tele-extenders already cause a light loss, the dim image may be difficult to focus and view. Effective apertures are rarely faster than f/8 or f/11, or even f/16. Extenders can be combined for greater magnification. The power should be multiplied to obtain the working power. For instance: two 2X extenders can be combined to form a 4X unit, which would have an exposure factor of 16 and require a 4-stop increase in exposure.

Catadioptric or Reflective Systems

Reflective optical systems employing mirrored optical surfaces enable long focal lengths to be folded inside of a compact assembly, thus saving space and weight. These systems usually combine reflective surfaces and refractive correcting lenses. The color correction is good and normally requires no correction for using infrared sensitive film. Because of the necessity of using the entire light path, an iris diaphragm usually cannot be incorporated in these systems. Neutral density filters or a reduced shutter opening may have to be used to reduce exposure. Careful comparative tests are advisable to determine the suitability of these lenses for the intended purpose.

These lenses typically have a secondary reflective surface either on the back surface of the front correcting element, or as a separate element mounted inside the lens. The light is then reflected back through a hole in the primary mirror at the back of the lens and onto the film. The blocking of the center of the lens by the secondary mirror results in the out-of-focus highlights and points being rendered on the film as rings (or donuts). This effect should be noted and this type of lens should not be used if this will be a problem. In many cases, these out-of-focus rings are desired and are the main reason for using the mirrored lens. It should be noted that mirror lenses typically have a T-number approximately one (1) stop slower than the actual f-number. Exposure tests should be run prior to use, or the lens should be calibrated on equipment capable of measuring the actual T-stop of the lens.

The primary requirement for achieving maximum resolving power and finest image quality with a tele-lens is careful focusing. Long focal length lenses possess inherently shallow depth-of-field characteristics. This is a law of physics and cannot be changed; therefore, some means of focusing through the lens must be employed. Secondly, camera steadiness must be assured by rigid lens mounting and absence of vibration. Thirdly, the finest quality filters, carefully chosen to fit the filming conditions, should be employed. A long lens shade is essential. It should be carefully designed so as not to restrict the angular coverage of the lens. It must also have a totally non-reflective interior, as should all surfaces of the lens mount that are exposed to the image-forming light.

Modern telephoto lenses have proven to be one of the most useful tools for creative cinematography, often rendering subject details, compression, and selectiveness that might otherwise have been impossible.

Zoom Lenses

by Bern Levy

In order to understand why we use a zoom lens, it is best to first understand what a zoom lens is. By definition a zoom lens is a precision optical/mechanical system, which can change its field of view without noticeably changing its aperture or focus. This is made possible by the use of complex cams and followers controlling precisely designed and manufactured optical components.

Today the zoom lens is used mainly as a variable prime, meaning that the zoom lens carries within it an infinite number of focal lengths which can be utilized for the specific composition required. The cinematographer has available almost every conceivable focal length and aperture found in fixed focal length lenses. Cine zooms have ranges up to 25X now, with focal lengths of 7.5mm to 625mm and apertures as high as f/11 currently available, leaving very few requirements for fixed focal length lenses. In addition to these properties, the zoom lens can achieve special effects by ever-changing the field of view, otherwise known as zooming.

Those characteristics which we consider important in selecting a fixed focal length lens are equally important in selecting a zoom lens. In addition to aperture and focal length, we must consider zoom range, minimum focusing distance, correction, etc. in determining which zoom lens is suitable for your purposes. Equally important are your own requirements for this lens. Is extremely close focusing necessary? Is high aperture important? Will you be shooting close-ups indoors? Or mostly outdoors from long distances? All aspects must be considered.

One lens may allow better operational flexibility than another lens and therefore reduce the demands on the camera. As an example, a close-focusing lens may cut production time as compared to a lens that requires the use of close-up attachments. A lens with a large zoom range may reduce the number of times the camera is repositioned. Reliability of the lens has a direct relationship to the manufacturer. The past record of the lens design as well as the manufacturer's reputation in the marketplace must be considered. Are service facilities available? Is the facility equipped with proper instrumentation and personnel? Will parts be available?

Another pertinent consideration is whether to purchase a new or used zoom lens. As the zoom lens is a mechanical system, the age and previous use of the lens will determine whether a used lens, at a lower cost, has a value over a new lens at a higher cost. Are the zoom and focus mechanisms smooth? What is the appearance of the coating? Are the front and rear elements scratched? The answers to these questions will help determine the value of a zoom lens.

Mechanics of Zoom Lenses

Perhaps the single most important factor in preparing a zoom lens for use is the mounting procedure. Unlike fixed focal length lens, a zoom will not perform correctly if not seated properly in the camera. The distance from the seat or flange of the lens mount to the film plane (known as the flange focal distance) is hypercritical. If not set to the prescribed dimension (17.52mm for Standard "C" mount, 40.0mm for Aaton, 52mm for Arriflex Standard, 38.1mm for CP, 48mm for Eclair) out-of-focus images will result when zooming from long focal lengths to short focal lengths. This phenomenon is a result of the depth of focus, the lens-to-film tolerance being greater at the long focal length than at the short focal length. To avoid mounting problems, both the lens mount and camera socket should be cleaned before inserting the lens into the camera. It must be pointed out that professional zoom lenses must be adjusted to an extremely small tolerance specified by the lens manufacturer, which could be as precise as .01mm (.0004") of the flange focal distance, and therefore, a small particle of dirt may actually interfere with the proper seating of these lenses.

While some zoom lens diaphragms are graduated in both f- and T-stops, exposure should only be set on the T scale. Because the large number of optical elements in a zoom lens affects the transmission of light through the lens, there is a difference between the geometric aperture (f-stop) and the photometric aperture (T-stop).

Zooming, or the changing of focal length, results in the changing of image size at the film plane without varying the subject-to-lens distance. This can be accomplished by either mechanical or electrical means. While most zoom lenses rely on the manual turning of the zoom barrel, a more controlled and therefore more consistently accurate rate can be achieved by the use of electrical motor drives. In some cases, this is not preferred. While some cinematographers prefer to actually rotate the zoom barrel directly by hand (they claim that this method gives them a much greater control), others prefer an electrical servo system with a rate control to provide a dampening effect. This allows the operator to start the zoom very slowly and then accelerate to the desired maximum speed. The situation can also be repeated, in reverse, to end the zoom slowly. This dampening effect is desirable as it tends to make the zoom movement itself less noticeable. Regardless of whether turning the zoom barrel by hand or by motor, it is suggested that the lens be zoomed the entire focal length range before actually making a take in order to distribute the lubrication within the zoom cams and bearings. This will result in a much smoother zoom effect, eliminating irregular movements or hang-ups.

Before attempting to focus a lens, the viewfinder eyepiece must be adjusted to your vision. It is recommended that the lens actually be defocused prior to setting this eyepiece. You must realize that in this procedure, the viewfinder is being set to adjust the focus of your eye to the ground glass viewing system of the camera only. The lens is not considered as part of this system. The viewfinder should be adjusted so that only the grain of the ground glass is sharp. At this point, the eyepiece should be locked in position so that it will not be moved accidentally during use.

When attempting to focus, the lens should always be set at its longest focal length and at full aperture, as these conditions establish the minimum depth of field for a zoom lens and provide maximum sensitivity. Similarly to zooming, the focus barrel should be turned throughout its entire range in order to distribute the lubrication for a smooth effect before making a take. For "grab" shots, one should know the hyperfocal distance of the lens. To review, the basic rule is that when the lens is focused on the hyperfocal distance, the depth of field extends from half the hyperfocal distance to infinity, providing the maximum focusing range for a possible "grab" shot (see tables on pages 174-200).

Do's and Don't's

It should be our aim to create pictures that do not bring attention to the mechanics involved in the production of the picture. We must remember that we are operating a motion-picture camera and not a *moving* picture camera. We must realize that every zoom movement, like every camera movement, should have a motivation. The zoom should not be used merely because it is available. The fact there is a zoom lens on a camera does not necessitate utilizing the lens for the *zoom* effect. The "tromboning" technique invented by 8mm amateurs and propagated by professionals around the world should be avoided unless that particular effect is required in the production.

Basically, a zoom lens contains an infinite series of focal lengths. We should consider the zoom as a variable prime lens using it in much the same manner as fixed focal length lenses. When a specific focal length is called for, the zoom lens should be set for that specific focal length and the scene shot just as if a fixed focal length lens was mounted on the camera.

On the other hand, when the production calls for a searching or revealing effect, the zoom lens is capable of handling this technique. The searching technique was inherited from broadcast television coverage of baseball and other major sports. It starts with an overall wide-angle shot of the arena. Upon the decision of the team involved to enact a sensational play, the lens is zoomed in to a tight shot of the player at the center of the action. The opposite type of zoom movement, "revealing" the subject, is used more often in commercials and theatrical films as it can impose tremendous impact if carried out correctly. In this type of zoom movement, the zoom lens is first set at the long focal length to provide a narrow angle of view and, upon cue, is zoomed to a wide-angle position to reveal another object to accent the plot.

An intimacy with a moving subject can be achieved by zooming at the same rate as the subject is moving either toward or away from the camera. This method keeps the subject size the same even though the subject is in motion. The effect is heightened by the changing of perspective in that while the subject size remains relatively constant throughout the sequence, the background relationship changes according to the distance from the subject to the background. The perspective changes only because the distance between the lens and the subject is changing. The focal length of the lens is not the controlling factor in determining perspective. The focal length of the lens determines the angle of view, which provides us with the required width and height of the picture.

The zoom lens can also be used to introduce speed. A very fast zoom from a wide angle to a tight shot of a speeding subject will accelerate the movement of that subject. Inanimate objects can be made to appear to move by proper zoom movements. The changing of image size in a given sequence can actually create the illusion of movement.

Zoom Lens Flexibility

There are a number of attachments available for zoom lenses to increase their flexibility. These attachments can be used to further change the angle of view, working distances, color and contrast, as well as protect the lens. One of the most commonly used front-mounted attachments is the close-up lens (sometimes referred to as a diopter). These attachments fit on the front of a zoom lens, permitting a closer than normal focusing range, as well as the full use of the zoom. Its prime limitation is that focusing to infinity is not possible.

One of the most recent front-mounted attachments is a unit to increase the focal length of a zoom. This telephoto attachment, while increasing the focal length, may reduce the zoom range whereas it is limited by its front diameter to a medium-wide angle.

As an example, a 15-to-1 zoom is reduced to a 6-to-1 because of this phenomenon. Another front-mounted attachment performs the opposite function. A retrozoom, or wide-angle attachment, will decrease the focal length; however, in this case, the zoom range is not affected. An additional benefit of the wide-angle attachment is that it reduces the minimum focusing distance.

The most important reason for utilizing front mounted attachments is that the geometric aperture (f-stop) is not affected, degradation of image quality is minimal and a normal focusing range to infinity is maintained.

On the other hand, rear mounted attachments, such as range extenders, not only multiply focal lengths, they also affect aperture and existing aberrations. As an example, a 2X range extender mounted on the rear of a 25-250mm, f/3.2 lens will double the focal length (50-500mm) as well as the aperture (f/6.4). Aberrations which may not have been noticeable on film are magnified 4X due to the geometry involved, creating an image of questionable quality. When sufficient light is available, such as during outdoor sporting events, the iris is stopped down at least halfway and these aberrations are reduced, generally resulting in acceptable images.

While rear-mounted filters do represent a less expensive method of light filtration, it must be pointed out that they also elongate the back focal distance of a lens to a dimension ⅓ the thickness of the filter material. As tolerances for mounting professional zoom lenses are measured in hundredths of a millimeter, this extension of the back focal distance of a zoom may seriously affect its image quality. Of course, cameras which are manufactured with filter slots have adjusted flange focal distances which compensate for this elongation. This deviation then demands that even though a filter is not used, a UV or clear optical flat of equivalent thickness to the normal filter material must be inserted in the optical path in order to compensate for the increased back focal distance.

Front filters, however, do not require any adjustment of the back focal distance and are therefore recommended. If no color filtration is required, a light UV can serve to increase the "snap" of a picture as well as serve as an inexpensive protective device for the front element of a zoom lens.

Cine Zoom Lenses on Video Cameras

Now that the video medium has progressed to state-of-the-art equipment, where gamma and other picture qualities are controllable enough to provide the "film look," cinematographers are finding a need for a greater variety of lenses to render the same quality images they have photographed on film. Unfortunately, professional television equipment manufacturers have not produced many "extreme" type lenses and therefore there is an urge to utilize the great variety of cine lenses on video cameras.

Cine lenses may be used successfully on black & white and single-tube color cameras. As most professional productions would utilize a prism-type camera, we must refer to this type of mechanism as being limited in its capability to accept cine lenses. The prism or beam splitter that breaks up the white light coming from the lens into the three primary colors requires an elongated back focal distance of a given lens in order to compensate for the glass in the prism. Whereas some extreme cine lenses do not have this extra back focal length, it is not possible to utilize them on professional video cameras. Depending upon the size of the actual prism in the camera, it has been found that focal lengths of 15mm and longer can be used successfully on most ⅔-inch prism-type cameras. Extreme wide-angle and high-aperture lenses cannot be used. Several optical adapters are currently available to enable you to utilize cine lenses on video cameras. The users of these devices report low-quality images in addition to bulkiness and high cost, negating their original concept.

Lens Maintenance

User maintenance is principally limited to keeping glass surfaces clean. No adjustments should be made to a zoom lens except by a qualified technician. As most major lens manufacturers maintain their own service centers or appoint service representatives, it is best to limit any repairs to this group. This is extremely important, as only a trained technician, who knows the effects of the adjustments and works with the proper tools and measuring instruments, can properly carry out a zoom lens repair.

Should maintenance be required, it is extremely important to realize that the service facility can not rectify the problem unless it is clearly indicated to them. Prior to shipping a lens to a service facility, it is essential that the problem be documented, clearly indicating all aspects of the difficulties encountered. If necessary, a test film, showing the problem, should accompany the lens. Terms such as "the lens isn't sharp" or "it doesn't work" should be avoided. Specific details should be indicated, such as, "the lens goes soft at a specific focal length," "the iris blades stick at f/?" or "the lens has been dropped" and possibly "the lens has been immersed in sea water." By giving these details, the service technician will be able to attack the problem and solve it quickly, resulting in a lower cost to you.

Last but not least, the lens should always be packaged properly. Do not attempt to ship a lens, whether to a service center or otherwise, without having proper packaging insulation surrounding it to a depth of at least 2". Just as important, it is essential that the lens be packaged so that there is absolutely no movement of the lens or any parts packaged therein. By adhering to these few rules, your zoom lens should provide you with excellent service over the years.

Lens Formulas

Hyperfocal Distance

Hyperfocal distance of a lens represents a special case of depth of field in which objects at infinity, as well as the nearest possible objects, are photographed with acceptable sharpness. Therefore, if a lens is focused at the hyperfocal distance, all image points between one-half that distance and infinity will not exceed a specific circle of confusion, or expressed more simply, will be acceptably sharp.

The formula for hyperfocal distance (using inches or fractions thereof) is:

$$H = \frac{F^2}{f \times Cc}$$

F = focal length of lens
f = f/stop number
Cc = circle of confusion

The circle of confusion for the hyperfocal distance can be briefly described as the image of a point situated outside the focused distance plane that will therefore not form the image of a point in the film plane, but a blurred circle of a diameter Cc.

Acceptable sharpness in past editions has been calculated as a .002 inch image of a point ("Circle of confusion"), for images on 35mm film. Because of larger magnification in present-day theaters, manufacturers have been using .001 inches in recent years, and these new tables follow that practice (.0006 inches (.015mm) is used in the 16mm tables). To read depth of field for larger or smaller circles of confusion, use the column under a smaller or larger lens f-stop. Acceptable sharpness is affected not only by the geometry of the cone of light imaging a point object; it is also affected by:

1. The imaging quality of the lens both on-axis and off-axis at the plane of best focus.
2. The imaging quality at large and small, as compared to intermediate iris diaphragm apertures.
3. Diffusion or flare, whether intentional or not.
4. The imaging quality of the films and printing methods used (negative, intermediate, and print).
5. Viewing conditions.
6. Object illumination and contrast.

If for any of these reasons the sharpness of the best image is less than the arbitrarily established norm, the apparent depth of field will be affected also. If the exit pupil of the lens, due to asymmetry, is not the same as the indicated f-stop, the depth of field will be affected.

Because depth of field has no sharply defined limits, the distances in the tables have been "rounded off" to figures compatible with the distance.

Depth of Field

The depth of field of a lens is the range of acceptable sharpness before and behind the plane of focus obtained in the final screened image. It should be understood that the determination of depth of field involves a subjective sensation that requires taking into account the condition under which the final projected image is viewed. The following two formulas are for calculating the depth of field with the help of the hyperfocal distance and the circle of confusion.

Depth of Field Calculations

First: Calculate the hyperfocal distance
(definition above)
(The tables are calculated
for Cc = .001" (.025mm) for 35mm film,
= .0006 (0.15mm) for 16mm film)

Second: Using H, calculate near and far depth-of-field limits

$$DN \text{ camera to near limit} = \frac{H \times S}{H + (S-F)}$$

$$DF \text{ camera to far limit} = \frac{H \times S}{H - (S-F)}$$

H = Hyperfocal distance
S = Distance from camera to object
F = Focal length of lens
Depth Total = DF-DN

When the object distance is less than 10 times the lens focal length, depth of field is very small, and tables are more appropriately combined and stated in terms of image magnification, rather than focal length and subject distance. (See "Extreme Closeup.")

Depth of Focus

The depth of focus should be clearly distinguished from the previously explained depth of field. The depth of focus is an infinitely small range behind the lens at the focal plane within which the film is positioned during exposure. This is most critical, particularly with short-focus lenses. If the film moves out of this precise position, either forward or backward, it will cause unsharp images produced by an increase of the diameter of the circle of confusion. The circle of confusion, in other words, is no longer an acceptably sharp point but a larger circle which is blurred. Precise placement of the film in the film aperture is a most important consideration for motion picture camera designers to avoid film buckling or breakage, or other mechanical problems such as variable pressure plates or poor registration, causing displacement of the film behind the lens during actual exposure. Each frame must be held securely in position and in perfect register in the exact focal plane and remain absolutely motionless during exposure. For close approximation the formula for depth of focus for a lens at a given f-stop is plus or minus:

$$\text{Depth of focus} = \frac{\text{focal length x f-stop}}{1000}$$

Lens Angle and Field of View

Field of view may be calculated by substituting film aperture size for image size; the field of view is then the object size. (Lens angle may be calculated with the aid of a table of tangents or a pocket scientific or slide-rule calculator; see tangents table.)

For 2:1 anamorphic lenses, the field or object size is double in the horizontal dimension.

A = Aperture (height or width) in inches
f = focal length of a lens in inches

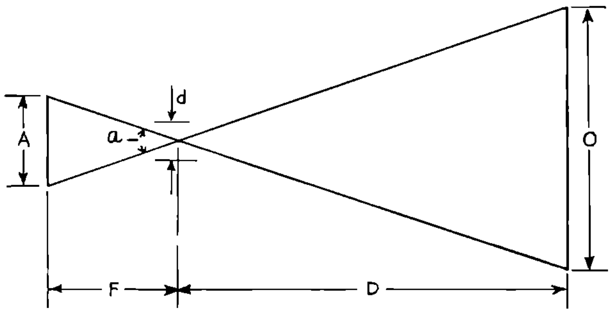
$$\text{Tangent } \tfrac{1}{2} \text{ viewing angle} = \frac{\tfrac{1}{2} A}{f}$$

The tangent of ½ viewing angle can be converted to degrees by consulting a tangent table. Multiply this angle by two to obtain the full viewing angle. For Cinemascope, or other two times squeeze wide screen processes, the formula is simply the aperture divided by the focal length of the lens, since 2 times ½ equals 1. Other squeeze ratios should use the following formula:

$$\text{Tangent } \tfrac{1}{2} \text{ viewing angle} = \frac{\tfrac{1}{2} \text{ A x Squeeze Ratio}}{f}$$

Using the above sketch one may calculate camera distance, object size, lens focal length or image size if any three are known.

O = object size in front of camera
D = distance from object to lens of camera
F = focal length of lens used
A = image size
and: a = lens angle when A = film aperture size
O = field of view when A = film aperture size



These components are connected together by the following basic formulas:

$$\frac{O}{A} = \frac{D}{F}$$

and that, in other terms, leads to the following four basic formulae:

$$D = \frac{O \times F}{A}; \quad \text{Distance} = \frac{\text{object size x focal length}}{\text{aperture size}}$$

$$O = \frac{D \times A}{F}; \quad \text{Object size} = \frac{\text{distance x aperture size}}{\text{focal length}}$$

$$F = \frac{D \times A}{O}; \quad \text{Focal length} = \frac{\text{distance x aperture size}}{\text{object size}}$$

$$A = \frac{F \times O}{D}; \quad \text{Aperture size} = \frac{\text{focal length x object size}}{\text{distance}}$$

All dimensions must be converted to the same units: feet, inches, meters or millimeters. (One inch equals 25.4 millimeters; one millimeter equals .0394 inches.) Note that D is measured to the lens (front principal point). Most cameras and lens scales are calibrated to the distance from the film plane (because lenses to be mounted on the camera are of various sizes). This convention should pose no problem when the object distance is greater than about 10 times the lens focal length. (See "Extreme Closeup Photography.")

Lens Aperture

F-stop or f-number is the ratio of the focal length of a lens to the diameter of the entrance pupil. (Approximately the aperture diaphragm size in a symmetrical lens).

T-stop is a measure of the light transmission of the lens. It is related to f-stop by the efficiency of light transmission. A lens which transmitted 100% of the light entering it would have the same f-stop and T number.

To compensate for backlash in the mechanism, always set a lens diaphragm by moving from the widest opening to the desired aperture. This method takes up any backlash that may be present and provides the most accurate setting. (Reference: ANSI PH 22.90.)

Lens Displacement When Focused Closer Than Infinity

d = lens displacement from infinity position
f = focal length of lens in inches
a = distance focused on in inches

$$d = \frac{f^2}{a - f}$$

EXAMPLE: The displacement of a 50mm (2 inch) lens focused at 10 feet (120 inches):

$$d = \frac{2^2}{120-2} = \frac{4}{118} = 0.031''$$

Extreme Close-up

In photographing subjects at a distance closer than the camera lens mount scale will allow, three options are open:

1. When available, extension rings or bellows may be used between the camera lens and the flange.

2. Supplementary lenses (commonly known as "diopters") may be mounted in front of the lens or screwed into filter holders on the lens.

3. Lenses especially designed for photomacrography may be employed. (The term "macro" is loosely defined; Kodak uses it when the scale is greater than 1:1, while many lenses are sold for "macro" for use down to 1:1 or 1:2.

Lenses used for general cinematography are designed and corrected for subjects many feet from the camera; "macro" lenses are corrected for whatever scale they are sold for, and would be expected to deliver a better image at that scale than a conventional lens with extension rings.)

The choice between extension rings or diopter lenses is determined by convenience, with a slight preference for the use of prime lenses and extension rings. Image aberration due to close focusing of prime lenses and due to the "simple lens" structure of diopters is minimized in each case by stopping down to f/8 or f/11. While a macro lens may be corrected for a larger aperture, depth of field (about ⅒th of an inch at f/8 at scale 1:2) may be a limiting factor. Depth of field at a given f-stop depends solely on the scale factor (copy ratio or image size divided by subject size), not on the use of extension tubes or diopters, nor on the lens focal length. Therefore, it is preferable to use a long focus lens to allow more room for lighting.

Extension of Prime Lens

As the prime lens is moved forward, less light is transmitted because the effective T-stop is progressively diminished by its distance from the film. At a subject-to-lens distance of about 10 focal lengths *(field width* of 8" for 35mm, or 4" for 16mm) this begins to become noticeable. The table shows the amount of illumination increase required to maintain full exposure in terms of image scale factor.

By convention, most camera lens distance scales are calibrated at a subject distance measured from the film plane because lenses of differing sizes are involved. The following close-up tables are calculated on *subject-to-lens* distance (to the front "principal point"; for practical purposes, the iris diaphragm, which is not necessarily the calibrated diaphragm ring).

Diopter Lenses

By definition, "diopter" is the measure of the power of the lens expressed as the reciprocal of the focal length in meters (1000 divided by the focal length of the lens in millimeters). The term is commonly used by cinematographers to refer to supplementary lenses used in close-up photography. The lenses are generally of a weak meniscus form and are marked with the number indicating the diopter power: +½ , +1, +2, etc.

When a prime lens is set at scale focus infinity, and a diopter lens is mounted in front of it, a subject will be in focus on the film plane if positioned at a distance from the diopter lens equivalent to the focal length of the diopter lens (2 meters for a ½ diopter lens, 1 meter for a 2 diopter lens, etc.). Two diopter lenses mounted close together may be used and the power is the sum of the powers of the two lenses. When two diopter lenses are combined, the highest power should be closest to the prime lens. Plus diopters should be placed in front of the prime lens with their convex (outward curve) side toward the subject. If an arrow is engraved on the rim of the diopter lens mount, it should point toward the subject.

Highest screen quality results with lower-power diopters. It is better to use a longer focal length prime lens and a less powerful plus-diopter lens than to employ a higher power diopter on a short focal length prime lens. Plus diopter lenses shorten the focal length of the prime lens and change its focus scale. The tables give typical figures for these factors. Because the prime lens is used "on scale" it is not necessary to increase exposure for close-ups photographed in this manner.

Depth Of Field For Close-up Photography

When the object distance is less than 10 times the lens focal length, depth of field is very small, and tables are more appropriately combined and stated in terms of image magnification, rather than focal length and subject distance. The difference in near and far depth also becomes small, and depth is stated in the table as the total zone of probable acceptable sharpness. Geometric calculation of depth of field for asymmetrical lenses (retro, tele, and zoom) is also to be taken as an approximate guide in these zones, because each has been designed for a specific range which may or may not include extreme close-up.

Extreme Closeup Lens Formulas

$$\text{Power in diopters} = \frac{1000}{F(mm)} \quad (= "P")$$

$$\text{Magnification "m"} = \frac{\text{image size}}{\text{object size}} = \frac{\text{image distance from lens}}{\text{object distance from lens}}$$

Combining "diopter" lens with prime lens

$$F_e = \frac{F \times \frac{1000}{P}}{F + \frac{1000}{P}} \text{ millimeters}$$

F = focal length prime lens
F_e = effective focal length, (combination)

Total depth of field in terms of "m":

$$D_t = \frac{2C\,N(1+m)}{m^2}$$

C= diameter of circle of confusion
N= f/number

Exposure factor for extended prime lenses:

$$\text{Exposure Factor} = \frac{EI(\text{close-up})}{EI(\text{normal})} = (1+m)^2$$

$$\text{Lens stop corrected for m: } N_I = \frac{N_E}{1+m}$$

N_I = indicated or calibrated lens stop
N_E = calculated or "normal" lens stop

$$\text{Stop change} = 6.6 \log(1+m) = \left[= \frac{\log(1+m)^2}{\log^2} \right]$$

Not all of these formulas are rigorous.
Some have very small factors discarded for practicality.

Split-Field Diopter Lenses

Split-field diopter lenses are *partial* lenses, cut so that they cover only a *portion* of the prime lens. They are generally cut in half, although they may be positioned in front of the prime lens so that more or less than half is covered. They may be compared with bifocals for human vision, in which the eye may focus near and far. They have an advantage over bifocals, however, in that they may be *focused sharply on both near and far subjects simultaneously.*

The depth of field of the prime lens is not extended. The split-field diopter lens simply permits focusing on a very close subject on one side of the frame, while a distant subject is photographed normally through the uncovered portion of the prime lens. Generally, the area in between will *not* be in focus. There are instances, such as using a zoom lens with a small aperture at the wide-angle position, when sharpness may extend all the way from the ultra-close-up to the distant subject. The split diopter-equipped lens possesses two distinct depths of field: one for the close subject (which may be very shallow or possess no depth whatever), and another for the distant subject (which will be the normal depth of field for the particular focal length lens and f-stop in use). It is important, therefore, to exclude subject matter from the middle distance because it will create a situation where the foreground is sharp, the middle distance is out of focus and the distant subject is sharp!

Split-field diopter lenses require ground-glass focusing to precisely line up both foreground and background subjects and visually check focus on each. This is particularly important with zoom lenses, which may require camera movement during the zoom.

Very unusual effects are possible that would otherwise require two separate shots to be later combined in an optical printer via a matting process. Making such split shots in the camera permits viewing the scene as it will appear, rather than waiting for both shots to be optically printed onto one film.

The proper power split-field diopter lens is positioned in front of the taking lens on the same side as the near object, so that it is sharply focused on one side of the frame. The uncovered portion of the conventional or zoom lens is focused in the usual manner on the distant subject. (Note: Use the "Plus Diopter Lenses Focus Conversion Table" to find near and far focusing distances with various power diopter lenses.) A zoom lens may be employed, either to obtain an intermediate focal length not available with conventional lenses, or to zoom during the shot. Study the shot through the focusing viewfinder at the f-stop to be used for filming.

The edge of the split diopter lens should be positioned, if possible, so that it lines up with a straight edge in the background, such as the corner of a room, the edge of a column or a bookcase. Eliminating the edge may prove difficult under certain conditions, particularly with a zoom lens, because the edge will shift across the frame slightly when the lens is zoomed. It is wise to leave space between the foreground and background subjects so that they do not overlap and so that each is removed from the lens edge. This will minimize "blending." The split diopter need not be lined up vertically — it may be used horizontally or at any angle to cover a foreground subject on top, bottom, either side or at an angle across the frame. Lighting may be employed to lighten or darken the background area where the split occurs, to make it less noticeable.

Split-field diopter shots cannot be filmed on the run. They require precise subject placement, camera positioning and balanced lighting to record an acceptable result without a telltale blur between. They have limited use and will not replace elaborate setups that require optical printing, process background projection or mattes. They may be used for simple combination shots where the cinematographer is allowed the time required for a precise lineup of the various elements involved.

Diopter and split-field diopter lenses may be ordered custom-made in a compound construction which can be more highly corrected than simple single-lens elements. Such compound lenses consist of two or more elements and are rather thick, so they require a special retaining ring.

Special Purpose Lenses

Swing Shift Lens

The Clairmont Swing Shift Lens System consists of a multi-axis moveable lens board receiver attached to a Arriflex style PL lens mount by a rubber bellows. Specially modified lenses are attached to the receiver board by two captive screws. The assembly is able to move the entire lens in the following directions: tilt up and down, swing side to side, shift position and focus right to left, or up and down. Tilting/swinging the lens plane alters the focus; tilting/swinging the film plane alters the shape. By combining the various parameters of movement, different and unusual effects can be accomplished, such as increased or decreased depth of field, selective planes of focus, repositioning of image without changing placement of the camera, and correction or addition of image distortion. The focal lengths available are 20mm, 24mm, 28mm, 35mm, 50mm, 60mm, and 80mm.

Panavision 45mm T2.8 Slant-Focus Lens

The plane of focus of this lens can be tilted in any direction (including vertical and diagonal) as well as horizontal by adjusting the rear lens rotating mount.

If the lens focus is set on an object near the center of the field of view, the plane of focus can be tilted so that objects (left side of frame and/or right side of frame) located along this tilted plane of focus will also be sharp.

If there is not an object near the center of the field of view, measure the distance to the near and far object and set the focus at an average between the two distances. The plane of focus can now be tilted so that the two objects will be brought into focus. In all situations, an object near the center of the field of view should still be in focus after tilting the lens.

Due to the tilting nature of this lens, it cannot be used with a Panaflex follow-focus. For the initial focus and any change in focus, eye focusing is necessary. This lens accepts a 1.4X Primo extender with negligible change in performance and no change in operation. The focal length becomes 63mm with a maximum aperture of T4.0. If filters are used with this lens they should (whenever possible) be glass filters in front of the lens. If needed, the lens does accept a 40.5mm rear filter.

Continental Camera Systems Remotely-Controlled "Pitching Lens" f/3.9 Optical Relay

Concept: A system to remotely control a prime lens that is mounted at the end of an optical relay tube. In normal configuration the 18" tube extends downward from the camera. The prime lens is mounted at right angles to the tube and can tilt 15° up to 90° down. The entire system rotates 380°. This allows lenses such as Nikkor or Arriflex to get into very small areas. Use of an anamorphic element between the end of the relay tube and camera allows a spherical lens to produce an anamorphic image on film.

Because focus is controlled in the relay tube, it is possible to continuously follow-focus from ½ inch to infinity, thus greatly extending the normal focus range of most prime lenses. The system may also be mounted vertically (as in a submarine) or extended straight out in a horizontal position.

Clear length of relay: 18" Maximum diameter: 3"

Control of Lens: Control console with built-in video monitor. Pressure-sensitive joystick for pan and tilt operation. System power requirements 110V, 220V or 24V DC.

Cameras: Arriflex IIC, Norelco PCP90 (video), Mitchell R35, Lightweight Technicolor VistaVision equipped with Nikon mount.

Focus: Remotely controlled from hand-held unit. Focus speed is proportional to focus command.

Taking Formats: 16mm, 35mm anamorphic, VistaVision.

Optics: Nikon mount through adapter rings can use a wide assortment of Nikkor and Arriflex lenses from 7.2 mm to 100mm. Speed of system is f/3.9 to f/32. Prime lens is set wide open and aperture is controlled in the relay system.

Suspension: Standard dolly with small jib arm and C.C.S. balanced cross arm at camera end of jib. Large telescopic billboard cranes and Chapman "Titan" cranes can be used.

Kenworthy Snorkel Camera Systems

A remote image-taking system with operator and camera components removed from shooting area. The camera looks into a periscope-like optical relay tube that extends downward below the camera and ends with a small front-surfaced mirror. Since the mass of the camera with operator is removed from the shooting area, considerations of scene staging are concerned only with the small end (1-¼" x 1-¼" at the mirror) of the tube. The tilting mirror is remotely controlled, as are other functions such as pan, focus, roll, zoom and iris. The mirror system permits more intimate shooting (due to its small size) than do add-on right-angled lens periscopes. It also permits tilting up in constricted situations because the mirror, rather than the tube/camera combination, does the tilting. The system allows viewpoints in tight quarters reachable from overhead, or from very low viewpoints or in miniature sets. Pans and tilts are on system nodal point. An added waterproof tube permits underwater or transition shots.

There are two systems available:

The Kenworthy Nettman Snorkel features fast optics and lightweight, interchangeable formats, and carries a shorter tube for use on lightweight dollies. The cameras are butterfly VistaVision, 65mm, and 16mm film and ⅔" video cameras. Camera lenses are used.

The type B Kenworthy Snorkel is designed for shooting actors with dialogue at moderate lighting levels. It carries a longer tube (48" or 66") which permits more overhead clearance for deeper penetration into four-walled sets or water tanks. This system uses 35mm only: Arriflex, Mitchell Mark II, Panaflex or other similar cameras. The Panacam is used for video. System lenses are used on the Type B; 28mm & 50mm T8 for film, 13mm T5.6 for video. Both systems can use anamorphic lenses. Type B requires a camera crane.

With both systems a console is used with a video monitor and pan, tilt and lens controls.

Dynalens

An optical stabilizing device mounted on the camera optical axis for compensating for image motion due to vibration of the camera.

A pair of gyro sensors detect rapid motion and drive two gimbal-mounted glass plates, between which is a liquid-filled cell. One plate moves around a vertical axis and the other around a horizontal axis in a manner which deviates the light path opposite to the vibratory movement, causing the image to stay still relative to the image receptor (film or video).

A low-frequency-response manually operated potentiometer on the control module adjusts the frequency sensitivity of the unit so controlled panning or tilting may be done.

The Dynalens is available in 2.3" diameter for 16mm film or small video cameras and 3.8" and 8" for larger format cameras. The maximum useful angular deviation is $\pm$ 6°.

LENS FOCAL LENGTH: **9.8mm**

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .001" (1/1000")

HYPER-FOCAL DISTANCE	12.41'	8.86'	6.20'	4.43'	3.10'	2.22'	1.55'	1.13'	0.78'	0.56'	0.39'	FIELD OF VIEW (w/projected image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825"×.446")	TV HEIGHT (.594")
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676"×.700")	
15	6'10" INF	5' 7" INF	4' 5" INF	3' 5" INF	2' 7" INF	2' INF	1' 5" INF	1' INF	1' INF	1' INF	0' INF	32' 0"×17' 4" 65' 0"×27' 2"	23' 0"
12	6' 1" 367'	5' 1" INF	4' 1" INF	3' 3" INF	2' 6" INF	2' INF	1' 5" INF	1' INF	1' INF	1' INF	0' INF	25' 7"×13'10" 52'12"×21' 9"	18' 5"
10	5' 6" 52'	4' 8" INF	3'10" INF	3' 1" INF	2' 4" INF	1'10" INF	1' 4" INF	1' 0" INF	0' 9" INF	0' 6" INF	0' 5" INF	21' 4"×11' 6" 43' 3"×18' 1"	15' 4"
9	5' 3" 33'	4' 6" INF	3' 8" INF	3' 0" INF	2' 4" INF	1' 9" INF	1' 4" INF	1' 0" INF	0' 9" INF	0' 6" INF	0' 5" INF	19' 2"×10' 4" 39' 0"×16' 3"	13'10"
8	4'10" 23'	4' 3" 82'	3' 6" INF	2'10" INF	2' 3" INF	1' 9" INF	1' 4" INF	1' 0" INF	0' 9" INF	0' 6" INF	0' 4" INF	17' 0"× 9' 3" 34' 6"×14' 6"	12' 3"
7	4' 6" 16' 1"	3'11" 33'	3' 4" INF	2' 9" INF	2' 2" INF	1' 8" INF	1' 3" INF	1' 0" INF	0' 8" INF	0' 6" INF	0' 4" INF	14'11"× 8' 1" 30' 3"×12' 8"	10' 9"
6	4' 0" 11' 7"	3' 7" 19'	3' 1" 184'	2' 7" INF	2' 1" INF	1' 7" INF	1' 3" INF	0'11" INF	0' 8" INF	0' 6" INF	0' 4" INF	12' 9"× 6'10" 25'11"×10' 9"	9' 2"
5	3' 7" 8' 5"	3' 2" 11' 6"	2' 9" 26'	2' 4" INF	1'11" INF	1' 6" INF	1' 2" INF	0'11" INF	0' 8" INF	0' 6" INF	0' 4" INF	10' 7"× 5' 9" 21' 6"× 9' 0"	7' 8"
4	3' 0" 5'11"	2' 9" 7' 3"	2' 5" 11' 3"	2' 1" 41'	1' 9" INF	1' 5" INF	1' 1" INF	0'11" INF	0' 8" INF	0' 6" INF	0' 4" INF	8' 6"× 4' 7" 17' 3"× 7' 2"	6' 1"
3	2' 5" 11' 5"	2' 3" 4' 6"	2' 0" 5'10"	1'10" 9' 3"	1' 6" 92'	1' 3" INF	1' 0" INF	0'10" INF	0' 7" INF	0' 6" INF	0' 4" INF	6' 4"× 3' 5" 12'10"× 5' 5"	4' 7"
2	1' 8¾" 2' 4½"	1' 7½" 2' 7"	1' 6" 2'11½"	1' 4½" 3' 8"	1' 2½" 5' 8"	1' ½" 21'	0'11" INF	0' 9" INF	0' 7" INF	0' 5" INF	0' 4" INF	4' 3"× 2' 3" 8' 6"× 3' 7"	3' 0"

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

LENS FOCAL LENGTH: **15mm** — CIRCLE OF CONFUSION = .001″ (1/1000″)

HYPER-FOCAL DISTANCE	29.06′	20.76′	14.53′	10.38′	7.27′	5.19″	3.63′	2.64′	1.82′	1.32′	0.91′	FIELD OF VIEW (w/projected image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825″×.446″)	TV HEIGHT (.594″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676″×.700″)	
30	15′ INF	12′ INF	10′ INF	8′ INF	6′ INF	4′ INF	3′ INF	3′ INF	2′ INF	1′ INF	1′ INF	41′10″×22′ 7″ 85′ 0″×35′ 6″	30′ 2″
20	11′10″ 64′	10′ 2″ 547′	8′ INF	7′ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	1′ INF	1′ INF	27′10″×15′ 1″ 56′ 7″×23′ 8″	20′ 1″
15	9′11″ 31′	8′ 9″ 54′	7′ 5″ INF	6′ 2″ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	1′ INF	1′ INF	20′11″×11′ 3″ 42′ 5″×17′ 9″	15′ 0″
10	7′ 5″ 15′ 3″	6′ 9″ 19′ 3″	5′11″ 32′	5′ 1″ 274′	4′ 3″ INF	3′ 5″ INF	2′ 8″ INF	2′ 1″ INF	1′ 6″ INF	1′ 2″ INF	0′10″ INF	13′11″× 7′ 6″ 28′ 3″×11′10″	10′ 0″
8	6′ 3″ 11′ 0″	5′ 9″ 13′ 0″	5′ 2″ 18′	4′ 6″ 35′	3′10″ INF	3′ 2″ INF	2′ 6″ INF	2′ 0″ INF	1′ 6″ INF	1′ 2″ INF	0′10″ INF	11′ 1″× 6′ 0″ 22′ 7″× 9′ 5″	8′ 0″
7	5′ 8″ 9′ 3″	5′ 3″ 10′ 7″	4′ 9″ 13′ 6″	4′ 2″ 21′	3′ 7″ 191′	3′ 0″ INF	2′ 5″ INF	1′11″ INF	1′ 5″ INF	1′ 1″ INF	0′10″ INF	9′ 9″× 5′ 3″ 19′ 8″× 8′ 3″	7′ 0″
6	5′ 0″ 7′ 7″	4′ 8″ 8′ 5″	4′ 3″ 10′ 3″	3′10″ 14′ 3″	3′ 3″ 34′	2′ 9″ INF	2′ 3″ INF	1′10″ INF	1′ 5″ INF	1′ 1″ INF	0′10″ INF	8′ 4″× 4′ 6″ 16′11″× 7′ 1″	6′ 0″
5	4′ 3″ 6′ 0″	4′ ½″ 6′ 7″	3′ 9″ 7′ 7″	3′ 5″ 9′ 8″	3′ 0″ 16′	2′ 7″ 137′	2′ 1″ INF	1′ 9″ INF	1′ 4″ INF	1′ 1″ INF	0′ 9″ INF	6′11″× 3′ 9″ 14′ 1″× 5′11″	5′ 0″
4	3′ 6¼″ 4′ 7½″	3′ 4″ 4′11½″	3′ 1½″ 5′ 6″	2′11″ 6′ 6″	2′ 7″ 8′11″	2′ 3″ 17′	1′11″ INF	1′ 7″ INF	1′ 3″ INF	1′ 0″ INF	0′ 9″ INF	5′ 6″× 3′ 0″ 11′ 3″× 4′ 8″	4′ 0″
3	2′ 8¾″ 3′ 4¼″	2′ 7½″ 3′ 6″	2′ 6″ 3′ 9½″	2′ 4″ 4′ 3″	2′ 1½″ 5′ 1″	1′11″ 7′ 1″	1′ 8″ 17′	1′ 5″ INF	1′ 2″ INF	0′11″ INF	0′ 8″ INF	4′ 1″× 2′ 3″ 8′ 4″× 3′ 6″	3′ 0″
2	1′10½″ 2′ 1¾″	1′ 9¾″ 2′ 2½″	1′ 9″ 2′ 3¾″	1′ 8¼″ 2′ 5¾″	1′ 7″ 2′11″	1′ 5″ 3′ 3″	1′ 4″ 4′ 5″	1′ 2″ 8′ 3″	0′11″ INF	0′10″ INF	0′ 8″ INF	2′ 9″× 1′ 6″ 5′ 7″× 2′ 4″	2′ 0″

LENS FOCAL LENGTH: **20mm**

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .001″ (1/1000″)

HYPER-FOCAL DISTANCE	51.67′	36.90′	25.83′	18.45′	12.92′	9.23′	6.46′	4.70′	3.23′	2.35′	1.61′	FIELD OF VIEW (w/projected image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825″×.446″)	TV HEIGHT (.594″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676″×.700″)	
40	22′ 177′	19′ INF	16′ INF	13′ INF	10′ INF	8′ INF	6′ INF	4′ INF	3′ INF	2′ INF	2′ INF	41′10″×22′ 7″ 85′ 0″×35′ 6″	30′ 2″
30	19′ 72′	17′ 160′	14′ INF	11′ INF	9′ INF	7′ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	31′ 4″×17′ 0″ 63′ 9″×26′ 7″	22′ 7″
20	14′ 5″ 33′	13′ 0″ 44′	11′ 3″ 89′	10′ INF	8′ INF	6′ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	20′11″×11′ 4″ 42′ 5″×17′ 9″	15′ 1″
15	11′ 8″ 21′ 1″	10′ 8″ 25′	9′ 6″ 36′	8′ 3″ 80′	6′11″ INF	5′ 9″ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	15′ 8″× 8′ 6″ 31′10″×13′ 3″	11′ 3″
10	8′ 5″ 12′ 5″	7′10″ 13′ 9″	7′ 3″ 16′ 4″	6′ 6″ 22′	5′ 8″ 44′	4′10″ INF	3′11″ INF	3′ 2″ INF	2′ 5″ INF	1′11″ INF	1′ 5″ INF	10′ 5″× 5′ 8″ 21′ 2″× 8′10″	7′ 6″
8	6′11″ 9′ 6″	6′ 7″ 10′ 3″	6′ 1″ 11′ 7″	5′ 7″ 14′ 2″	4′11″ 21′	4′ 3″ 60′	3′ 7″ INF	3′ 0″ INF	2′ 4″ INF	1′10″ INF	1′ 4″ INF	8′ 4″× 4′ 6″ 16′11″× 7′ 1″	6′ 0″
6	5′ 4½″ 6′ 9½″	5′ 2″ 7′ 2″	4′10″ 7′10″	4′ 6″ 8′11″	4′ 1″ 11′ 2″	3′ 8″ 17′	3′ 1″ 85′	2′ 8″ INF	2′ 1″ INF	1′ 8″ INF	1′ 3″ INF	6′ 3″× 3′ 4″ 12′ 8″× 5′ 3″	4′ 6″
5	4′ 6¾″ 5′ 6″	4′ 5″ 5′ 9″	4′ 2½″ 6′ 2″	3′11″ 6′10″	3′ 7″ 8′ 2″	3′ 3″ 10′11″	2′10″ 22′	2′ 5″ INF	2′ 0″ INF	1′ 7″ INF	1′ 3″ INF	5′ 2″× 2′10″ 10′ 6″× 4′ 5″	3′ 9″
4	3′ 8½″ 4′ 4″	3′ 7¼″ 4′ 5¾″	3′ 5½″ 4′ 9″	3′ 3½ 5′ 1″	3′ ½″ 5′ 9″	2′10″ 7′ 1″	2′ 6″ 10′ 6″	2′ 2″ 27′	1′ 9″ INF	1′ 6″ INF	1′ 2″ INF	4′ 2″× 2′ 3″ 8′ 5″× 3′ 6″	3′ 0″
3	2′10″ 3′ 2¼″	2′ 9¼″ 3′ 3¼″	2′ 8¼″ 3′ 4¾″	2′ 7″ 3′ 7″	2′ 5″ 3′11″	2′ 3″ 4′ 5″	2′ ½″ 5′ 7″	1′10″ 8′ 4″	1′ 7″ 42′	1′ 4″ INF	1′ 1″ INF	3′ 1″× 1′ 8″ 6′ 3″× 2′ 7″	2′ 3″
2	1′11¼″ 2′ 1″	1′10¾″ 2′ 1¼″	1′10¼″ 2′ 2″	1′ 9½″ 2′ 3″	1′ 8¾″ 2′ 4½″	1′ 7¾″ 2′ 6½″	1′ 6¼″ 2′11″	1′ 5″ 3′ 6″	1′ 3″ 5′ 3″	1′ 1″ 13′	0′11″ INF	2′ 0″× 1′ 1″ 4′ 2″× 1′ 9″	1′ 6″

LENS FOCAL LENGTH: 25mm

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .001″ (1/1000″)

HYPER-FOCAL DISTANCE	80.73′	57.66′	40.36′	28.83′	20.18′	14.42′	10.09′	7.34′	5.05′	3.67′	2.52′	FIELD OF VIEW (w/projected image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825″×.446″)	TV HEIGHT (.594″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676″×.700″)	
50	31′ 131′	27′ 376′	22′ INF	18′ INF	14′ INF	11′ INF	8′ INF	6′ INF	5′ INF	3′ INF	2′ INF	41′10″×22′ 7″ 85′ 0″×35′ 6″	30′ 2″
25	19′ 1″ 36′	17′ 5″ 44′	15′ 5″ 65′	13′ 188′	11′ INF	9′ INF	7′ INF	6′ INF	4′ INF	3′ INF	2′ INF	20′11″×11′ 4″ 42′ 5″×17′ 9″	15′ 1″
15	12′ 8″ 18′ 5″	1′11″ 20′ 3″	10′11″ 23′10″	9′10″ 31′	8′ 7″ 58′	7′ 4″ INF	6′ 0″ INF	5′ INF	4′ INF	3′ INF	2′ INF	12′ 6″× 6′ 9″ 25′ 5″×10′ 7″	9′ 0″
12	10′ 5″ 14′ 1″	9′11″ 15′ 2″	9′ 3″ 17′ 1″	8′ 6″ 20′ 7″	7′ 6″ 30′	6′ 7″ 72′	5′ 6″ INF	4′ 7″ INF	3′ 7″ INF	2′10″ INF	2′ 0″ INF	10′ 0″× 5′ 5″ 20′ 4″× 8′ 6″	7′ 2″
10	8′11″ 11′ 5″	8′ 6″ 12′ 1″	8′ 0″ 13′ 3″	7′ 5″ 15′ 4″	6′ 8″ 19′10″	5′11″ 33′	5′ 0″ INF	4′ 3″ INF	3′ 4″ INF	2′ 8″ INF	2′ 0″ INF	8′ 4″× 4′ 6″ 16′11″× 7′ 1″	6′ 0″
8	7′ 3½″ 8′10½″	7′ ½″ 9′ 3″	6′ 8″ 10′ 0″	6′ 3″ 11′ 1″	5′ 9″ 13′ 3″	5′ 2″ 18′ 0″	4′ 6″ 39′	3′10″ INF	3′ 1″ INF	2′ 6″ INF	1′11″ INF	6′ 8″× 3′ 7″ 13′ 6″× 5′ 8″	4′ 9″
6	5′ 7″ 6′ 6″	5′ 5″ 6′ 8½″	5′ 2½″ 7′ 1″	5′ 0″ 7′ 7″	4′ 8″ 8′ 7″	4′ 3″ 10′ 3″	3′ 9″ 14′10″	3′ 4″ 33′	2′ 9″ INF	2′ 3″ INF	1′ 9″ INF	4′ 0″× 2′ 8″ 10′ 1″× 4′ 3″	3′ 7″
5	4′ 8½″ 5′ 4″	4′ 7¼″ 5′ 5¾″	4′ 5½″ 5′ 8½″	4′ 3″ 6′ 1″	4′ 0″ 6′ 8″	3′ 9″ 7′ 8″	3′ 4″ 9′11″	3′ 0″ 16′	2′ 6″ 553′	2′ 1″ INF	1′ 8″ INF	4′ 2″× 2′ 3″ 8′ 5″× 3′ 6″	3′ 0″
4	3′ 9¾″ 4′ 2½″	3′ 9″ 4′ 3½″	3′ 7¾″ 4′ 5¼″	3′ 6″ 4′ 7½″	3′ 4″ 5′ 0″	3′ 1½″ 5′ 6″	2′10″ 6′ 7″	2′ 7″ 8′ 9″	2′ 3″ 19′	1′11″ INF	1′ 7″ INF	3′ 3″× 1′ 9″ 6′ 8″× 2′10″	2′ 4″
3	2′10¾″ 3′ 1½″	2′10¼″ 3′ 2″	2′ 9½″ 3′ 3″	2′ 8¾″ 3′ 4¼″	2′ 7¼″ 3′ 6″	2′ 6″ 3′ 9½″	2′ 3½″ 4′ 3″	2′ 1½″ 5′ 1″	1′11″ 7′ 5″	1′ 8″ 16′	1′ 4″ INF	2′ 5″× 1′ 4″ 5′ 0″× 2′ 1″	1′ 9″
2	1′11½″ 2′ ½″	1′11¼″ 2′ ¾″	1′11″ 2′ 1¼″	1′10½″ 2′ 1¾″	1′ 9¾″ 2′ 2¾″	1′ 9″ 2′ 3¾″	1′ 8″ 2′ 6″	1′ 6¾″ 2′ 9″	1′ 5″ 3′ 4″	1′ 4″ 4′ 5″	1′ 1″ 9′ 8″	1′ 7″× 0′10″ 3′ 3″× 1′ 4″	1′ 2″

LENS FOCAL LENGTH: **35mm**

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .001" (1/1000")

HYPER-FOCAL DISTANCE	158.23'	113.02'	79.11'	56.51'	39.56'	28.26'	19.78'	14.38'	9.89'	7.19'	4.94'	FIELD OF VIEW (w/projected image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825"×.446")	TV HEIGHT (.594")
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676"×.700")	
50	38' 73'	35' 90'	31' 136'	27' 434'	22' INF	18' INF	14' INF	11' INF	8' INF	6' INF	5' INF	29'10"×16' 2" 60' 8"×25' 4"	21' 6"
25	21' 7" 29' 8"	20' 6" 32' 1"	19' 0" 37'	17' 4" 45'	15' 4" 68'	13' 217'	11' INF	9' INF	7' INF	6' INF	4' INF	14'11"× 8' 1" 30' 3"×12' 8"	10' 9"
15	13' 8" 16' 7"	13' 3" 17' 3"	12' 7" 18' 6"	11'10" 20' 5"	10'10" 24' 2"	9'10" 32'	8' 6" 62'	7' 4" INF	6' 0" INF	4'10" INF	3' 8" INF	8'11"× 4'10" 18' 1"× 7' 7"	6' 5"
12	11' 2" 13' 0"	10'10" 13' 5"	10' 5" 14' 2"	9'11" 15' 3"	9' 3" 17' 3"	8' 5" 20'10"	7' 6" 31'	6' 7" 72'	5' 5" INF	4' 6" INF	3' 6" INF	7' 1"× 3'10" 14' 6"× 6' 0"	5' 1"
10	9' 5" 10' 8"	9' 2½" 10'11½"	8'11" 11' 5"	8' 6" 12' 2"	8' 0" 13' 5"	7' 5" 15' 6"	6' 8" 20'	5'11" 33'	5' 0" INF	4' 2" INF	3' 4" INF	5'11"× 3' 2" 12' 1"× 5' 0"	4' 3"
8	7' 7¼" 8' 5¼"	7' 5½" 8' 7½"	7' 3" 8'11"	7' 0" 9' 4"	6' 8" 10' 0"	6' 3" 11' 2"	5' 8" 15' 5"	5' 2" 18'	4' 5" 42'	3' 9" INF	3' 1" INF	4' 9"× 2' 7" 9' 7"× 4' 0"	3' 5"
6	5' 9¼" 6' 3"	5' 8½" 6' 4"	5' 7" 6' 6"	5' 5" 6' 8½"	5' 2½" 7' 1"	4'11" 7' 7"	4' 7" 8' 7"	4' 3" 10' 3"	3' 9" 15' 3"	3' 3" 36'	2' 9" INF	3' 6"× 1'11" 7' 2"× 3' 0"	2' 6"
5	4'10¼" 5' 2"	4' 9½" 5' 2¾"	4' 8½" 5' 4"	4' 7" 5' 6"	4' 5½" 5' 8½"	4' 3" 6' 1"	4' 0" 6' 8"	3' 9" 7' 8"	3' 4" 10' 1"	2'11" 16'	2' 6" INF	2'11"× 1' 7" 5'11"× 2' 6"	2' 1"
4	3'10¾" 4' 1¼"	3'10¼" 4' 1¾"	3' 9¾" 4' 2½"	3' 9" 4' 3½"	3' 7½" 4' 5½"	3' 6" 4' 8"	3' 4" 5' 0"	3' 1½" 5' 6"	2'10" 6' 9"	2' 7" 9' 0"	2' 3" 21'	2' 4"× 1' 3" 4' 9"× 2' 0"	1' 8"
3	2'11¼" 3' ¾"	2'11" 3' 1"	2'10¾" 3' 1½"	2'10¼" 3' 2"	2' 9½" 3' 3"	2' 8½" 3' 4¼"	2' 7¼" 3' 6½"	2' 6" 3' 9½"	2' 3½" 4' 4"	2' 1½" 5' 2"	1'10" 7' 7"	1' 9"× 0'11" 3' 6"× 1' 6"	1' 3"
2	2' 0" 2' ¼"	1'11¾" 2' ½"	1'11½" 2' ½"	1'11¼" 2' ¾"	1'10¾" 2' 1¼"	1'10½" 2' 1¾"	1' 9¾" 2' 2¾"	1' 9" 2' 3¾"	1' 8" 2' 6"	1' 6¾" 2' 9"	1' 5" 3' 4"	1' 2"× 0' 7" 2' 3"× 1' 0"	0'10"

LENS FOCAL LENGTH: **40mm**

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .001" (1/1000")

HYPER-FOCAL DISTANCE	206.67'	147.62'	103.33'	73.81'	51.67'	36.90'	25.83'	18.79'	12.92'	9.39'	6.46'	FIELD OF VIEW (w/projected image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825"×.446")	TV HEIGHT (.594")
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676"×.700")	
50	40' 3" 66'	37' 76'	34' 97'	30' 155'	25' INF	22' INF	17' INF	14' INF	10' INF	8' INF	6' INF	26' 2"×14' 1" 53' 1"×22' 2"	18'10"
25	22' 4" 28' 5"	21' 5" 30' 1"	20' 2" 33' 0"	18' 8" 38'	16'10" 48'	15' 77'	13' 775'	11' INF	9' INF	7' INF	5' INF	13' 0"× 7' 0" 26' 6"×11' 1"	9' 5"
15	14' 0" 16' 2"	13' 8" 16' 8"	13' 1" 17' 6"	12' 6" 18'10"	11' 8" 21' 2"	10' 8" 25'	9' 6" 36'	8' 4" 74'	6'11" INF	5' 9" INF	5' INF	7' 9"× 4' 3" 15'10"× 6' 7"	5' 7"
12	11' 4" 12' 8½"	11' 1" 13' 0"	10' 9" 13' 7"	10' 4" 14' 4"	9' 9" 15' 7"	9' 1" 17' 9"	8' 3" 22'	7' 4" 33'	6' 3" 169'	5' 4" INF	4' 3" INF	6' 3"× 3' 4" 12' 8"× 5' 3"	4' 6"
10	9' 6½" 10' 6"	9' 4½" 10' 8"	9' 1½" 11' 0"	8'10" 11' 7"	8' 5" 12' 5"	7'11" 13' 8"	7' 3" 16' 4"	6' 7" 21'	5' 8" 44'	4'10" INF	3'11" INF	5' 2"× 2' 9" 10' 6"× 4' 5"	3' 9"
8	7' 8½" 8' ¾"	7' 7" 8' 5½"	7' 5" 8' 8"	7' 3" 9' 0"	6'11" 9' 5"	6' 7" 10' 2"	6' 2" 11' 7"	5' 8" 13'11"	5' 0" 21'	4' 4" 54'	3' 7" INF	4' 1"× 2' 3" 8' 4"× 3' 6"	3' 0"
6	5'10" 6' 2"	5' 9¼" 6' 3"	5' 8" 6' 4½"	5' 6¾" 6' 6½"	5' 4½" 6' 9½"	5' 2" 7' 2"	4'11" 7'10"	4' 7" 8'10"	4' 2" 11' 2"	3' 8" 17'	3' 2" 85'	3' 1"× 1' 8" 6' 3"× 2' 7"	2' 3"
5	4'10½" 5' 1½"	4'10¾" 5' 2"	4' 9¼" 5' 3"	4' 8¼" 5' 4¼"	4' 6¾" 5' 6½"	4' 5" 5' 9¼"	4' 2½" 6' 2"	4' 0" 6' 9"	3' 8" 8' 2"	3' 4" 10' 8"	2'10" 22' 1"	2' 7"× 1' 5" 5' 2"× 2' 2"	1'10"
4	3'11" 4' 1"	3'10¾" 4' 1¼"	3'10¼" 4' 1¾"	3' 9½" 4' 2¾"	3' 8½" 4' 4"	3' 7½" 4' 5¾"	3' 5½" 4' 8½"	3' 3¾" 5' 1"	3' 0" 5' 9"	2'10" 6'11"	2' 6" 10' 6"	2' 0"× 1' 1" 4' 1"× 1' 9"	1' 6"
3	2'11½" 3' ½"	2'11¼" 3' ¾"	2'11" 3' 1"	2'10½" 3' 1½"	2'10" 3' 2"	2' 9¼" 3' 3¼"	2' 8¼" 3' 4½"	2' 7¼" 3' 6½"	2' 5¼" 3'11"	2' 3¼" 4' 5"	2' ¼" 5' 7"	1' 6"× 10" 3' 1"× 1' 3"	1' 1"
2	1'11¾" 2' ¼"	1'11¾" 2' ¼"	1'11½" 2' ½"	1'11½" 2' ¾"	1'11¼" 2' 1"	1'10¾" 2' 1¼"	1'10½" 2' 2"	1' 9¾" 2' 2¾"	1' 8¾" 2' 4½"	1' 7¾" 2' 6½"	1' 6½" 2'10¾"	1' 0"× 6" 2' 0"× 10"	8"

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

LENS FOCAL LENGTH: **50mm**

CIRCLE OF CONFUSION = .001″ (1/1000″)

HYPER-FOCAL DISTANCE	322.92′	230.66′	161.46′	115.33′	80.73′	57.66′	40.36′	29.36′	20.18′	14.68′	10.09′	FIELD OF VIEW (w/projected image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825″×.446″)	TV HEIGHT (.594″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676″×.700″)	
50	43′ 4″ 59′ 2″	41′ 1″ 64′	38′ 72′	35′ 88′	31′ 131′	27′ 376′	22′ INF	19′ INF	14′ INF	11′ INF	8′ INF	20′11″×11′ 3″ 42′ 5″×17′ 9″	15′ 0″
25	23′ 2″ 27′ 1″	22′ 7″ 28′ 1″	21′ 8″ 29′ 7″	20′ 7″ 31′11″	19′ 1″ 36′	17′ 5″ 44′	15′ 5″ 66′	14′ 168′	11′ INF	9′ INF	7′ INF	10′ 5″× 5′ 8″ 21′ 2″× 8′10″	7′ 6″
15	14′ 4″ 15′ 9″	14′ 1″ 16′ 0″	13′ 9″ 16′ 6″	13′ 3″ 17′ 3″	12′ 8″ 18′ 5″	11′11″ 20′ 3″	10′11″ 23′10″	9′11″ 31′	8′ 7″ 58′	7′ 5″ INF	6′ 0″ INF	6′ 3″× 3′ 4″ 12′ 8″× 5′ 3″	4′ 6″
12	11′ 6¾″ 12′ 5½″	11′ 5″ 12′ 8″	11′ 2″ 12′11½″	10′10″ 13′ 5″	10′ 5″ 14′ 1″	9′11″ 15′ 2″	9′ 3″ 17′ 1″	8′ 6″ 20′ 4″	7′ 6″ 30′	6′ 7″ 66′	5′ 6″ INF	5′ 0″× 2′ 8″ 10′ 1″× 4′ 3″	3′ 7″
10	9′ 8½″ 10′ 3¾″	9′ 7″ 10′ 5½″	9′ 5″ 10′ 8″	9′ 2½″ 10′11½″	8′11″ 11′ 5″	8′ 6″ 12′ 1″	8′ 0″ 13′ 3″	7′ 6″ 15′ 2″	6′ 8″ 19′10″	5′11″ 31′	5′ 0″ INF	4′ 1″× 2′ 3″ 8′ 4″× 3′ 6″	3′ 0″
8	7′ 9¾″ 8′ 2½″	7′ 8¾″ 8′ 3½″	7′ 7½″ 8′ 5″	7′ 6″ 8′ 7″	7′ 3½″ 8′10½″	7′ ½″ 9′ 3″	6′ 8″ 10′ 0″	6′ 3″ 11′ 0″	5′ 8″ 13′ 3″	5′ 2″ 17′ 7″	4′ 6″ 39′	3′ 3″× 1′ 9″ 6′ 8″× 2′ 9″	2′ 4″
6	5′10¾″ 6′ 1¼″	5′10¼″ 6′ 2″	5′ 9½″ 6′ 2¾″	5′ 8½″ 6′ 4″	5′ 7″ 6′ 5¾″	5′ 5″ 6′ 8½″	5′ 2½″ 7′ 1″	5′ 0″ 7′ 6″	4′ 8″ 8′ 6″	4′ 3″ 10′ 2″	3′ 9″ 14′10″	2′ 5″× 1′ 4″ 5′ 0″× 2′ 1″	1′ 9″
5	4′11″ 5′ 1″	4′10¾″ 5′ 1¼″	4′10¼″ 5′ 2″	4′ 9½″ 5′ 2¾″	4′ 8½″ 5′ 4″	4′ 7″ 5′ 5¾″	4′ 5½″ 5′ 8½″	4′ 3″ 6′ 0″	4′ 0″ 6′ 8″	3′ 9″ 7′ 7″	3′ 4″ 9′11″	2′ 0″× 1′ 1″ 4′ 1″× 1′ 9″	1′ 6″
4	3′11½″ 4′ ½″	3′11¼″ 4′ ¾″	3′10¾″ 4′ 1¼″	3′10½″ 4′ 1¾″	3′ 9¾″ 4′ 2½″	3′ 9″ 4′ 3½″	3′ 7¾″ 4′ 5¼″	3′ 6¼″ 4′ 7½″	3′ 4″ 5′ 0″	3′ 1¾″ 5′ 6″	2′ 10″ 6′ 7″	1′ 7″× 0′10″ 3′ 3″× 1′ 4″	1′ 2″
3	2′11¾″ 3′ ¼″	2′11½″ 3′ ½″	2′11½″ 3′ ¾″	2′11″ 1″	2′10¾″ 3′ 1½″	2′10¼″ 3′ 2″	2′ 9½″ 3′ 3″	2′ 8¾″ 3′ 4″	2′ 7¼″ 3′ 6″	2′ 6″ 3′ 9″	2′ 3½″ 4′ 3″	1′ 2″× 0′ 8″ 2′ 5″× 1′ 0″	0′10″
2	2′ 0″ 2′ 0″	1′11¾″ 2′ ¼″	1′11¾″ 2′ ¼″	1′11¾″ 2′ ½″	1′11½″ 2′ ½″	1′11¼″ 2′ ¾″	1′11″ 2′ 1¼″	1′10½″ 2′ 1¾″	1′ 9¾″ 2′ 2¾″	1′ 9″ 2′ 3¾″	1′ 8″ 2′ 6″	0′ 9″× 0′ 5″ 1′ 7″× 0′ 8″	0′ 7″

LENS FOCAL LENGTH: **85mm**

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .001" (1/1000")

HYPER-FOCAL DISTANCE	933.23'	666.59'	466.62'	333.30'	233.31'	166.65'	116.65'	84.84'	58.33'	42.42'	29.16'	FIELD OF VIEW (w/projected image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825"×.446")	TV HEIGHT (.594")
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676"×.700")	
100	90' 4" 112'	87' 118'	82' 127'	77' 143'	70' 175'	63' 250'	54' 700'	46' INF	37' INF	30' INF	23' INF	24' 7"×13' 3" 49'11"×20'10"	17' 8"
50	47' 6" 52'10"	46' 6" 54' 1"	45' 2" 56' 1"	43' 6" 58'10"	41' 2" 64'	38' 71'	35' 88'	31' 122'	27' 350'	23' INF	18' INF	12' 3"× 6' 8" 24'11"×10' 5"	8'10"
25	24' 4" 25' 8½"	24' 1" 25'11½"	23' 9" 26' 5"	23' 3" 27' 0"	22' 7" 28' 0"	21' 9" 29' 5"	20' 7" 31'10"	19' 4" 35'	17' 6" 44'	15' 9" 61'	13' 175'	6' 1"× 3' 3" 12' 5"× 5' 2"	4' 5"
15	14' 9" 15' 3"	14' 8" 15' 4¼"	14' 6¼" 15' 6"	14' 4" 15' 8½"	14' 1" 16' 0"	13' 9" 16' 6"	13' 4" 17' 3"	12' 9" 18' 3"	11'11" 20' 2"	11' 1" 23' 2"	9'11" 30'11"	3' 8"× 2' 0" 7' 4"× 3' 1"	2' 7"
12	11'10¼" 12' 2"	11' 9½" 12' 2¾"	11' 8½" 12' 3¾"	11' 7" 12' 5½"	11' 5" 12' 8"	11' 2½" 12'11"	10'11" 13' 4"	10' 6" 14' 0"	9'11" 15' 1"	9' 4" 16' 9"	8' 6" 20' 5"	2'11"× 1' 7" 5'10"× 2' 5"	2' 1"
10	9'10¾" 10' 1¼"	9'10¼" 10' 1¾"	9' 9½" 10' 2¾"	9' 8½" 10' 3¾"	9' 7" 10' 5½"	9' 5" 10' 7½"	9' 2½" 10'11½"	8'11" 11' 4"	8' 6" 12' 1"	8' 1" 13' 1"	7' 5" 15' 3"	2' 5"× 1' 4" 4'10"× 2' 0"	1' 9"
8	7'11¼" 8' ¾"	7'11" 8' 1¼"	7'10½" 8' 1¾"	7' 9¾" 8' 2½"	7' 8¾" 8' 3¼"	7' 7½" 8' 4¾"	7' 6" 8' 7"	7' 3½" 8'10"	7' ½" 9' 3"	6' 9" 9'10"	6' 3" 11' 0"	1'11"× 1' 0" 3'10"× 1' 7"	1' 4"
7	6'11½" 7' ½"	6'11¼" 7' ¾"	6'10¾" 7' 1¼"	6'10¼" 7' 1¾"	6' 9½" 7' 2¾"	6' 8¾" 7' 3¾"	6' 7¼" 7' 5½"	6' 5½" 7' 7½"	6' 3" 7'11½"	6' 0" 8' 5"	5' 8" 9' 2"	1' 8"× 0'11" 3' 4"× 1' 5"	1' 2"
6	5'11½" 6' ½"	5'11½" 6' ½"	5'11" 6' 1"	5'10¾" 6' 1¼"	5'10¼" 6' 2"	5' 9½" 6' 2¾"	5' 8½" 6' 4"	5' 7¼" 6' 4"	5' 5½" 6' 8½"	5' 3" 7' 0"	5' 0" 7' 7"	1' 5"× 0' 9" 2'10"× 1' 2"	1' 0"
5	4'11¾" 5' ¼"	4'11½" 5' ½"	4'11½" 5' ½"	4'11¼" 5' 1"	4'10¾" 5' 1¼"	4'10¼" 5' 1¾"	4' 9½" 5' 2¾"	4' 8¾" 5' 3¾"	4' 7¼" 5' 5¾"	4' 5½" 5' 8"	4' 3" 6' 0"	1' 2"× 0' 8" 2' 4"× 1' 0"	0'10"
4	3'11¾" 4' ¼"	3'11¾" 4' ¼"	3'11¾" 4' ¼"	3'11½" 4' ½"	3'11¼" 4' ¾"	3'10¾" 4' 1¼"	3'10½" 4' 1¾"	3' 9¾" 4' 2½"	3' 9" 4' 3½"	3' 8" 4' 5"	3' 6¼" 4' 7½"	0'11"× 0' 6" 1'10"× 0'10"	0' 8"

LENS FOCAL LENGTH: 100mm

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .001" (1/1000")

HYPER-FOCAL DISTANCE	1292'	922.62'	645.83'	461.31'	322.92'	230.66'	161.46'	117.42'	80.73'	58.71'	40.36'	FIELD OF VIEW (w/projected Image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825"×.446")	TV HEIGHT (.594")
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676"×.700")	
100	92'10" 108' 5"	90' 3" 112'	87' 118'	82' 128'	76' 145'	70' 177'	62' 263'	54' 674'	45' INF	37' INF	29' INF	20'11"×11' 3" 42' 5"×17' 9"	15' 0"
50	48' 2" 52' 0"	47' 5" 52'10"	46' 5" 54' 2"	45' 1" 56' 1"	43' 4" 59' 2"	41' 1" 64'	38' 72'	35' 87'	31' 131'	27' 337'	22' INF	10' 5"× 5' 8" 21' 2"× 8'10"	7' 6"
25	24' 6¼" 25' 6"	24' 4" 25' 8½"	24' 1" 26' 0"	23' 9" 26' 5"	23' 2" 27' 1"	22' 7" 28' 0"	21' 8" 29' 7"	20' 7" 31' 9"	19' 1" 36'	17' 6" 44'	15' 5" 66'	5' 2"× 2' 9" 10' 6"× 4' 5"	3' 9"
20	19' 8½" 20' 3¾"	19' 7" 20' 5¼"	19' 5" 20' 7½"	19' 2" 20'11"	18'10" 21' 4"	18' 5" 21'11"	17'10" 22'10"	17' 1" 24' 1"	16' 0" 26' 7"	14'11" 30'	13' 5" 40'	4' 1"× 2' 3" 8' 4"× 3' 6"	3' 0"
15	14'10" 15' 2¼"	14' 9" 15' 3"	14' 8" 15' 4¼"	14' 6¼" 15' 6"	14' 4" 15' 9"	14' 1" 16' 0"	13' 9" 16' 6"	13' 4" 17' 2"	12' 8" 18' 5"	11'11" 20' 2"	10'11" 23'10"	3' 1"× 1' 8" 6' 3"× 2' 7"	2' 3"
12	11'10¾" 12' 1¼"	10'10¼" 12' 2"	11' 9¼" 12' 2¾"	11' 8½" 12' 3¾"	11' 6¾" 12' 5½"	11' 5" 12' 8"	11' 2" 12'11½"	10'11" 13' 4"	10' 5" 14' 1"	10' 0" 15' 1"	9' 3" 17' 1"	2' 5"× 1' 4" 5' 0"× 2' 1"	1' 9"
10	9'11" 10' 1"	9'10¾" 10' 1¼"	9'10¼" 10' 2"	9' 9½" 10' 2¾"	9' 8½" 10' 3¼"	9' 7" 10' 5½"	9' 5" 10' 8"	9' 2½" 10'11"	8'11" 11' 0"	8' 7" 12' 0"	8' 0" 13' 3"	2' 0"× 1' 1" 4' 1"× 1' 9"	1' 6"
8	7'11½" 8' ½"	7'11¼" 8' ¾"	7'10¾" 8' 1¼"	7'10¼" 8' 1¾"	7' 9¼" 8' 2½"	7' 8¾" 8' 3½"	7' 7½" 8' 5"	7' 6" 8' 7"	7' 3½" 8'10½"	7' ½" 9' 3"	6' 8" 10' 0"	1' 7"× 0'10" 3' 3"× 1' 4"	1' 2"
7	6'11½" 7' ½"	6'11½" 7' ½"	6'11" 7' 1"	6'10¾" 7' 1¼"	6'10¼" 7' 2"	6' 9½" 7' 2¾"	6' 8½" 7' 3¾"	6' 7¼" 7' 5¼"	6' 5½" 7' 8"	6' 3" 7'11½"	6' 0" 8' 6"	1' 5"× 0' 9" 2'10"× 1' 2"	1' 0"
6	5'11¾" 6' ¼"	5'11½" 6' ½"	5'11¼" 6' ¾"	5'11" 6' 1"	5'10¾" 6' 1¼"	5'10¼" 6' 2"	5' 9½" 6' 2¾"	5' 8½" 6' 3¾"	5' 7" 6' 5¾"	5' 5½" 6' 8"	5' 2½" 7' 1"	1' 2"× 0' 8" 2' 5"× 1' 0"	0'10"
5	4'11¾" 5' ¼"	4'11¾" 5' ¼"	4'11½" 5' ½"	4'11½" 5' ½"	4'11" 5' 1"	4'10¾" 5' 1¼"	4'10¼" 5' 2"	4' 9½" 5' 2¾"	4' 8½" 5' 4"	4' 7¼" 5' 5¾"	4' 5½" 5' 8½"	1' 0"× 0' 6" 2' 0"× 0'10"	0' 8"

LENS FOCAL LENGTH: **150mm**

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .001" (1/1000")

HYPER-FOCAL DISTANCE	2906'	2076'	1453'	1038'	726.6'	519.0'	363.3'	264.2'	181.6'	132.1'	90.82'	FIELD OF VIEW (w/projected image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825"×.446")	TV HEIGHT (.594")
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676"×.700")	
150	142' 8" 158' 2"	140' 162'	136' 167'	131' 175'	124' 189'	116' 211'	106' 255'	96' 347'	82' 861'	70' INF	57' INF	20'11"×11' 3" 42' 5"×17' 9"	15' 0"
100	96' 8" 103' 7"	95' 5" 105' 1"	93' 7" 107' 5"	91' 3" 111'	88' 116'	84' 124'	78' 138'	73' 161'	65' 222'	57' 412'	48' INF	13'11"× 7' 6" 28' 3"×11'10"	10' 0"
75	73' 1" 77' 0"	72' 5" 77'10"	71' 4" 79' 1"	69'11" 80'10"	68' 0" 83' 8"	65' 6" 88'	62' 95'	58' 105'	53' 128'	48' 174'	41' 431'	10' 5"× 5' 8" 21' 2"× 8'10"	7' 6"
50	49' 2" 50'10½"	48'10" 51' 3"	48' 4" 51' 9"	47' 8" 52' 6"	46' 9" 53' 8"	45' 7" 55' 4"	43'11" 58' 0"	42' 1" 62'	39' 69'	36' 80'	32' 111'	6'11"× 3' 9" 14' 1"× 5'10"	5' 0"
25	24' 9½" 25' 2¾"	24' 8½" 25' 3½"	24' 7" 25' 5¼"	24' 5" 25' 7½"	24' 2" 25'10½"	23'10" 26' 3"	23' 5" 26'10"	22'10" 27' 7"	22' 0" 29' 0"	21' 0" 30'10"	19' 7" 34' 6"	3' 5"× 1'10" 7' 0"× 2'11"	2' 6"
20	19'10¼" 20' 1¾"	19' 9¾" 20' 2¼"	19' 8¾" 20' 3¼"	19' 7½" 20' 4¾"	19' 5½" 20' 7"	19' 3" 20' 9½"	19' 0" 21' 2"	18' 7" 21' 8"	18' 0" 22' 6"	17' 4" 23' 7"	16' 5" 25' 8"	2' 9"× 1' 6" 5' 6"× 2' 4"	2' 0"
18	17'10¾" 18' 1¼"	7'10¼" 18' 2"	17' 9¼" 18' 2¾"	17' 8¼" 18' 3¾"	17' 6¾" 18' 5½"	17' 5" 18' 8"	17' 2" 18'11½"	16'10" 19' 4"	16' 5" 20' 0"	15'10" 20'10"	15' 0" 22' 5"	2' 5"× 1' 4" 5' 0"× 2' 1"	1' 9"
15	14'11" 15' 1"	14'10¾" 15' 1¼"	14'10¼" 15' 2"	14' 9½" 15' 2¾"	14' 8½" 15' 4"	14' 7" 15' 5½"	14' 5" 15' 8"	14' 2½" 15'11"	13'10" 16' 4"	13' 6" 16'11"	12'11" 18' 0"	2' 0"× 1' 1" 4' 1"× 1' 9"	1' 6"
12	11'11½" 12' ½"	11'11¼" 12' ¾"	11'10¾" 12' 1¼"	11'10¼" 12' 1¾"	11' 9¾" 12' 2½"	11' 8¾" 12' 3¼"	11' 7½" 12' 5"	11' 6" 12' 7"	11' 3" 12'10"	11' 0" 13' 2"	10' 7" 13'10"	1' 7"× 0'10" 3' 3"× 1' 4"	1' 2"
10	9'11¾" 10' ¼"	9'11½" 10' ½"	9'11¼" 10' ¾"	9'10¾" 10' 1¼"	9'10¼" 10' 1¾"	9' 9¾" 10' 2½"	9' 8¾" 10' 3¼"	9' 7¾" 10' 4¾"	9' 6" 10' 7"	9' 3½" 10'10"	9' 0" 11' 3"	1' 4"× 0' 9" 2' 8"× 1' 2"	1' 0"
8	7'11¾" 8' ¼"	7'11¾" 8' ¼"	7'11½" 8' ½"	7'11¼" 8'10¾"	7'11" 8' 1"	7'10½" 8' 1½"	7'10" 8' 2¼"	7' 9" 8' 3"	7' 8" 8' 4½"	7' 6½" 8' 6"	7' 4" 8' 9"	1' 1"× 0' 7" 2' 2"× 0'11"	0' 9"

LENS FOCAL LENGTH: **200mm**

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .001″ (1/1000″)

HYPER-FOCAL DISTANCE	5167′	3690′	2583′	1845′	1292′	922.62′	645.83′	469.70′	322.92′	234.85′	161.46′	FIELD OF VIEW (w/projected Image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825″×.446″)	TV HEIGHT (.594″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676″×.700″)	
200	192′ 7″ 208′ 1″	190′ 211′	186′ 217′	180′ 224′	173′ 237′	164′ 255′	153′ 290′	140′ 348′	124′ 525′	108′ INF	89′ INF	20′11″×11′ 3″ 42′ 5″×17′ 9″	15′ 0″
100	98′ 1″ 102′ 0″	97′ 4″ 102′ 9″	96′ 3″ 104′ 0″	94′10″ 105′ 9″	92′10″ 108′ 5″	90′ 3″ 112′	87′ 118′	82′ 127′	76′ 145′	70′ 174′	62′ 263′	10′ 5″× 5′ 8″ 21′ 2″× 8′10″	7′ 6″
75	73′11″ 76′ 1″	73′ 6″ 76′ 7″	72′10″ 77′ 3″	72′ 1″ 78′ 2″	70′11″ 79′ 7″	69′ 4″ 81′ 8″	67′ 2″ 84′10″	65′ 89′	61′ 98′	57′ 110′	51′ 140′	7′ 9″× 4′ 3″ 15′10″× 6′ 7″	5′ 7″
50	49′ 6¼″ 50′ 6″	49′ 4″ 50′ 8½″	49′ ½″ 51′ 0″	48′ 8″ 51′ 5″	48′ 2″ 52′ 0″	47′ 5″ 52′10″	46′ 5″ 54′ 2″	45′ 2″ 56′ 0″	43′ 4″ 59′ 2″	41′ 3″ 64′	38′ 72′	5′ 2″× 2′ 9″ 10′ 6″× 4′ 5″	3′ 9″
25	24′10½″ 25′ 1½″	24′10″ 25′ 2″	24′ 9″ 25′ 3″	24′ 8″ 25′ 4″	24′ 6¼″ 25′ 6″	24′ 4″ 25′ 8½″	24′ 1″ 26′ 0″	23′ 9″ 26′ 5″	23′ 2″ 27′ 1″	22′ 7″ 28′ 0″	21′ 7″ 29′ 7″	2′ 7″× 1′ 5″ 5′ 2″× 2′ 2″	1′10″
20	19′11″ 20′ 1″	19′10¾″ 20′ 1¼″	19′10¼″ 20′ 2″	19′ 9½″ 20′ 2¾″	19′ 8½″ 20′ 3¾″	19′ 7″ 20′ 5¼″	19′ 5″ 20′ 7½″	19′ 2″ 20′10½″	18′10″ 21′ 4″	18′ 5″ 21′10″	17′10″ 22′10″	2′ 0″× 1′ 1″ 4′ 1″× 1′ 9″	1′ 6″
18	17′11¼″ 18′ ¾″	17′11″ 18′ 1″	17′10¼″ 18′ 1½″	17′10″ 18′ 2¼″	17′ 9″ 18′ 3″	17′ 8″ 18′ 4¼″	17′ 6″ 18′ 6″	17′ 4″ 18′ 8½″	17′ ½″ 19′ 1″	16′ 9″ 19′ 6″	16′ 2″ 20′ 3″	1′10″× 1′ 0″ 3′ 8″× 1′ 6″	1′ 4″
15	14′11½″ 15′ ½″	14′11¼″ 15′ ¾″	14′11″ 15′ 1″	14′10″ 15′ 1½″	14′ 9″ 15′ 2¼″	14′ 8″ 15′ 3″	14′ 6½″ 15′ 4¼″	14′ 4″ 15′ 6″	14′ 1″ 15′ 9″	14′ 16′ 0″	13′ 9″ 16′ 6″	1′ 6″× 0′10″ 3′ 1″× 1′ 3″	1′ 1″
12	11′11¾″ 12′ ¼″	11′11½″ 12′ ½″	11′11¼″ 12′ ¾″	11′11″ 12′ 1″	11′10¾″ 12′ 1¼″	11′10¼″ 12′ 2″	11′ 9¼″ 12′ 2¾″	11′ 8½″ 12′ 3¾″	11′ 6¾″ 12′ 5½″	11′ 5″ 12′ 8″	11′ 2″ 12′11½″	1′ 2″× 0′ 8″ 2′ 5″× 1′ 0″	0′10″
10	9′11¾″ 10′ ¼″	9′11¾″ 10′ ¼″	9′11½″ 10′ ½″	9′11½″ 10′ ½″	9′11″ 10′ 1″	9′10¾″ 10′ 1¼″	9′10¼″ 10′ 2″	9′ 9½″ 10′ 2¾″	9′ 8½″ 10′ 3¾″	9′ 7″ 10′ 5¼″	9′ 5″ 10′ 8″	1′ 0″× 0′ 6″ 2′ 0″× 0′10″	0′ 8″
8	8′ 0″ 8′ 0″	7′11¾″ 8′ ¼″	7′11¾″ 8′ ¼″	7′11¾″ 8′ ¼″	7′11½″ 8′ ½″	7′11¼″ 8′ ¾″	7′10¾″ 8′ 1¼″	7′10½″ 8′ 1¾″	7′ 9¾″ 8′ 2½″	7′ 9″ 8′ 3¼″	7′ 7½″ 8′ 5″	0′ 9″× 0′ 5″ 1′ 7″× 0′ 8″	0′ 7″

LENS FOCAL LENGTH: **400mm**

35mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .001" (1/1000")

HYPER-FOCAL DISTANCE	20,667'	14,762'	10,333'	7381'	5167'	3690'	2583'	1879'	1292'	939.4'	645.8'	FIELD OF VIEW (w/projected Image)	
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	1.85:1 AR (.825"×.446")	TV HEIGHT (.594")
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	ANA 2.39:1 AR (1.676"×.700")	
400	392' 5" 407'11"	389' 411'	385' 416'	379' 423'	371' 434'	361' 449'	346' 473'	330' 508'	305' 579'	281' 697'	247' INF	20'11"×11' 3" 42' 5"×17' 9"	15' 0"
200	198' 1" 202' 0"	197' 4" 202' 9"	196' 2" 204' 0"	194' 9" 205' 7"	197' 7" 208' 1"	190' 211'	186' 217'	181' 224'	173' 237'	165' 254'	153' 290'	10' 5"× 5' 8" 21' 2"× 8'10"	7' 6"
150	148'11" 151' 1"	148' 6" 151' 6"	147'10" 152' 2"	147' 0" 153' 1"	145' 9" 154' 6"	144' 2" 156' 4"	141' 9" 159' 3"	139' 163'	134' 170'	129' 178'	122' 195'	7' 9"× 4' 3" 15'10"× 6' 7"	5' 7"
100	99' 6¼" 100' 6"	99' 4" 100' 8"	99' ½" 101' 0"	98' 8" 101' 4"	98' 1" 102' 0"	97' 4" 102' 9"	96' 3" 104' 0"	94'11" 105' 8"	92'10" 108' 5"	90' 5" 112'	87' 118'	5' 2"× 2' 9" 10' 6"× 4' 5"	3' 9"
75	74' 8¾" 75' 3¼"	74' 7½" 75' 4½"	74' 5½" 75' 6½"	74' 3" 75' 9"	73'11" 76' 1"	73' 6" 76' 7"	72'11" 77' 3"	72' 2" 78' 1"	70'11" 79' 7"	69' 6" 81' 6"	67' 2" 84'10"	3'10"× 2' 1" 7'10"× 3' 3"	2' 9"
50	49'10½" 50' 1½"	49'10" 50' 2"	49' 9" 50' 3"	49' 8" 50' 4"	49' 6¼" 50' 6"	49' 4" 50' 8½"	49' ½" 51' 0"	48' 8" 51' 4"	48' 2" 52' 0"	47' 6" 52'10"	46' 5" 54' 2"	2' 7"× 1' 5" 5' 2"× 2' 2"	1'10"
35	34'11¼" 35' ¾"	34'11" 35' 1"	34'10½" 35' 1½"	34'10" 35' 2"	34' 9" 35' 3"	34' 8" 35' 4"	34' 6¼" 35' 5¾"	34' 4½" 35' 8"	34' 1" 35'11½"	33' 9" 36' 4"	33' 2" 37' 0"	1' 9"× 0'11" 3' 7"× 1' 6"	1' 3"
25	24'11¾" 25' ¼"	24'11½" 25' ½"	24'11¼" 25' ¾"	24'11" 25' 1"	24'10½" 25' 1½"	24'10" 25' 2"	24' 9" 25' 3"	24' 8" 25' 4"	24' 6¼" 25' 6"	24' 4" 25' 8"	24' 1" 26' 0"	1' 3"× 0' 8" 2' 6"× 1' 1"	0'11"
20	19'11¾" 20' ¼"	19'11¾" 20' ¼"	19'11½" 20' ½"	19'11½" 20' ½"	19'11" 20' 1"	19'10¾" 20' 1¼"	19'10¼" 20' 2"	19' 9½" 20' 2¾"	19' 8½" 20' 3¾"	19' 7" 20' 5¼"	19' 5" 20' 7½"	1' 0"× 0' 6" 2' 0"× 0'10"	0' 8"
18	17'11¾" 18' ¼"	17'11¾" 18' ¼"	17'11¾" 18' ¼"	17'11½" 18' ½"	17'11¼" 18' ¾"	17'11" 18' 1"	17'10½" 18' 1½"	17'10" 18' 2"	17' 9" 18' 3"	17' 8" 18' 4¼"	17' 6" 18' 6"	0'10"× 0' 6" 1' 9"× 0' 9"	0' 8"
15	15' 0" 15' 0"	14'11¾" 15' ¼"	14'11¾" 15' ¼"	14'11¾" 15' ¼"	14'11½" 15' ½"	14'11¼" 15' ¾"	14'11" 15' 1"	14'10½" 15' 1½"	14'10" 15' 2¼"	14' 9" 15' 3"	14' 8" 15' 4¼"	0' 9"× 0' 5" 1' 6"× 0' 7"	0' 6"

16mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

LENS FOCAL LENGTH: **8mm**

CIRCLE OF CONFUSION = .0006″ (6/10,000″)

HYPER-FOCAL DISTANCE	13.78′	9.84′	6.89′	4.92′	3.44′	2.46′	1.72′	1.25′	0.86′	0.63′	0.43′	FIELD OF VIEW (w/projected Image)
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	STD & TV (.380″×.286″) SUPER 16 1.85:1 AR (.463″×.251″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	
25	9′ INF	7′ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	1′ INF	1′ INF	1′ INF	0′ INF	30′ 2″×22′ 8″ 36′ 9″×19′11″
15	7′ 2″ INF	5′ 11″ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	1′ INF	1′ INF	1′ INF	0′ INF	18′ 1″×13′ 7″ 22′ 1″×11′11″
8	5′ 1″ 19′	4′ 5″ 43′	3′ 8″ INF	3′ 1″ INF	2′ 5″ INF	1′11″ INF	1′ 5″ INF	1′ 1″ INF	0′ 9″ INF	0′ 7″ INF	0′ 5″ INF	9′ 7″× 7′ 3″ 11′ 9″× 6′ 4″
6	4′ 2″ 10′ 7″	3′ 9″ 15′ 4″	3′ 3″ 46′	2′ 8″ INF	2′ 2″ INF	1′ 9″ INF	1′ 4″ INF	1′ 0″ INF	0′ 9″ INF	0′ 7″ INF	0′ 5″ INF	7′ 3″× 5′ 5″ 8′ 9″× 4′ 9″
4	3′ 1″ 5′ 8″	2′10″ 6′ 9″	2′ 6″ 9′ 7″	2′ 3″ 21′	1″10″ INF	1′ 6″ INF	1′ 2″ INF	0′11″ INF	0′ 9″ INF	0′ 7″ INF	0′ 5″ INF	4′10″× 3′ 7″ 5′10″× 3′ 2″
3	2′ 5½″ 3′10″	2′ 3½″ 4′ 4″	2′ 1″ 5′ 4″	1′10″ 7′ 8″	1′ 7″ 23′	1′ 4″ INF	1′ 1″ INF	0′11″ INF	0′ 8″ INF	0′ 6″ INF	0′ 5″ INF	3′ 7″× 2′ 8″ 4′ 5″× 2′ 4″
2	1′ 9″ 2′ 4″	1′ 8″ 2′ 6″	1′ 6½″ 2′10″	1′ 5″ 3′ 4″	1′ 3″ 4′ 9″	1′ 1″ 10′ 8″	0′11″ INF	0′ 9″ INF	0′ 7″ INF	0′ 6″ INF	0′ 4′ INF	2′ 5″× 1′10″ 2′11″× 1′ 7″
1.5	1′ 4¼″ 1′ 8¼″	1′ 3½″ 1′ 9¼″	1′ 2¾″ 1′11″	1′ 1¾″ 2′ 2″	1′ ½″ 2′ 8″	0″11″ 3′10″	0′ 9½″ 12′	0′ 8″ INF	0′ 6½″ INF	0′ 5″ INF	0′ 4″ INF	1′ 9″× 1′ 4″ 2′ 2″× 1′ 2″
1	0′11¾″ 1′ 1″	0′11″ 1′ 1¼″	0′10½″ 1′ 2″	0′10″ 1′ 3″	0′ 9¼″ 1′ 5″	0′ 8½″ 1′ 8¼″	0′ 7½″ 2′ 5″	0′ 6¾″ 5′ 0″	0′ 5½″ INF	0′ 4½″ INF	0′ 3½″ INF	1′ 2″× 0′11″ 1′ 5″× 0′ 9″

16mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

LENS FOCAL LENGTH: 9.5mm — **CIRCLE OF CONFUSION = .0006″ (6/10,000″)**

HYPER-FOCAL DISTANCE	19.43′	13.88′	9.71′	6.94′	4.86′	3.47′	2.43′	1.77′	1.21′	0.88′	0.61′	FIELD OF VIEW (w/projected Image)
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	STD & TV (.380″×.286″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	SUPER 16 1.85:1 AR (.463″×.251″)
25	12′ INF	9′ INF	7′ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	1′ INF	1′ INF	1′ INF	25′ 4″×19′ 1″ 30′11″×16′ 9″
15	8′ 6″ 66′	7′ 3″ INF	5′11″ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	1′ INF	1′ INF	1′ INF	15′ 3″×11′ 5″ 18′ 6″×10′ 1″
8	5′ 8″ 13′ 7″	5′ 1″ 19′	4′ 5″ 45′	3′ 9″ INF	3′ 0″ INF	2′ 5″ INF	1′10″ INF	1′ 5″ INF	1′ 0″ INF	0′10″ INF	0′ 7″ INF	8′ 1″× 6′ 1″ 9′10″× 5′ 4″
6	4′ 7″ 8′ 8″	4′ 2″ 10′ 7″	3′ 9″ 15′ 8″	3′ 3″ 44′	2′ 8″ INF	2′ 2″ INF	1′ 9″ INF	1′ 4″ INF	1′ 0″ INF	0′ 9″ INF	0′ 7″ INF	6′ 1″× 4′ 7″ 7′ 5″× 4′ 0″
4	3′ 4″ 5′ 0″	3′ 1½″ 5′ 7″	2′10″ 6′10″	2′ 6″ 9′ 5″	2′ 2″ 23′	1′10″ INF	1′ 6″ INF	1′ 3″ INF	0′11″ INF	0′ 9″ INF	0′ 6″ INF	4′ 0″× 3′ 0″ 4′11″× 2′ 8″
3	2′ 7¼″ 3′ 6½″	2′ 5¼″ 3′10″	2′ 3½″ 4′ 4″	2′ 1″ 5′ 3″	1′10″ 7′10″	1′ 7″ 22′	1′ 4″ INF	1′ 1″ INF	0′10″ INF	0′ 8″ INF	0′ 6″ INF	3′ 0″× 2′ 3″ 3′ 8″× 2′ 0″
2	1′ 9¾″ 2′ 2¾″	1′ 9″ 2′ 4″	1′ 8″ 2′ 6″	1′ 6½″ 2′ 9½″	1′ 5″ 3′ 5″	1′ 3″ 4′ 9″	1′ 1″ 11′ 4″	0′11″ INF	0′ 9″ INF	0′ 7″ INF	0′ 6″ INF	2′ 0″× 1′ 6″ 2′ 5″× 1′ 4″
1.5	1′ 4¾″ 1′ 7½″	1′ 4¼″ 1′ 8¼″	1′ 3½″ 1′ 9¼″	1′ 2¾″ 1′11″	1′ 1¾″ 2′ 2″	1′ ½″ 2′ 7½″	0′11″ 3′ 1″	0′ 9½″ 9′11″	0′ 8″ INF	0′ 6½″ INF	0′ 5″ INF	1′ 6″× 1′ 1″ 1′10″× 1′ 0″
1	0′11½″ 1′ ½″	0′11¼″ 1′ 1″	0′11″ 1′ 1¼″	0′10½″ 1′ 2″	0′ 10″ 1′ 3″	0′ 9¼″ 1′ 4¾″	0′ 8½″ 1′ 8½″	0′ 7¾″ 2′ 4″	0′ 6½″ 5′ 8″	0′ 5½″ INF	0′ 4½″ INF	1′ 0″× 0′ 9″ 1′ 3″× 0′ 8″

LENS FOCAL LENGTH: 12mm

16mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .0006″ (6/10,000″)

HYPER-FOCAL DISTANCE	31.00′	22.14′	15.50′	11.07′	7.75′	5.54′	3.88′	2.82′	1.94′	1.41′	0.97′	FIELD OF VIEW (w/projected Image)
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	STD & TV (.380″×.286″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	SUPER 16 1.85:1 AR (.463″×.251″)
25	14′ 129′	12′ INF	10′ INF	8′ INF	6′ INF	5′ INF	3′ INF	3′ INF	2′ INF	1′ INF	1′ INF	20′ 1″×15′ 1″ 24′ 6″×13′ 3″
15	10′ 1″ 29′	8′11″ 46′	7′ 8″ 465′	6′ 4″ INF	5′ 1″ INF	4′ INF	3′ INF	2′ INF	2′ INF	1′ INF	1′ INF	12′ 0″× 9′ 1″ 14′ 8″× 7′11″
8	6′ 4″ 10′ 9″	5′11″ 12′ 6″	5′ 3″ 16′ 6″	4′ 8″ 29′	3′11″ INF	3′ 3″ INF	2′ 7″ INF	2′ 0″ INF	1′ 7″ INF	1′ 0″ INF	0′10″ INF	6′ 5″× 4′10″ 7′10″× 4′ 3″
6	5′ ½″ 7′ 5″	4′ 9″ 8′ 3″	4′ 4″ 9′ 9″	3′11″ 13′ 1″	3′ 5″ 27′	2′11″ INF	2′ 4″ INF	1′11″ INF	1′ 6″ INF	1′ 0″ INF	0′10″ INF	4′10″× 3′ 7″ 5′10″× 3′ 2″
4	3′ 6½″ 4′ 7″	3′ 4½″ 4′10½″	3′ 2″ 5′ 5″	2′11″ 6′ 3″	2′ 8″ 8′ 3″	2′ 4″ 14′	2′ 0″ INF	1′ 8″ INF	1′ 4″ INF	1′ 0″ INF	0′ 9″ INF	3′ 2″× 2′ 5″ 3′11″× 2′ 1″
3	2′ 9″ 3′ 3¾″	2′ 7¾″ 3′ 5¾″	2′ 6″ 3′ 8½″	2′ 4½″ 4′ 1″	2′ 2″ 4′11″	1′11″ 6′ 7″	1′ 8″ 13′	1′ 5″ INF	1′ 2″ INF	1′ 0″ INF	0′ 9″ INF	2′ 5″× 1′ 9″ 2′11″× 1′ 7″
2	1′10½″ 2′ 1¾″	1′10″ 2′ 2½″	1′ 9¼″ 2′ 3½″	1′ 8¼″ 2′ 5¼″	1′ 7″ 2′ 8½″	1′ 5½″ 3′ 2″	1′ 4″ 4′ 2″	1′ 2″ 6′11″	1′ 0″ INF	0′10″ INF	0′ 8″ INF	1′ 7″× 1′ 2″ 1′11″× 1′ 0″
1.5	1′ 5¼″ 1′ 7″	1′ 4¾″ 1′ 7¼″	1′ 4½″ 1′ 8″	1′ 3¾″ 1′ 9″	1′ 3″ 1′10¼″	1′ 2¼″ 2′ ½″	1′ 1″ 2′ 5½″	1′ 0″ 3′ 2″	0′10″ 6′ 8″	0′ 9″ INF	0′ 7″ INF	1′ 2″× 0′11″ 1′ 5″× 0′ 9″
1	0′11¾″ 1′ ¼″	0′11½″ 1′ ½″	0′11¼″ 1′ ¾″	0′11″ 1′ 1¼″	0′ 10¾″ 1′ 1¾″	0′10¼″ 1′ 2¾″	0′ 9½″ 1′ 4¼″	0′ 9″ 1′ 6½″	0′ 8″ 2′ 1″	0′ 7″ 3′ 5″	0′ 6″ INF	0′ 9″× 0′ 7″ 0′11″× 0′ 6″

16mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

LENS FOCAL LENGTH: **16mm** — CIRCLE OF CONFUSION = .0006″ (6/10,000″)

HYPER-FOCAL DISTANCE	55.11′	39.37′	27.56′	19.68′	13.78′	9.84′	6.89′	5.01′	3.44′	2.51′	1.72′	FIELD OF VIEW (w/projected image)
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	STD & TV (.380″×.286″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	SUPER 16 1.85:1 AR (.463″×.251″)
50	26′ 539′	22′ INF	18′ INF	14′ INF	11′ INF	8′ INF	6′ INF	5′ INF	3′ INF	2′ INF	2′ INF	30′ 2″×22′ 8″ 36′ 9″×19′11″
25	17′ 2″ 46′	15′ 4″ 69′	13′ 270′	11′ INF	9′ INF	7′ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	15′ 1″×11′ 4″ 18′ 4″× 9′11″
15	12′ 0″ 20′ 7″	10′10″ 24′ 3″	9′ 9″ 33′	8′ 6″ 63′	7′ 2″ INF	5′11″ INF	5′ INF	4′ INF	3′ INF	2′ INF	2′ INF	9′ 0″× 6′ 9″ 11′ 0″× 6′ 0″
10	8′ 6″ 12′ 3″	8′ 0″ 13′ 5″	7′ 4″ 15′ 8″	6′ 8″ 20′	5′10″ 36′	5′ 0″ INF	4′ 1″ INF	3′ 4″ INF	2′ 7″ INF	2′ 0″ INF	1′ 6″ INF	6′ 0″× 4′ 6″ 7′ 4″× 4′ 0″
8	7′ 0″ 9′ 4″	6′ 8″ 10′ 0″	6′ 2″ 11′ 3″	5′ 8″ 13′ 6″	5′ 1″ 19′	4′ 5″ 43′	3′ 8″ INF	3′ 1″ INF	2′ 5″ INF	1′11″ INF	1′ 5″ INF	4′ 9″× 3′ 7″ 5′10″× 3′ 2″
6	5′ 5″ 6′ 9″	5′ 2½″ 7′ 1″	4′11″ 7′ 8″	4′ 7″ 8′ 8″	4′ 2″ 10′ 7″	3′ 9″ 15′ 4″	3′ 3″ 46′	2′ 9″ INF	2′ 2″ INF	1′ 9″ INF	1′ 4″ INF	3′ 7″× 2′ 8″ 4′ 4″× 2′ 4″
5	4′ 7″ 5′ 6″	4′ 5½″ 5′ 9″	4′ 3″ 6′ 1″	4′ 0″ 6′ 8″	3′ 8″ 7′10″	3′ 4″ 10′ 2″	2′11″ 18′	2′ 6″ INF	2′ 1″ INF	1′ 8″ INF	1′ 34″ INF	3′ 0″× 2′ 3″ 3′ 8″× 2′ 0″
4	3′ 8¾″ 4′ 3¾″	3′ 7½″ 4′ 5½″	3′ 6″ 4′ 8″	3′ 4″ 5′ 0″	3′ 1″ 5′ 8″	2′10″ 6′ 9″	2′ 6″ 9′ 7″	2′ 3″ 20′	1′10″ INF	1′ 7″ INF	1′ 2″ INF	2′ 5″× 1′ 9″ 2′11″× 1′ 7″
3	2′10¼″ 3′ 2″	2′ 9½″ 3′ 3″	2′ 8½″ 3′ 4½″	2′ 7¼″ 3′ 6½″	2′ 5½″ 3′10″	2′ 3½″ 4′ 4″	2′ 1″ 5′ 4″	1′11″ 7′ 6″	1′ 7″ 23′	1′ 4″ INF	1′ 1″ INF	1′ 9″× 1′ 4″ 2′ 2″× 1′ 2″
2	1′11¼″ 2′ 1″	1′10¾″ 2′ 1¼″	1′10¼″ 2′ 2″	1′ 9¾″ 2′ 2¾″	1′ 9″ 2′ 4″	1′ 8″ 2′ 6″	1′ 6½″ 2′10″	1′ 5″ 3′ 4″	1′ 3″ 4′ 9″	1′ 1½″ 9′11″	0′11″ INF	1′ 2″× 0′11″ 1′ 5″× 0′ 9″

16mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

LENS FOCAL LENGTH: **25mm** CIRCLE OF CONFUSION = .0006″ (6/10,000″)

HYPER-FOCAL DISTANCE	134.6′	96.11′	62.27′	48.05′	33.64′	24.03′	16.82′	12.23′	8.41′	6.12′	4.20′	FIELD OF VIEW (w/projected image)
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	STD & TV (.380″×.286″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	SUPER 16 1.85:1 AR (.463″×.251″)
50	36′ 80′	33′ 104′	29′ 195′	25′ INF	20′ INF	16′ INF	13′ INF	10′ INF	7′ INF	5′ INF	4′ INF	19′ 3″×14′ 6″ 23′ 6″×12′ 9″
25	21′ 1″ 30′ 8″	19′10″ 33′ 9″	18′ 3″ 40′	16′ 5″ 52′	14′ 98′	12′ INF	10′ INF	8′ INF	6′ INF	5′ INF	4′ INF	9′ 7″× 7′ 3″ 11′ 9″× 6′ 4″
15	13′ 6″ 16′11″	13′ 0″ 17′ 9″	12′ 3″ 19′ 4″	11′ 5″ 21′10″	10′ 5″ 27′	9′ 3″ 40′	7′11″ 139′	6′ 9″ INF	5′ 5″ INF	4′ INF	3′ INF	5′ 9″× 4′ 4″ 7′ 0″× 3′10″
10	9′ 3½″ 10′ 9½″	9′ ½″ 11′ 2″	8′ 9″ 11′ 9″	8′ 3″ 12′ 7″	7′ 9″ 14′ 3″	7′ 1″ 17′ 2″	6′ 3″ 25′	5′ 6″ 55′	4′ 7″ INF	3′10″ INF	3′ 0″ INF	3′10″× 2′11″ 4′ 8″× 2′ 6″
8	7′ 6½″ 8′ 6″	7′ 4½″ 8′ 9″	7′ 2″ 9′ 1″	6′10″ 9′ 7″	6′ 6″ 10′ 6″	6′ 0″ 12′ 0″	5′ 5″ 15′ 3″	4′10″ 23′	4′ 1″ 164′	3′ 6″ INF	2′ 9″ INF	3′ 1″× 2′ 4″ 3′ 9″× 2′ 0″
6	5′ 9″ 6′ 3¼″	5′ 7¾″ 6′ 4¾″	5′ 6″ 6′ 7″	5′ 4″ 6′10½″	5′ 1″ 7′ 4″	4′10″ 8′ 0″	4′ 5″ 9′ 4″	4′ 0″ 11′ 9″	3′ 6″ 21′	3′ 0″ 317′	2′ 6″ INF	2′ 3″× 1′ 9″ 2′ 9″× 1′ 6″
5	4′ 9¾″ 5′ 2¼″	4′ 9″ 5′ 3¼″	4′ 7¾″ 5′ 4¾″	4′ 6¼″ 5′ 7″	4′ 4″ 5′10½″	4′ 1½″ 6′ 4″	3′10″ 7′ 1″	3′ 7″ 8′ 5″	3′ 2″ 12′ 4″	2′ 9″ 27′	2′ 3″ INF	1′11″× 1′ 5″ 2′ 4″× 1′ 3″
4	3′10½″ 4′ 1½″	3′10″ 4′ 2″	3′ 9¼″ 4′ 3″	3′ 8¼″ 4′ 4¼″	3′ 6¾″ 4′ 6½″	3′ 5″ 4′ 9½″	3′ 3″ 5′ 3″	3′ 0″ 5′11″	2′ 9″ 7′ 8″	2′ 5″ 11′ 7″	2′ 1″ 82′	1′ 6″× 1′ 2″ 1′10″× 1′ 0″
3	2′11¼″ 3′ ¾″	2′11″ 3′ 1¼″	2′10½″ 3′ 1¾″	2′ 9¾″ 3′ 2½″	2′ 9″ 3′ 3½″	2′ 8″ 3′ 5¼″	2′ 6½″ 3′ 8″	2′ 5″ 3′11½″	2′ 2½″ 4′ 8″	2′ 0″ 5′11″	1′ 9″ 10′ 6″	1′ 2″× 0′10″ 1′ 4″× 0′ 9″
2	1′11¾″ 2′ ¼″	1′11½″ 2′ ½″	1′11¼″ 2′ ¾″	1′11″ 2′ 1″	1′10¾″ 2′ 1½″	1′10¼″ 2′ 2¼″	1′ 9¼″ 2′ 3¼″	1′ 8¾″ 2′ 4¾″	1′ 7½″ 2′ 7½″	1′ 6″ 2′11½″	1′ 4½″ 3′10″	0′ 9″× 0′ 7″ 0′11″× 0′ 6″

LENS FOCAL LENGTH: **35mm**

16mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .0006″ (6/10,000″)

HYPER-FOCAL DISTANCE	263.7′	188.4′	131.9′	94.18′	65.93′	47.09′	32.96′	23.97′	16.48′	12.0′	8.24′	FIELD OF VIEW (w/projected image)
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	STD & TV (.380″×.286″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	SUPER 16 1.85:1 AR (.463″×.251″)
50	42′ 0″ 62′	40′ 68′	36′ 81′	33′ 107′	28′ 207′	24′ INF	20′ INF	16′ INF	12′ INF	10′ INF	7′ INF	13′ 9″×10′ 4″ 16′ 9″× 9′ 1″
25	22′10″ 27′ 7″	22′ 1″ 28′10″	21′ 0″ 30′10″	19′ 9″ 34′ 0″	18′ 2″ 40′	16′ 4″ 53′	14′ 104′	12′ INF	10′ INF	8′ INF	6′ INF	6′10″× 5′ 2″ 8′ 4″× 4′ 6″
15	14′ 2½″ 15′11″	13′11″ 16′ 4″	13′ 6″ 16′11″	12′11″ 17′10″	12′ 3″ 19′ 5″	11′ 5″ 22′ 0″	10′ 4″ 28′	9′ 3″ 40′	7′10″ 167′	6′ 8″ INF	5′ INF	4′ 2″× 3′ 1″ 5′ 0″× 2′ 9″
10	9′ 7½″ 10′ 4¾″	9′ 6″ 10′ 6½″	9′ 3½″ 10′10″	9′ ½″ 11′ 2″	8′ 8″ 11′ 9″	8′ 3″ 12′ 8″	7′ 8″ 14′ 4″	7′ 1″ 17′ 2″	6′ 3″ 25′	5′ 5″ 60′	4′ 6″ INF	2′ 9″× 2′ 1″ 3′ 4″× 1′10″
8	7′ 9″ 8′ 3″	7′ 8″ 8′ 4¼″	7′ 6½″ 8′ 6″	7′ 4½″ 8′ 9″	7′ 1½″ 9′ 1″	6′10″ 9′ 7″	6′ 5″ 10′ 7″	6′ 0″ 12′ 0″	5′ 5″ 15′ 6″	4′10″ 24′	4′ 1″ 273′	2′ 2″× 1′ 8″ 2′ 8″× 1′ 5″
6	5′10½″ 6′ 1¾″	5′ 9¾″ 6′ 2½″	5′ 9″ 6′ 3½″	5′ 7¾″ 6′ 5″	5′ 6″ 6′ 7″	5′ 4″ 6′10″	5′ 1″ 7′ 4″	4′10″ 8′ 0″	4′ 5″ 9′ 5″	4′ 0″ 12′ 0″	5′ 6″ 22′	1′ 7″× 1′ 3″ 2′ 0″× 1′ 1″
5	4′11″ 5′ 1¼″	4′10½″ 5′ 1¾″	4′ 9¾″ 5′ 2½″	4′ 9″ 5′ 3¼″	4′ 7¾″ 5′ 5″	4′ 6¼″ 5′ 7″	4′ 4″ 5′10½″	4′ 1½″ 6′ 4″	3′10″ 7′ 2″	3′ 6″ 8′ 7″	3′ 1″ 12′ 9″	1′ 4″× 1′ 0″ 1′ 8″× 0′11
4	3′11¼″ 4′ ¾″	3′11″ 4′ 1″	3′10½″ 4′ 1½″	3′10″ 4′ 2¼″	3′ 9¼″ 4′ 3″	3′ 8¼″ 4′ 4½″	3′ 6¾″ 4′ 6½″	3′ 5″ 4′ 9½″	3′ 2½″ 5′ 3″	3′ 0″ 6′ 0″	2′ 8″ 7′ 9″	1′ 1″× 0′10″ 1′ 4″× 0′ 9″
3	2′11¾″ 3′ ¼″	2′11½″ 3′ ½″	2′11¼″ 3′ ¾″	2′11″ 3′ 1¼″	2′10½″ 3′ 1¾″	2′ 9¾″ 3′ 2½″	2′ 9″ 3′ 3½″	2′ 8″ 3′ 5¼″	2′ 6½″ 3′ 8″	2′ 5″ 4′ 0″	2′ 2½″ 4′ 9″	0′10″× 0′ 7″ 1′ 0″× 0′ 6″
2	1′11¾″ 2′ ¼″	1′11¾″ 2′ ¼″	1′11¾″ 2′ ¼″	1′11½″ 2′ ½″	1′11¼″ 2′ ¾″	1′11″ 2′ 1″	1′10¾″ 2′ 1½″	1′10¼″ 2′ 2¼″	1′ 9¼″ 2′ 3¼″	1′ 8½″ 2′ 4¾″	1′ 7¼″ 2′ 7½″	0′ 6″× 0′ 5″ 0′ 8″× 0′ 4″

LENS FOCAL LENGTH: **50mm**

16mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .0006″ (6/10,000″)

HYPER-FOCAL DISTANCE	538.2′	384.4′	269.1′	192.2′	134.6′	96.11′	67.27′	48.93′	33.64′	24.46′	16.82′	FIELD OF VIEW (w/projected image)
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	STD & TV (.380″×.286″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	SUPER 16 1.85:1 AR (.463″×.251″)
50	45′ 9″ 55′ 1″	44′ 3″ 57′ 6″	42′ 2″ 61′	40′ 68′	36′ 80′	33′ 104′	29′ 195′	25′ INF	20′ INF	16′ INF	13′ INF	9′ 7″×7′ 3″ 11′ 9″×6′ 4″
25	23′11″ 26′ 3″	23′ 6″ 26′ 9″	22′11″ 22′ 7″	22′ 2″ 28′ 9″	21′ 1″ 30′ 8″	19′10″ 33′ 9″	18′ 3″ 40′	16′ 7″ 51′	14′ 97′	12′ INF	10′ INF	4′ 9″×3′ 7″ 5′10″×3′ 2″
15	14′ 7″ 15′ 5¼″	14′ 5½″ 15′ 7½″	14′ 2½″ 15′10½″	13′11″ 16′ 3″	13′ 6″ 16′11″	13′ 0″ 17′ 9″	12′ 3″ 19′ 4″	11′ 6″ 21′ 8″	10′ 5″ 27′	9′ 4″ 39′	7′11″ 139′	2′10″×2′ 2″ 3′ 6″×1′11″
10	9′ 9¾″ 10′ 2¼″	9′ 9″ 10′ 3½″	9′ 7¾″ 10′ 4¾″	9′ 6″ 10′ 6½″	9′ 3½″ 10′ 9½″	9′ ½″ 11′ 2″	8′ 9″ 11′ 9″	8′ 4″ 12′ 7″	7′ 9″ 14′ 3″	7′ 1″ 16′11″	6′ 3″ 25′	1′11″×1′ 5″ 2′ 4″×1′ 3″
8	7′10½″ 8′ 1½″	7′10″ 8′ 2″	7′ 9¼″ 8′ 3″	7′ 8¼″ 8′ 4¼″	7′ 6½″ 8′ 6″	7′ 4½″ 8′ 9″	7′ 2″ 9′ 1″	6′11″ 9′ 7″	6′ 6″ 10′ 6″	6′ 0″ 11′11″	5′ 5″ 15′ 3″	1′ 6″×0′ 2″ 1′10″×1′ 0″
6	5′11¼″ 6′ ¾″	5′11″ 6′ 1¼″	5′10½″ 6′ 1¾″	5′ 9¾″ 6′ 2¼″	5′ 9″ 6′ 3¼″	5′ 7¾″ 6′ 4¾″	5′ 6″ 6′ 7″	5′ 4″ 6′10″	5′ 1″ 7′ 4″	4′10″ 7′11″	4′ 5″ 9′ 4″	1′ 2″×0′10″ 1′ 4″×0′ 9″
5	4′11½″ 5′ ½″	4′11¼″ 5′ ¾″	4′11″ 5′ 1″	4′10½″ 5′ 1½″	4′ 9¾″ 5′ 2¼″	4′ 9″ 5′ 3¼″	4′ 7¾″ 5′ 4¾″	4′ 6½″ 5′ 7″	4′ 4″ 5′10½″	4′ 2″ 6′ 3″	3′10″ 7′ 1″	0′11″×0′ 8″ 1′ 2″×0′ 7″
4	3′11¾″ 4′ ¼″	3′11½″ 4′ ½″	3′11¼″ 4′ ¾″	3′11″ 4′ 1″	3′10½″ 4′ 1½″	3′10″ 4′ 2″	3′ 9¼″ 4′ 3″	3′ 8½″ 4′ 4¼″	3′ 6¾″ 4′ 6½″	3′ 5½″ 4′ 9½″	3′ 2¾″ 5′ 3″	0′ 9″×0′ 7″ 0′11″×0′ 6″
3	2′11¾″ 3′ ¼″	2′11¾″ 3′ ¼″	2′11¾″ 3′ ¼″	2′11½″ 3′ ½″	2′11¼″ 3′ ¾″	2′11″ 3′ 1¼″	2′10½″ 3′ 1¾″	2′10″ 3′ 2½″	2′ 9″ 3′ 3½″	2′ 8″ 3′ 5″	2′ 6½″ 3′ 8″	0′ 7″×0′ 5″ 0′ 8″×0′ 4″
2	2′ 0″ 2′ 0″	2′ 0″ 2′ 0″	2′ 0″ 2′ 0″	1′11¾″ 2′ ¼″	1′11¾″ 2′ ¼″	1′11½″ 2′ ½″	1′11¼″ 2′ ¾″	1′11″ 2′ 1″	1′10¾″ 2′ 1½″	1′10¼″ 2′ 2¼″	1′ 9½″ 2′ 3¼″	0′ 4″×0′ 3″ 0′ 5″×0′ 3″

LENS FOCAL LENGTH: **85mm**

16mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .0006″ (6/10,000″)

HYPER-FOCAL DISTANCE	1555′	1111′	778.7′	555.5′	389.9′	277.8′	194.4′	141.4′	97.21′	70.70′	48.61′	FIELD OF VIEW (w/projected image)
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	STD & TV (.380″×.286″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	SUPER 16 1.85:1 AR (.463″×.251″)
100	94′ 0″ 106′10″	91′ 9″ 109′11″	89′ 115′	85′ 122′	80′ 135′	74′ 156′	66′ 206′	59′ 342′	49′ INF	41′ INF	33′ INF	11′ 4″×8′ 6″ 13′10″×7′ 6″
50	48′ 5″ 51′ 8″	47′10″ 52′ 4″	47′ 0″ 53′ 5″	45′11″ 54′11″	44′ 4″ 57′ 4″	42′ 5″ 61′	40′ 67′	37′ 77′	33′ 103′	29′ 171′	25′ INF	5′ 8″×4′ 3″ 6′11″×3′ 9″
25	24′ 7¼″ 25′ 5″	24′ 5½″ 25′ 7″	24′ 2½″ 25′10″	23′11″ 26′ 2″	23′ 6″ 26′ 9″	22′11″ 27′ 6″	22′ 2″ 28′ 8″	21′ 3″ 30′ 4″	19′11″ 33′ 8″	18′ 6″ 39′	16′ 6″ 51′	2′10″×2′ 1″ 3′ 5″×1′10″
15	14′10¼″ 15′ 1¾″	14′ 9½″ 15′ 2½″	14′ 8¾″ 15′ 3½″	14′ 7¼″ 15′ 5″	14′ 5½″ 15′ 7″	14′ 3″ 15′10½″	13′11″ 16′ 3″	13′ 7″ 16′ 9″	13′ 0″ 17′ 9″	12′ 5″ 19′ 0″	11′ 6″ 21′ 8″	1′ 8″×1′ 3″ 2′ 0″×1′ 1″
10	9′11¼″ 10′ ¾″	9′11″ 10′ 1″	9′10½″ 10′ 1½″	9′ 9¾″ 10′ 2¼″	9′ 9″ 10′ 3″	9′ 7¾″ 10′ 4½″	9′ 6″ 10′ 6½″	9′ 4″ 10′ 9″	9′ ¾″ 11′ 2″	8′ 9″ 11′ 8″	8′ 4″ 12′ 8″	1′ 1″×0′10″ 1′ 4″×0′ 8″
8	7′11½″ 8′ ½″	7′11¼″ 8′ ¾″	7′11″ 8′ 1″	7′10¾″ 8′ 1½″	7′10″ 8′ 2″	7′ 9¼″ 8′ 3″	7′ 8¼″ 8′ 4″	7′ 6¾″ 8′ 5¾″	7′ 4½″ 8′ 8½″	7′ 2½″ 9′ 0″	6′10″ 9′ 7″	0′ 1″×0′ 8″ 1′ 1″×0′ 7″
7	6′11¾″ 7′ ¼″	6′11″ 7′ ½″	6′11¼″ 7′ ¾″	6′11″ 7′ 1″	6′10½″ 7′ 1½″	6′10″ 7′ 2¼″	6′ 9″ 7′ 3″	6′ 8″ 7′ 4¼″	6′ 6¼″ 7′ 6½″	6′ 4½″ 7′ 9″	6′ 1½″ 8′ 2″	0′ 9″×0′ 7″ 0′11″×0′ 6″
6	5′11¾″ 6′ ¼″	5′11¾″ 6′ ¼″	5′11½″ 6′ ½″	5′11¼″ 6′ ¾″	5′11″ 6′ 1″	5′10½″ 6′ 1½″	5′ 9¾″ 6′ 2¼″	5′ 9″ 6′ 3¼″	5′ 7¾″ 6′ 4¾″	5′ 6¼″ 6′ 6½″	5′ 4″ 6′10″	0′ 8″×0′ 6″ 0′ 9″×0′ 5″
5	4′11¾″ 5′ ¼″	4′11¾″ 5′ ¼″	4′11¾″ 5′ ¼″	4′11½″ 5′ ½″	4′11¼″ 5′ ¾″	4′11″ 5′ 2¼″	4′10½″ 5′ 1½″	4′10″ 5′ 2¼″	4′ 9″ 5′ 3¼″	4′ 8″ 5′ 4½″	4′ 6¼″ 5′ 7″	0′ 6″×0′ 5″ 0′ 8″×0′ 4″
4	4′ 0″ 4′ 0″	4′ 0″ 4′ 0″	3′11¾″ 4′ ¼″	3′11¾″ 4′ ¼″	3′11½″ 4′ ½″	3′11¼″ 4′ ¾″	3′11″ 4′ 1″	3′10¾″ 4′ 1½″	3′10″ 4′ 2″	3′ 9½″ 4′ 3″	3′ 8½″ 4′ 4¼″	0′ 5″×0′ 4″ 0′ 6″×0′ 3″

LENS FOCAL LENGTH: 100mm — **16mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW** — CIRCLE OF CONFUSION = .0006″ (6/10,000″)

HYPER-FOCAL DISTANCE	2153′	1538′	1076′	768.9′	538.2′	384.4′	269.1′	196.8′	134.6′	97.85′	67.27′	FIELD OF VIEW (w/projected Image)
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	STD & TV (.380″×.286″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	SUPER 16 1.85:1 AR (.463″×.251″)
200	183′ 220′	177′ 230′	169′ 246′	159′ 270′	146′ 318′	132′ 417′	115′ 779′	99′ INF	80′ INF	66′ INF	50′ INF	19′ 3″×14′ 6″ 23′ 6″×12′ 9″
100	95′ 7″ 104′10″	93′11″ 106′11″	91′ 6″ 110′	88′ 115′	84′ 123′	79′ 135′	73′ 159′	66′ 204′	57′ 389′	49′ INF	40′ INF	9′ 7″× 7′ 3″ 11′ 9″× 6′ 4″
50	48′10″ 51′ 2″	48′ 5″ 51′ 8″	47′ 9″ 52′ 5″	47′ 0″ 53′ 6″	45′ 9″ 55′ 1″	44′ 3″ 57′ 6″	42′ 2″ 61′	40′ 67′	36′ 80′	33′ 103′	29′ 195′	4′ 9″× 3′ 7″ 5″10″× 3′ 2″
25	24′ 8½″ 25′ 3½″	24′ 7¼″ 25′ 5″	24′ 5″ 25′ 7″	24′ 2½″ 25′10″	23′11″ 26′ 3″	23′ 6″ 26′ 9″	22′11″ 27′ 7″	22′ 2″ 28′ 8″	21′ 1″ 30′ 8″	19′11″ 33′ 7″	18′ 3″ 40′	2′ 5″× 1′ 9″ 2′11″× 1′ 7″
15	14′10¾″ 15′ 1¼″	14′10¼″ 15′ 1¾″	14′ 9½″ 15′ 2½″	14′ 8½″ 15′ 3½″	14′ 7″ 15′ 5¼″	14′ 5½″ 15′ 7¼″	14′ 2½″ 15′10¾″	13′11″ 16′ 3″	13′ 6″ 16′11″	13′ 0″ 17′ 9″	12′ 3″ 19′ 4″	1′ 5″× 1′ 1″ 1′ 9″× 0′11″
10	9′11½″ 10′ ½″	9′11¼″ 10′ ¾″	9′11″ 10′ 1″	9′10½″ 10′ 1½″	9′ 9¾″ 10′ 2¼″	9′ 9″ 10′ 3¼″	9′ 7¾″ 10′ 4¾″	9′ 6″ 10′ 6½″	9′ 3½″ 10′ 9½″	9′ 1″ 11′ 2″	8′ 9″ 11′ 9″	0′11″× 0′ 8″ 1′ 2″× 0′ 7″
8	7′11¾″ 8′ ¼″	7′11½″ 8′ ½″	7′11¼″ 8′ ¾″	7′11″ 8′ 1″	7′10½″ 8′ 1½″	7′10″ 8′ 2″	7′ 9¼″ 8′ 3″	7′ 8¼″ 8′ 4″	7′ 6½″ 8′ 6″	7′ 5″ 8′ 8½″	7′ 2″ 9′ 1″	0′ 9″× 0′ 7″ 0′11″× 0′ 6″
6	5′11¾″ 6′ ¼″	5′11¾″ 6′ ¼″	5′11¾″ 6′ ¼″	5′11½″ 6′ ½″	5′11¼″ 6′ ¾″	5′11″ 6′ 1¼″	5′10½″ 6′ 1¾″	5′ 9¾″ 6′ 2¼″	5′ 9″ 6′ 3¼″	5′ 7¾″ 6′ 4¾″	5′ 6″ 6′ 7″	0′ 7″× 0′ 5″ 0′ 8″× 0′ 4″

LENS FOCAL LENGTH: **135mm**

16mm CAMERA DEPTH-OF-FIELD, HYPERFOCAL DISTANCE & FIELD OF VIEW

CIRCLE OF CONFUSION = .0006″ (6/10,000″)

HYPER-FOCAL DISTANCE	3923′	2802′	1962′	1401′	980.9′	700.6′	490.4′	356.7′	245.2′	178.3′	122.6′	FIELD OF VIEW (w/projected image)
	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	STD & TV (.380″×.286″)
LENS FOCUS (FEET)	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	NEAR FAR	SUPER 16 1.85:1 AR (.463″×.251″)
200	190′ 4″ 211′	187′ 215′	182′ 223′	175′ 233′	166′ 251′	156′ 280′	142′ 338′	128′ 455′	110′ INF	94′ INF	76 INF	14′ 3″×10′ 9″ 17′ 5″× 9′ 5″
100	97′ 6″ 102′ 7″	96′ 7″ 103′ 8″	95′ 2″ 105′ 4″	93′ 4″ 107′ 8″	90′ 9″ 111′	88′ 117′	83′ 126′	78′ 139′	71′ 169′	64′ 228′	55′ 542′	7′ 1″× 5′ 4″ 8′ 8″× 4′ 8″
50	49′ 4½″ 50′ 8″	49′ 1½″ 50′11″	48′ 9″ 51′ 4″	48′ 3″ 51′10″	47′ 7″ 52′ 8″	46′ 8″ 53′10″	45′ 5″ 55′ 8″	43′10″ 58′ 2″	41′ 6″ 63′	39′ 70′	36′ 84′	3′ 6″× 2′ 8″ 4′ 4″× 2′ 4″
25	24′10″ 25′ 2″	24′ 9¼″ 25′ 2¾″	24′ 8¼″ 25′ 3¾″	24′ 6¾″ 25′ 5½″	24′ 4½″ 25′ 8″	24′ 1½″ 25′11″	23′ 9″ 26′ 4″	23′ 4″ 26′11″	22′ 8″ 27′10″	21′11″ 29′ 1″	20′ 9″ 31′ 5″	1′ 9″× 1′ 4″ 2′ 2″× 1′ 2″
15	14′11¼″ 15′ ¾″	14′11″ 15′ 1″	14′10¾″ 15′ 1½″	14′10″ 15′ 2″	14′ 9¼″ 15′ 2¾″	14′ 8¼″ 15′ 4″	14′ 6½″ 15′ 5¾″	14′ 4½″ 15′ 8″	14′ 1½″ 16′ 0″	13′10″ 16′ 4″	13′ 4″ 17′ 1″	1′ 0″× 0′ 9″ 1′ 3″× 0′ 8″
10	9′11¾″ 10′ ¼″	9′11½″ 10′ ½″	9′11½″ 10′ ½″	9′11¼″ 10′ ¾″	9′10¾″ 10′ 1¼″	9′10¼″ 10′ 1¾″	9′ 9½″ 10′ 2½″	9′ 8¾″ 10′ 3½″	9′ 7¼″ 10′ 5¼″	9′ 5½″ 10′ 7″	9′ 3″ 10′10½″	0′ 8″× 0′ 6″ 0′10″× 0′ 5″
8	7′11¾″ 8′ ¼″	7′11¾″ 8′ ¼″	7′11¾″ 8′ ¼″	7′11½″ 8′ ½″	7′11¼″ 8′ ¾″	7′11″ 8′ 1″	7′10½″ 8′ 1½″	7′ 9¾″ 8′ 2¼″	7′ 9″ 8′ 3¼″	7′ 8″ 8′ 4½″	7′ 6″ 8′ 6½″	0′ 6″× 0′ 5″ 0′ 8″× 0′ 4″
6	6′ 0″ 6′ 0″	6′ 0″ 6′ 0″	5′11¾″ 6′ ¼″	5′11¾″ 6′ ¼″	5′11½″ 6′ ½″	5′11½″ 6′ ½″	5′11¼″ 6′ ¾″	5′10¾″ 6′ 1¼″	5′10¼″ 6′ 1¾″	5′ 9½″ 6′ 2½″	5′ 8¾″ 6′ 3¾″	0′ 5″× 0′ 4″ 0′ 6″× 0′ 3″

VistaVision Lens Table

Focal length mm	Horizontal		Vertical		Equivalent focal lengths for other formats for same field of view			
					Horizontal		Vertical	
	Angle degrees	Field of View @100′	Angle degrees	Field of View @100′	1.85:1 (.825″)	Ana (2x.838″)	1.85:1 (.446″)	Ana (.700″)
28mm	67.9°	134.7′	48.4°	89.9′	16mm	32mm	13mm	20mm
35	56.6	107.8	39.6	71.9	19	40	16	25
50	41.3	75.4	28.3	50.3	28	56	21	35
85	25	44.4	16.8	29.6	47	96	38	60
100	21.4	37.7	14.3	25.2	56	113	45	71
150	14.3	25.1	9.6	16.8	83	169	68	106

Field of view at other distances is proportional (28mm at 43′ is 134.7′x.43 = 57.9′). VistaVision field of view is based on full negative aperture (.991″x1.485″) since it is primarily used for special effects. Other formats are projection apertures.

(The depth-of-field, lens angle and field-of-view tables were computed by Michael Whitney and Philip Chen of Digital Productions and edited by Percy Angress.)

VERTICAL ANGLE VS. EFFECTIVE FOCAL LENGTH
(Focal Length in Millimeters)

TRANSMITTED OR PROJECTED IMAGE	0.189″	0.260″	0.375″	0.500″	0.158″	0.286″	0.251″	0.446″	0.594″	0.700″	0.991″	0.870″
ANGLE (DEGREES)	TV ½″ TUBE	TV ⅔″ TUBE	TV 1″ TUBE	TV 1¼″ TUBE	SUPER -8	16mm	SUPER -16 1.85:1 AR	35mm 1.85:1 AR	35mm TV TRANS	35mm ANA	35mm VISTA	65mm
0.5	550	757	1091	1445	460	832	731	1298	1729	2037	2884	2532
0.7	393	541	780	1039	328	595	522	927	1235	1455	2060	1809
1	275	378	546	728	230	416	365	649	864	1019	1442	1266
1.5	183	252	364	485	153	277	244	433	576	679	961	844
2	138	189	273	364	115	208	183	325	432	509	721	633
2.5	110	151	218	291	92	166	146	260	346	407	577	506
3	92	126	182	242	77	139	122	216	288	339	481	422
3.5	79	108	156	208	66	119	104	185	247	291	412	362
4	69	95	136	182	57	104	91	162	216	255	360	316
4.5	61	84	121	162	51	92	81	144	192	226	320	281
5	55	76	109	145	46	83	73	130	173	204	288	253
6	46	63	91	121	38	69	61	108	144	170	240	211
7	39	54	78	104	33	59	52	93	123	145	206	181
8	34	47	68	91	29	52	46	81	108	127	180	158
9	30	42	61	81	25	46	41	72	96	113	160	140
10	27	38	54	73	23	42	36	65	86	102	144	126
15	18	25	36	48	15	28	24	43	57	68	96	84
20	14	19	27	36	11	21	18	32	43	50	71	63
25	11	15	21	29	9	16	14	26	34	40	57	50
30	9	12	18	24	7	14	12	21	28	33	47	41
35	8	10	15	20	6	12	10	18	24	28	40	35
40	7	9	13	17	6	10	9	16	21	24	35	30
45	6	8	11	15	5	9	8	14	18	21	30	27
50	5	7	10	14	4	8	7	12	16	19	27	24
55	5	6	9	12	4	7	6	11	15	17	24	21
60	4	6	8	11	3	6	6	10	13	15	22	19
65	4	5	7	10	3	6	5	9	12	14	20	17
70	3	5	7	9	3	5	5	8	11	13	18	16
75	3	4	6	8	3	5	4	7	10	12	16	14
80	3	4	6	8	2	4	4	7	9	11	15	13
85	3	4	5	7	2	4	3	6	8	10	14	12
90	2	3	5	6	2	4	3	6	8	9	13	11
95	2	3	4	6	2	3	3	5	7	8	12	10
100	2	3	4	5	2	3	3	5	6	7	11	9

HORIZONTAL ANGLE VS. EFFECTIVE FOCAL LENGTH (Focal Length in Millimeters)

TRANS-MITTED OR PROJECTED IMAGE	0.252"	0.346"	0.5"	0.667"	0.209"	0.380"	0.463"	0.825"	1.676"	1.485"	1.912"
ANGLE (Degrees)	TV ½" TUBE	TV ⅔" TUBE	TV 1" TUBE	TV 1¼" TUBE	SUPER-8	16mm	SUPER-16 1.85:1 AR	35mm 1.85:1 AR	35mm ANA	35mm VISTA	65mm
0.5	733	1007	1455	1941	608	1106	1348	2401	4878	4322	5565
0.7	524	719	1039	1387	435	790	963	1715	3484	3087	3975
1	367	504	728	971	304	553	674	1201	2439	2161	2782
1.5	244	336	485	647	203	369	449	800	1626	1441	1855
2	183	252	364	485	152	276	337	600	1219	1081	1391
2.5	147	201	291	388	122	221	269	480	975	864	1113
3	122	168	242	323	101	184	225	400	813	720	927
3.5	105	144	208	277	87	158	192	343	697	617	795
4	92	126	182	243	76	138	168	300	610	540	695
4.5	81	112	162	216	68	123	150	267	542	480	618
5	73	101	145	194	61	111	135	240	488	432	556
6	61	84	121	162	51	92	112	200	406	360	463
7	52	72	104	138	43	79	96	171	348	308	397
8	46	63	91	121	38	69	84	150	304	270	347
9	41	56	81	108	34	61	75	133	270	240	309
10	37	50	73	97	30	55	67	120	243	216	278
15	24	33	45	64	20	37	45	80	162	143	184
20	18	25	36	48	15	27	33	59	121	107	138
25	14	20	29	38	12	22	27	47	96	85	110
30	12	16	24	32	10	18	22	39	79	70	91
35	10	14	20	27	8	15	19	33	68	60	77
40	9	12	17	23	7	13	16	29	58	52	67
45	8	11	15	20	6	12	14	25	51	46	59
50	7	9	14	18	6	10	13	22	46	40	52
55	6	8	12	16	5	9	11	20	41	36	47
60	6	8	11	15	5	8	10	18	37	33	42
65	5	7	10	13	4	8	9	16	33	30	38
70	5	6	9	12	4	7	8	15	30	27	35
75	4	6	8	11	3	6	8	14	28	25	32
80	4	5	8	10	3	6	7	12	25	22	29
85	3	5	7	9	3	5	6	11	23	21	26
90	3	4	6	8	3	5	6	10	21	19	24
95	3	4	6	8	2	4	5	10	20	17	22
100	3	4	5	7	2	4	5	9	18	16	20

Extreme Close Up
35mm DEPTH of FIELD and EXPOSURE FACTOR
vs.
Magnification or Field of View

Circle of Confusion = 0.001″

Magnification Ratio		Field of View 1.85:1 AR	DEPTH OF FIELD (Total: front + back, in inches)											Exposure Increase Factor	T-Stop Increase
Dec.	Frac.		f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32		
0.100	1/10	4.46″×8.25″	0.22″	0.31″	0.44″	0.62″	0.88″	1.23″	1.76″	2.42″	3.52″	4.84″	7.04″	1.21	.27
0.111	1/9	4.01×7.43	0.18	0.25	0.36	0.51	0.72	1.01	1.44	1.98	2.89	3.97	5.77	1.23	.30
0.125	1/8	3.57×6.6	0.14	0.20	0.29	0.40	0.58	0.81	1.15	1.58	2.30	3.17	4.61	1.27	⅓
0.143	1/7	3.12×5.78	0.11	0.16	0.22	0.31	0.45	0.63	0.89	1.23	1.79	2.46	3.58	1.31	.39
0.167	1/6	2.68×4.95	0.08	0.12	0.17	0.23	0.34	0.47	0.67	0.92	1.34	1.84	2.68	1.36	.45
0.200	1/5	2.23×4.12	0.06	0.08	0.12	0.17	0.24	0.34	0.48	0.66	0.96	1.32	1.92	1.44	.53
0.250	1/4	1.78×3.3	0.04	0.06	0.08	0.11	0.16	0.22	0.32	0.44	0.64	0.88	1.28	1.56	⅔
0.333	1/3	1.34×2.48	0.02	0.03	0.05	0.07	0.09	0.14	0.19	0.26	0.38	0.53	0.77	1.78	.83
0.500	1/2	.89×1.65	0.012	0.017	0.02	0.03	0.05	0.07	0.10	0.13	0.19	0.26	0.38	2.25	1⅓
0.667	2/3	.67×1.24	0.007	0.010	0.015	0.02	0.03	0.04	0.06	0.08	0.12	0.17	0.24	2.78	1.47
0.750	3/4	.59×1.10	0.006	0.009	0.012	0.017	0.03	0.04	0.05	0.07	0.10	0.14	0.20	3.06	1⅔
0.875	7/8	.51× .94	0.005	0.007	0.010	0.014	0.02	0.03	0.04	0.05	0.08	0.11	0.16	3.52	1.81
1.0	1/1	.45× .83	0.004	0.006	0.008	0.011	0.016	0.03	0.03	0.04	0.06	0.09	0.13	4.0	2.0

Extreme Close Up
16mm DEPTH of FIELD and EXPOSURE FACTOR
vs.
Magnification or Field of View

Circle of Confusion = 0.0006″

Magnification Ratio		Field of View (projected Image)		DEPTH OF FIELD (Total: front + back, in Inches)											Exposure Increase Factor	T-Stop Increase
		.286″×.380″	.251″×.463″	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32		
Dec.	Frac.	Std. 16	Super 16													
0.100	1/10	2.86×3.80	2.51×4.63	0.13″	0.19″	0.26″	0.37″	0.53″	0.74″	1.06″	1.45″	2.11″	2.90″	4.22″	1.21	.27
0.111	1/9	2.58×3.42	2.26×4.17	0.11	0.15	0.22	0.30	0.43	0.61	0.87	1.19	1.73	2.38	3.46	1.23	.30
0.125	1/8	2.29×3.04	2.01×3.70	0.09	0.12	0.17	0.24	0.35	0.48	0.69	0.95	1.38	1.90	2.76	1.27	⅓
0.143	1/7	2.0 ×2.66	1.76×3.24	0.07	0.09	0.13	0.19	0.27	0.38	0.54	0.74	1.07	1.48	2.15	1.31	.39
0.167	1/6	1.71×2.28	1.50×2.78	0.05	0.07	0.10	0.14	0.20	0.28	0.40	0.55	0.80	1.11	1.61	1.36	.45
0.200	1/5	1.43×1.90	1.26×2.32	0.04	0.05	0.07	0.10	0.14	0.20	0.29	0.40	0.58	0.79	1.15	1.44	.53
0.250	1/4	1.14×1.52	1.00×1.85	0.02	0.03	0.05	0.07	0.10	0.13	0.19	0.26	0.38	0.53	0.77	1.56	⅔
0.333	1/3	.859×1.14	.754×1.39	0.014	0.02	0.03	0.04	0.06	0.08	0.12	0.16	0.23	0.32	0.46	1.78	.83
0.500	1/2	.572×.760	.502×.926	0.007	0.010	0.014	0.02	0.03	0.04	0.06	0.08	0.12	0.16	0.23	2.25	1⅓
0.667	2/3	.429×.570	.376×.694	0.004	0.006	0.009	0.013	0.018	0.03	0.04	0.05	0.07	0.10	0.14	2.78	1.47
0.750	3/4	.381×.507	.335×.617	0.004	0.005	0.007	0.010	0.015	0.02	0.03	0.04	0.06	0.08	0.12	3.06	1⅔
0.875	7/8	.327×.434	.286×.529	0.003	0.004	0.006	0.008	0.012	0.016	0.02	0.03	0.05	0.07	0.09	3.52	1.81
1.0	1/1	.286×.380	.251×.463	0.002	0.003	0.005	0.007	0.010	0.013	0.019	0.03	0.04	0.05	0.08	4.0	2.0

PLUS DIOPTER LENSES FOCUS CONVERSION TABLE

16mm or 35mm Camera

(MAY BE USED WITH ANY FOCAL LENGTH LENS)

NOTE: Position diopter lens in front of camera lens so that arrow (if inscribed on rim) points toward subject, or with convex (outward) curve toward subject. When two diopters are used in combination, place highest power nearest camera lens. The actual field size photographed depends slightly on the separation between diopter and camera lens.

Power of Supplementary Lens in Diopters	Focusing Distance on Lens Mount in FEET	Actual Distance Focused on in INCHES From Diopter Lens
+½	Inf.	78¾
	25	69½
	15	64¾
	10	59¼
	6	51
	4	43¼
+1	Inf.	39⅜
	25	34¾
	15	32⅜
	10	29⅝
	6	25½
	4	21⅝
+2	Inf.	19⅝
	25	18½
	15	17¾
	10	16⅞
	6	15½
	4	14
+3 (2+1)	Inf.	13⅛
	25	12½
	15	12¼
	10	11⅞
	6	11⅛
	4	10⅜
+4	Inf.	9⅞
+5	Inf.	7⅞
+6	Inf.	6½
+8	Inf.	5
+10	Inf.	4

Camera Filters

by Ira Tiffen, ASC Associate Member

Camera filters are transparent or translucent optical elements that alter the properties of light entering the camera lens for the purpose of improving the image being recorded. Filters can affect contrast, sharpness, highlight flare, color, and light intensity, either individually or in various combinations. They can also create a variety of "special effects." It is important to recognize that, even though there are many possibly confusing variations and applications, all filters behave in a reasonably predictable way. This section is intended to explain the basic optical characteristics of camera filters as well as their applications. It is a foundation upon which to build through experience. Textual data cannot fully inform. There is always something new.

In their most successful applications, filter effects blend in with the rest of the image to help get the message across. Exercise caution when using a filter in a way that draws attention to itself *as an effect*. Combined with all the other elements of image-making, filters make visual statements, manipulate emotions and thought, and make believable what otherwise would not be. They get the viewer involved.

Filter Planning

Filter effects can become a key part of the "look" of a film, if considered in the planning stages. They can also provide a crucial last–minute fix to unexpected problems, if you have them readily available. Where possible, it is best to run advance tests for pre–conceived situations when time allows.

Filter References

There are several filter manufacturers who should be contacted regarding available filter types and nomenclature. Filters of the same name, but of different manufacturers, may not have the same characteristics. The one industry standard is the Wratten system for filter colors. Wratten–numbered filters have defined transmission properties that are at least cross–referenced by the various key suppliers.

Filter Factors

Many filter types absorb light, and this must be compensated for when calculating exposure. These filters are supplied with either a recommended "filter factor" or a "stop value." Filter factors are multiples of the unfiltered exposure. Stop values are added to the stop to be set without the filter. Multiple filters will add stop values. Since each stop added is a doubling of the exposure, a filter factor of 2 is equal to a one-stop increase. Example: three filters of one stop each will need three additional stops, or a filter factor of 2x2x2 = 8 times the unfiltered exposure.

When in doubt in the field about compensation needed for a filter, you might use your light meter with the incident bulb removed. If you have a flat diffuser, use it; otherwise just leave the sensor bare. Aim it at an unchanging light source of sufficient intensity. On the ground, facing up at a blank sky can be a good field situation. Make a reading without the filter. Watch out for your own shadow. Make a reading with the filter covering the entire sensor. No light should enter from the sides. The difference in the readings is the compensation needed for that filter. You could also use a spot meter, reading the same bright patch, with similar results. There are some exceptions to this depending on the filter color, the meter sensitivity, and the target color, but it's often better than taking a guess.

Filter Grades

Many filter types are available in a range of "grades" of differing strengths. This allows the extent of the effect to be tailored to suit various situations. The grade-numbering systems may vary with manufacturer, but genrally, the higher the number, the stronger the effect. Unless otherwise stated by the manufacturer, there is no mathematical relationship between the numbers and the strengths. A grade 4 is not twice the strength of a grade 2. A grade 1 plus a grade 4 doesn't add up to a grade 5.

Camera Filters for Both Color and Black & White

Ultraviolet Filters

Film often exhibits a greater sensitivity to something invisible to humans: ultraviolet light. This occurs most often outdoors, especially at high altitudes, where the UV–

absorbing atmosphere is thinner, and over long distances, such as in marine scenes. It can show up as a bluish color cast with color film, or it can cause a low–contrast haze that diminishes details, especially when viewing faraway objects, in either color or black & white. Ultraviolet filters absorb UV light generally without affecting light in the visible region.

It is important to distinguish between UV–generated haze and that of airborne particles, such as smog. The latter is made up of opaque matter that absorbs visible light as well as UV, and will not be appreciably removed by a UV filter.

Ultraviolet filters come in a variety of absorption levels, usually measured by their percent transmission at 400 nanometers (nm), the visible UV wavelength boundary. Use a filter that transmits zero percent at 400nm for aerial and far–distant scenes; one that transmits in the ten to thirty percent range is fine for average situations.

Infrared Filters

Certain special situations call for the use of black & white or color infrared sensitive films. For aerial haze penetration, recording heat effects, and other purposes they are invaluable. Their color and tonal renditions are very different, however, from other film types (consult film manufacturers for further details). Various filters are used to reduce unwanted visible light. Red, orange, and yellow filters, as used for panchromatic black & white film, can enhance contrast and alter color. Total visible light absorption, transmitting only infrared, as with the Wratten #87 or #89 series of filters, can also be useful. The results will vary with film type and other factors. Prior testing for most situations is a must.

Neutral-Density Filters

When it is desirable to maintain a particular lens opening for sharpness or depth-of-field purposes, or simply to obtain proper exposure when confronted with too much light intensity, use a neutral-density (ND) filter. This will absorb light evenly throughout the visible spectrum, effectively altering exposure without requiring a change in lens opening and without introducing a color shift.

Neutral-density filters are denoted by (optical) density value. Density is defined as the log, to base 10, of the *opac-*

ity. Opacity (degree of absorption) of a filter is the reciprocal of (and inversely proportional to) its *transmittance*. As an example, a filter with a compensation of one stop has a transmittance of 50%, or 0.5 times the original light intensity. The reciprocal of the transmittance, 0.5, is 2. The log, base 10, of 2 is approximately 0.3, which is the nominal density value. The benefit of using density values is that they can be added when combined. Thus two ND .3 filters have a density value of 0.6. However, their combined transmittance would be found by multiplying 0.5 x 0.5 = 0.25, or 25% of the original light intensity.

Neutral-density filters are also available in combination with other filters. Since it is preferable to minimize the number of filters used (see section on multiple filters), common combinations such as a Wratten 85 (daylight conversion filter for tungsten film) with a ND filter are available from manufacturers as one filter, as in the 85N6. In this case, the two-stop ND .6 value is in addition to the exposure compensation needed for the base 85 filter.

Gradated ND Filters, or Wedges

Often it is necessary or desirable to balance light intensity in one part of a scene with another, in situations where you don't have total light control, as in bright exteriors. Exposing for the foreground will produce a washed–out, overexposed sky. Exposing for the sky will leave the foreground dark, underexposed. Gradated, or wedge, ND filters are part clear, part neutral density, with a smoothly graded transition between. This allows the transition to be blended into the scene, often imperceptibly. An ND .6–to–clear, with a two- stop differential, will most often compensate the average bright sky–to–foreground situation.

These filters are also available in combination colors, as where the entire filter is, for example, a Wratten 85, while one half also combines a graded–transition neutral density, as in the 85–to–85N6. This allows the one filter to replace the need for two.

Gradated, or wedge, filters generally come in three transition types. The most commonly used is the "soft" gradation. It has a wide enough transition area on the filter to blend smoothly into most scenes, even with a wide-angle lens (which tends to narrow the transition). A long focal length, however, might only image in the center of the transition. In this case, or where the blend must take place in a narrow, straight area, use a "hard" gradation. This is ideal for featureless marine horizons. For situations where an extremely gradual blend is required, an "attenuator" is used. It changes density almost throughout its length.

Certain types of part clear, part neutral-density filters are called sky-control filters. They may have a sharp, not gradated, dividing line, requiring careful alignment and choice of lens opening to blend in the edge.

The key to getting best results with gradated filters is to help the effect blend in as naturally as possible. Keep it close to the lens to maximize transition softness. Avoid having objects in the image that extend across the transition in a way that would highlight the existence of the filter. Don't move the camera unless the transition can be maintained in proper alignment with the image throughout the move. Make all positioning judgments through a reflex viewfinder at the actual shooting aperture, as the apparent width of the gradation is affected by a change in aperture.

Gradated filters are best used in a square, or rectangular format, in a rotating, slidable position in a matte box. This will allow proper location of the transition within the image. They can be used in tandem, for example, with one affecting the upper half and the second affecting the lower half of the image. The center area can also be allowed to overlap, creating a stripe of the combination of effects in the middle, most effectively with gradated filters in colors. (See section on "Gradated Color Filters.")

Polarizing Filters

Polarizers allow color and contrast enhancement, as well as reflection control, using optical principles different from any other filter types. Most light that we record is reflected light that takes on its color and intensity from the objects we are looking at. White light, as from the sun reflecting off a blue object, appears blue because all other colors are absorbed by that object. A small portion of the reflected light bounces off the object without being absorbed and colored, retaining the original (often white) color of its source. With sufficient light intensity, such as outdoor sunlight, this reflected "glare" has the effect of washing out the color saturation of the object. It happens that, for many surfaces, the reflected glare we don't want is polarized while the colored reflection we do want isn't.

The waveform description of light defines non–polarized light as vibrating in a full 360° range of directions

No Filter

Polarizer for reflection control.

around its travel path. Polarized light is defined as vibrating in only one such direction. A polarizing filter passes light through in only one vibratory direction. It is generally used in a rotating mount to allow for alignment as needed. In our example above, if it is aligned perpendicularly to the plane of vibration of the polarized reflected glare, the glare will be absorbed. The rest of the light, the true-colored reflection vibrating in all directions, will pass through no matter how the polarizing filter is turned. The result is that colors will be more strongly saturated, or darker. This effect varies as you rotate the polarizer through

No Filter

Polarizer for blue sky and Didymium for red enhancement.

a quarter–turn, producing the complete variation of effect, from full to none.

Polarizers are most useful for increasing general outdoor color saturation and contrast. Polarizers can darken a blue sky, a key application, on color as well as on black & white film, but there are several factors to remember when doing this. To deepen a blue sky, it must be blue to start with, not white or hazy. Polarization is also angle–dependent. A blue sky will not be equally affected in all directions. The areas of deepest blue are determined by the following "rule of thumb." When setting up an exterior shot, make a right angle between thumb and forefinger.

No Filter

Polarizer for exposure control.

Point your forefinger at the sun. The area of deepest blue will be the band outlined by your thumb as it rotates around the pointing axis of your forefinger, directing the thumb from horizon to horizon. Generally, as you aim your camera either more into or away from the sun, the effect will gradually diminish. There is no effect directly at or away from the sun. Do not pan with a polarizer without checking to see that the change in camera angle doesn't create undesirably noticeable changes in color or saturation. Also, with an extra–wide–angle view, the area of deepest blue may appear as a distinctly darker band in the sky. Both situations are best avoided. In all cases, the effect of the polarizer will be visible when viewing through it.

Polarizers need approximately 1 ½ to 2 stops exposure compensation, without regard to rotational orientation or subject matter. They are also available in combination with certain standard conversion filters, such as the 85BPOL. In this case, add the polarizer's compensation to that of the second filter.

Certain camera optical systems employ internal surfaces that themselves polarize light. Using a standard (linear) polarizer will cause the light to be further absorbed by the internal optics, depending on the relative orientation. A circular polarizer is a linear one to which has been added, on the side facing the camera, a quarter wave "retarder." This "corkscrews" the plane of polarization, effectively depolarizing it, eliminating the problem. The circular polarizer otherwise functions in the same manner.

Polarizers can also control unwanted reflections from surfaces such as glass and water. For best results, be at an angle of 32 to 34 degrees incident to the reflecting surface. Viewing through while rotating the polarizer will show the effect. It may not always be advisable to remove all reflections. Leaving some minimal reflection will preserve a sense of context to a close-up image through the reflecting surface. A close–up of a frog in water will appear as a frog out of water without some tell–tale reflections.

For relatively close imaging of documents, pictures, and small three-dimensional objects in a lighting–controlled environment, as on a copy stand, plastic polarizers mounted on lights aimed at 45 degrees to the subject from both sides of the camera will maximize the glare–reducing efficiency of a polarizer on the camera lens. The camera, in this case, is aimed straight at the subject surface, not at an angle. The lighting polarizers should both be in the same, perpendicular orientation to the one on the lens. Again, you can judge the effect through the polarizer.

Special Effect Filters

The following filter types are available in a wide range of grades useful in both color and black & white imaging. They have no recommended filter factors, but may require exposure compensation based on a several considerations. Filters that lower contrast or create flare, where contrast and/or light intensity is higher, will do more for any given grade. Working with light, the more they have, the more they can do. The same filter, in two different lighting conditions, may produce two different effects. With diffusion, or image-softening filters, higher contrast scenes appear sharper, needing more diffusion, than scenes of lower contrast. Diffusion requirements will also vary with other conditions. Smaller film formats will allow less diffusion, as will large-screen projection. Color may allow less diffusion than black & white. Producing for television may require a greater degree of diffusion to survive the transition. These relationships should cause you to choose exposure and filter grade based on the situation and personal experience. Prior testing is always recommended when possible.

Diffusion Filters

Many different techniques have been developed to diffuse image–forming light. Stronger versions can blur reality for a dream-like effect. In more subtle forms, diffusion can soften wrinkles to remove years from a face. The optical effects all involve bending a percentage of the image–forming light from its original path to defocus it.

Some of the earliest "portrait" diffusion filters are still in use today — "nets." Fine mesh, like a stocking, stretched across the lens, has made many a face appear flawlessly youthful. More recently, these can also be obtained as standard–sized hard optical filters. Nets function through "selective diffusion." They have a greater effect on small details, such as wrinkles and skin blemishes, than on the rest of the image. The clear spaces in the mesh transmit light unchanged, preserving the overall sharp appearance of the image. Light striking the flat surface of the net lines, however, is reflected or absorbed. A light–colored mesh will reflect enough to tint shadows, either making them lighter, which lowers contrast, or adding its color while leaving highlight areas alone. The effect of diffusion, however, is produced by the refraction of light that just strikes the edges of the mesh lines. This light is bent at a different angle, changing its distance to the film plane, putting it out of focus. It happens that this has a proportionately greater effect on finer details than on larger image elements. The result is that fewer wrinkles or blemishes are visible on a face that otherwise retains an overall, relatively sharp appearance.

No Filter

Low Contrast

The finer the mesh, the more the image area covered by mesh lines, and the greater the effect. Sometimes, multiple layers are used to produce even stronger results.

Mesh with a square pattern can produce small four-point stars from lights in the scene. Most of the time, this is not desirable. Most mesh patterns used have a hexagonal pattern to minimize this effect.

As with any filter that has a discrete pattern, be sure that depth of field doesn't cause the net filter lines to become visible in the image. Using small apertures or short focal length lenses makes this more likely, as does using a

No Filter

Fog Filter

smaller film format. Generally, mid–range or larger apertures are suitable, but test before critical situations.

When diffusing to improve an actor's facial appearance, it is important not to draw attention to the presence of the filter, especially with stronger grades, when diffusion is not required elsewhere. It may be desirable to lightly diffuse adjacent scenes or subjects which would not otherwise need it, to ensure that the stronger filtration, where needed, is not made obvious.

In diffusing faces, it is especially important that the eyes do not get overly soft and dull. This is the theory behind what might be called circular diffusion filters. A se-

No Filter

Double Fog Filter

ries of concentric circles, sometimes also having additional radial lines, are etched or cast into the surface of a clear filter. These patterns have the effect of selectively bending light in a somewhat more efficient way than nets, in a more radial orientation. This requires that the center of the circular pattern is aligned with one of the subject's eyes, not always an easy task, to keep it sharp. The rest of the image will exhibit the diffusion effect.

A variation on the clear–center concept is the center-spot filter. This is a special-application filter that has a moderate degree of diffusion surrounding a clear central area that is generally larger than that of circular diffusion filters mentioned previously. Use it to help isolate the main subject, held sharp in the clear center, while diffusing a distracting background, especially in situations where a long lens and depth–of–field differentiation aren't possible.

Another portrait diffusion type involves the use of small "dimples," or clear refracting shapes dispersed on an otherwise clear optical surface. They can be round or diamond–shaped. These are capable of more efficient selective diffusion than the net type, and have no requirement to be aligned with the subject's eye. They don't lower contrast by tinting shadows, as light–colored nets do. These dimples refract light throughout their surface, not just at the edges. For any given amount of clear space through the filter, which is relative to overall sharpness, they can hide fine details more efficiently than net filters. A more recent development involves a minutely detailed series of patterns, made up of tiny "lenslets," each with a greater degree of curvature, with more optical power, than that developed by the dimples previously mentioned. This produces a maximum of selective diffusion efficiency for any given amount of overall sharpness.

The above types of filters, though most often used for "portrait" applications, also find uses wherever general sharpness is too great, and must be subtly altered.

Some diffusion filters also cause highlight areas to flare. They can scatter light, having an effect on lowering contrast. These are closely related to fog or mist filters. These include "dot" filters which incorporate small, discrete optical elements of various sizes that selectively diffuse, lower contrast, and cause mild highlight flare. They can be very effective in achieving these combined effects.

Sliding Diffusion Filters

When attempting to fine–tune the application of diffusion within a sequence, the ability to vary the strength of the effect while filming can be invaluable. This can be accomplished by employing an oversized filter that has a gradated diffusion effect throughout its length. It is mounted to allow sliding the proper grade area in front of the lens, which can be changed "on–camera." When even more subtle changes are required, maintaining consistent diffusion throughout the image while varying the overall strength, a dual "opposing gradient" filter arrangement can be used.

Fog and Mist Filters

A natural fog causes lights to glow and flare. Contrast is generally lower, and sharpness may be affected as well. Fog and mist filters mimic the effect of atomized water droplets in the air. The soft glow can be used to make lighting more visible. For example, the effect of humidity in a tropical scene can be enhanced. In lighter grades, these filters can take the edge off excess contrast and sharpness. Heavier grades can create unnatural effects, as for fantasy sequences. In general, however, the effect of a strong natural fog is not produced accurately by these filters in their stronger grades, because they are too fuzzy, with too much contrast. For that, Double Fog or gradated fog filters are recommended.

Gradated fog filters, sometimes called "scenic," are part clear or light fog, and part denser fog effect. Aligning the clear or weaker half with the foreground and the stronger half with the background will render an effect more like that of a natural fog, accumulating strength with distance.

Double Fogs have milder flare and softening characteristics than standard fog filters, while exhibiting a much greater effect on contrast, especially in the stronger grades. A very thick natural fog will still allow close–up objects to appear sharp. So will a double fog filter. The key to the effect is the much lower contrast combined with a minimal amount of highlight flare.

Mist filters generally produce highlight flare that, because it stays closer to the source, appears more as a "halo" than the more outwardly extended flare of a fog filter. The mist filters create an almost pearlescent glow to highlights. The lighter grades also find uses in toning down the excessive sharpness and contrast of modern film and lens combinations without detracting from the image.

Low-Contrast Filters

There are many situations, such as bright sunlit exteriors, where proper contrast is difficult to maintain, and exposing for either highlights or shadows will leave the other severely under- or overexposed. Low-contrast filters come in two key types. The first type creates a small amount of "localized" flare near highlight areas within the image. This reduces contrast by lightening nearby shadow areas, leaving highlights almost unchanged. A variation of this type also includes a light-absorbing element in the filter which, without exposure compensation, will reduce contrast by also darkening highlights. Use this latter filter when lighter shadows are not desired. In both cases, the mild flare produced from bright highlights is sometimes used as a lighting effect.

A second, more recently developed type of filter reduces contrast without any localized flare. It uses ambient light, not just light in the image area, to lighten shadows evenly throughout. Use it where contrast control is needed without any other apparent effect on sharpness or highlight flare.

Star-Effect Filters

Lighting can be enhanced in ways that go beyond what exists in nature. Star filters create points of light, like "stars," streaking outward from a central light source. This can make lighting within the scene take on a more glittering, glamorous appearance. This effect is usually produced by a series of thin lines etched into the flat optical surface of a clear filter. These lines act as cylindrical lenses, diffracting light points into long thin lines of light running perpendicular to the etched lines. Lines on the filter positioned horizontally produce vertically oriented star lines.

The size and brightness of the star lines produced are first a function of the size, shape, and brightness of the light source. You have additional control through the choice of a particular spacing between the lines on the filter. Generally these spacings are measured in millimeters. A 1mm spacing has twice as many lines per unit area as a 2mm spacing. It will produce a brighter star for any given source. Spacings offered generally range from 1mm to 4mm, as well as both narrower and wider distances for specialty effects.

The number of directions in which the lines run determines the number of points produced. Lines in one direction produce a two–pointed star, just a streak through the center of the light. Filters with 4, 6, 8, 12, and more points are available. Although the more common types have a symmetrical arrangement of points, they can also be obtained with asymmetric patterns, which tend to appear more "natural," or less synthetic.

With an 8- or 12-point filter, the many star lines will tend to overpower the rest of the image, so use them carefully.

As with any filter that has a discrete pattern, be sure that depth of field doesn't cause the filter lines to become visible in the image. Using small apertures or short focal length lenses makes this more likely, as will using a smaller film format, such as 16mm vs. 35mm given an equal field of view. Generally, mid–range apertures or larger is sufficient, but test before critical situations.

Filters for Black & White

Tone-Control Filters

Black & white panchromatic film records only tonal differences between colored objects, which appear as black, white, or different shades of gray. Proper rendition depends on your own desires, and the differences between film sensitivity to colors and that of the eye. The latter is due to the fact that most emulsions are more sensitive to blue, violet and ultraviolet than to other colors. Therefore, blue appears to be lighter on film than it does to the eye. This can make a blue sky light enough to appear a similar shade of light gray as the clouds that are in it, making the clouds "disappear." A more "correct" cloud presence is obtained through the use of a yellow filter, such as a Wratten #8, which can absorb blue light, darkening the sky to more closely match what the eye would see. The #8 also acts as a general compensator for most subjects, giving a tonal rendition similar to that of the eye. Deeper colors, further to the red end of the spectrum, such as Wratten #15 deep yellow, #16 orange, and #25 and #29 red filters, will produce progressively deeper and artificially more dramatic renditions of blue sky.

Remember that, since these filters act on color differences to produce tonal differences, the required colors must be present. The part of the sky you are recording must be blue to be affected. Sky sections closer to the sun, or nearer the horizon, are generally less blue than elsewhere. Use of a gradated neutral-density filter can darken a sky relative to the foreground, but will not increase contrast between a blue sky and the clouds.

Using filters for contrast control can be a matter of artistic preference, or of necessity. It is possible for two disparate colors, say a certain orange and blue, to record as the identical tone, eliminating any visible difference between them. Filters will lighten objects of their own color and darken those of their complement. Complementary color pairs are: green–red; orange–blue; violet–yellow. An orange filter in the above case will darken the blue and lighten the orange; a blue filter will perform the reverse.

A green filter, such as Wratten #11, can be used to lighten green foliage to show more detail. It may also be used to provide more pleasing skin tones outdoors, especially against blue sky.

Any filter used for the above purposes will have a greater effect if slightly underexposed. Its function depends on absorbing light of its complementary colors to increase the proportion of light of colors similar to itself. Exposure compensation is often needed to allow proper image density, but the relative difference is reduced by the addition of light at the absorbed wavelengths through additional exposure.

Filters for Color

Recording color involves greater knowledge about light sources than is necessary for black & white imaging. Sunlight, daylight and exterior lighting at different times of day,as well as incandescent, fluorescent, and other artificial sources, all have color characteristics that vary significantly. We see images through our eyes only after they are processed by our brain, which has the ability to make certain adjustments to the way we see color. White will still appear white to the eye in various lighting situtations, as long as we don't have more than one type visible at a time. Film has no such internal compensation. It is designed to see only a certain type of light as white — all others will appear different to the extent of their difference. Filters are required to provide the necessary fine–tuning.

The following discussion of Color Conversion, Light Balancing, Color Compensating, Decamired, and Fluorescent filters will be better understood after consulting the section on color temperature and light-source characteristics.

Color-conversion Filters

Color-conversion filters are used to correct for sizable differences in color temperature between the film and the light source. These include both the Wratten #80 (blue) and the Wratten #85 (amber) series of filters. Since they see frequent outdoor use, in bright sunlight, the #85 series, espe-

No Filter

Graduated Color Filter

cially the #85 and #85B, are also available in combination with various neutral- density filters for exposure control.

Light-balancing Filters

Light-balancing filters are used to make minor corrections in color temperature. These are comprised of both the Wratten #81 (yellowish) and the Wratten #82 (bluish) series of filters. They are often used in combination with color-conversion filters. Certain #81 series filters may also be available in combination with various neutral density filters for exposure control.

No Filter

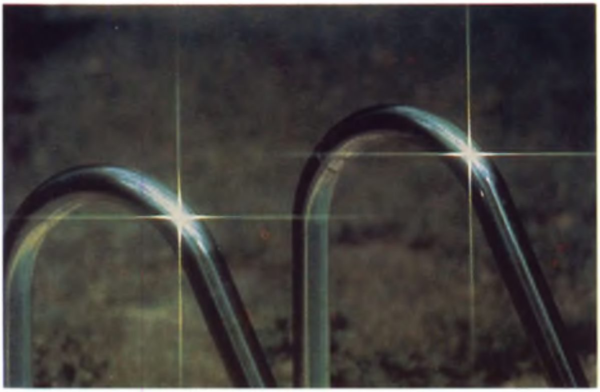
Sepia Filter

Color-compensating Filters

Color-compensating filters are used to make adjustments to the red, blue or green characteristics of light. These find applications in correcting for color balance, light source variations, different reversal film batches, and other color effects. They are available in density variations of Cyan, Magenta, Yellow, as well as Red, Blue , and Green filters.

Decamired Filters

Decamired filters (a trademark of their manufacturer) are designed to more easily handle unusual color tempera-



4 Point Star

Split-Field Lens

ture variations than previously mentioned filters. Available in incremental mired shifts (see lighting section on mireds) in both a red and a blue series, decamired filters can be readily combined to create almost any required correction.

Fluorescent and Other Discontinuous Spectra Lighting Correction

Since filters never actually add color, but only absorb certain wavelengths to increase the relative proportion of others, the original light source must include the colors you want. Some sources are totally deficient in certain wavelengths, which filters alone cannot add back. This is particularly true of many types of metal halide lighting. With other lighting types, such as fluorescent, color temperature measurements may not provide the correct filter requirements since color temperature theory is based on having a continuous spectrum, meaning light at all wavelengths. It is possible for a light source to have a sufficient spectral distribution to emulate a correctable color temperature when so measured, but its effect on film can be very different. (See section on lighting for additional details.)

Gradated Color Filters, or Wedges

Similar to Gradated ND filters, these filters are also produced in a wide range of standard and custom colors, densities, and proportions for many applications. A blue–to–clear filter can add blue to a white, hazy sky without affecting the foreground. An orange–to–clear filter can enliven a tepid sunset. Color can be added to the bottom of the scene, as with a green–to–clear filter used to enrich the appearance of a lawn.

Stripe filters are another type of gradated filter, having a thin stripe of color or neutral density running through the center of the filter, gradating to clear on either side. These are used to horizontally paint various colors in layers into a sky, as well as for narrow–area light balancing.

Coral Filters

As the sun moves through the sky, the color temperature of its light changes. It is often necessary to compensate for this in a variety of small steps as the day progresses, to match the appearance of different adjacent sequences to look as if they all took place at the same time. Coral filters include a range of graded filters of a color similar to an 85 conversion filter. From light to heavy, any effect from basic correction to warmer or cooler than "normal" is possible. Corals can also compensate for the overly cool blue effect of outdoor shade.

Sepia Filters

People often associate sepia–toned images with "early times." This makes sepia filters useful tools for producing believable flashbacks and for period effects with color film. Other colors are still visible, which is different from original sepia–toned photography, but these colors appear to be infused with an overall sepia tint.

Didymium Filters

This type of filter, which may be called by a trade name (see manufacturers), is a combination of rare earth elements in glass. It completely removes a portion of the spectrum in the orange region. The effect is to increase the color saturation intensity of certain brown, orange, and reddish objects by eliminating the muddy tones and maximizing the crimson and scarlet components. Its most frequent use is for obtaining strongly saturated fall foliage. The effect is minimal on objects of other colors. Skin tones might be overly warm. Even after color timing to correct for any unwanted bias in these other areas, the effect on reddish objects will still be apparent.

Underwater Color-correction Filters

When filming underwater, the light you are recording is filtered by the water it passes through. Longer-wavelength reds and oranges are absorbed until only blue is left. The actual effect is determined by numerous factors, such as light source (sun or artificial), water quality, and the water path. The latter is the distance the light travels through the water. In natural (sun)light, this is the depth of the subject from the surface plus the subject–to–camera distance. For artificial lighting, it is the distance from the light to the subject to the camera. The longer the water path, the greater the filtering effect of the water. In many cases, certain color-compensating (CC) filters can absorb enough shorter wavelengths to restore better color balance. The difference between corrected and uncorrected color can be dramatic. The use of faster-speed films will facilitate the use of light absorbing correcting filters.

Differences Between Camera and Lab Correction

It is the job of the lab timer to fine–tune the finished color rendition of the film. This accounts for variables in exposure, print stock and processing. Timing can also be used to impart certain color effects, both for standard correction and special situations. The difference is that lab correction has only the range of colors and densities available in the film emulsion to work with, and is limited to the range of variation of the printer. These are much more limiting than the multitude of colorants in the real world, and the number of ways in which adjustments can be made at the camera. Filtering on the camera brings the lab that much closer to the desired result, providing a greater latitude of timing options.

There will be times when counting on the lab is the only choice. Labs can also produce some unusual effects. When faced with a low-light situation, in daylight using tungsten film, it may be necessary for exposure reasons to pull the 85 filter and correct in the printing. When you do this, however, neutral gray tones will appear slightly yellow, even when all else looks correct. This effect can be used to artificially enhance lush green foliage colors through the addition of yellow. It may have other uses, but you will not achieve the same result as if you had used the 85 filter.

LL-D

The LL-D (trademark of its manufacturer) was designed to help in the above situation. It requires no exposure compensation, and makes sufficient adjustments to the film to enable the timer to match the color of a properly 85–filtered original. It is not an all–around replacement for the 85. Use it only where needed for exposure purposes, and for subsequently printer–timed work.

Special Application Filters

Contrast Viewing Filters

Balancing lighting by eye is a matter of experience. Decisions can be aided through the use of contrast viewing filters. These are designed to handicap the eye, with its much greater range of apparent densities, to resemble the range of the various types of film. Use contrast viewers to judge relative highlight and shadow densities. There are viewers for black & white film, as well as various viewer densities for color film. A darker viewer is used for slower film speeds, where you would tend to use brighter lighting. Faster film, which can be used in dimmer settings, would require a lighter viewer. Details can be obtained from the manufacturers.

Other Filter Considerations

Effect of Depth of Field and Focal Length Changes

Standard color filters generally function without change through variations in depth of field and focal length. This may not be true of many of the "special effect" filter types. There are no solid rules for predicting the variation in filter effect due to depth–of–field or focal length changes. There are some things we can expect, however. Let's look at a fog/mist type filter that causes a light to glow, or flare. Take the example of a certain grade filter where we can see that the ratio of light diameter to glow diameter is, say, 1:3. As we view this through a changing focal length, we will see that the ratio remains the same, although the magnification will vary accordingly. So the decision to use a filter of a different grade to maintain a certain appearance at different focal lengths will be based on wanting to change the ratio, as opposed to any otherwise corresponding relationship. Tests are advisable for critical applications.

Sizes, Shapes, and Mounting Techniques

Filters are available in round and rectangular shapes in many sizes. Round filters generally come supplied with metal rings that mount directly to the lens. Frugal filter users might find it preferable to employ adapters allowing the use of a set of filters of a single size with many lenses of equal or smaller sizes. Round filters also can be supplied with self-rotating mounts, where needed, as for polarizers. They can be readily stacked in combination. Rectangular filters require the use of a special filter holder, or matte box. They offer the additional benefit of allowing slidability for effects that must be precisely aligned within an image, such as gradated filters. In all cases, it is advisable to use a mounting system that allows for sturdy support and ready manipulation. In addition, the use of a lens shade at the outermost mounting position (from the lens) will minimize the effect of stray off–axis reflections.

Multiple Filter Use

When any single filter is not enough to produce the desired results, use combinations. Choose carefully, to minimize the number required. Usually the job can be done with no more than three filters. Use filters that individually add to the final effect, without canceling each other out. For example, don't use a polarizer, which can increase color saturation, in combination with a low-contrast filter which reduces saturation, unless it works for some other reason (the polarizer could also be reducing reflections, for instance). Generally, the order in which filters are mounted is not important.

Secondary Reflections

Lighting can cause flare problems, especially when using more than one filter. Lights in the image pose the greatest difficulties. They can reflect between filter surfaces and cause unwanted secondary reflections. Maintaining parallelism between filters, and further aligning the lights in the image with their secondary reflections where possible, can minimize this problem. In critical situations, it may be best to make use of a matte box with a tilting filter stage. Tilting filter(s) of good optical quality only a few degrees in such a unit can divert the secondary reflections out of the lens axis, out of the image, without introducing unwanted distortion or noticeable changes in the filter's effect.

Custom (Homemade and Field–Ready) Filters

There will be times when you need an effect and don't have time to obtain one ready–made. Certain effects can be produced that, although different from factory filters, can be useful in a pinch, or for unusual custom situations. Net diffusion effects can be produced as they were originally, by stretching and affixing one or more layers of stocking material to the lens end, held in place with a rubber band. There are also numerous possibilities with a clear filter (or several) available. Petroleum jelly can cause flare or diffusion, or even some star-like streaks depending on its application, to a clear filter, spread with a finger or cloth. The chief benefit here is that the effect can also be applied only to selected portions of the scene. Breathing on a clear filter can produce interesting but temporary foglike results. Using cut gels can simulate certain gradated filter effects. When doing this, be sure to keep the filter close to the lens, and use larger lens openings, to keep the visible edge as soft as possible.

TABLE I: FILTER COMPENSATOR

Lens stop no filter	Filter Factors 1.25	1.6	2	2.5	3.2	4	5	6	8	10	12.5	16	20	25
22	20	18	16	14	12.7	11	10	9	8	7	6.3	5.6	5	4.5
20	18	16	14	12.7	11	10	9	8	7	6.3	5.6	5	4.5	4
18	16	14	12.7	11	10	9	8	7	6.3	5.6	5	4.5	4	3.6
16	14	12.7	11	10	9	8	7	6.3	5.6	5	4.5	4	3.6	3.2
14	12.7	11	10	9	8	7	6.3	5.6	5	4.5	4	3.6	3.2	2.8
12.7	11	10	9	8	7	6.3	5.6	5	4.5	4	3.6	3.2	2.8	2.5
11	10	9	8	7	6.3	5.6	5	4.5	4	3.6	3.2	2.8	2.5	2.2
10	9	8	7	6.3	5.6	5	4.5	4	3.6	3.2	2.8	2.5	2.2	2
9	8	7	6.3	5.6	5	4.5	4	3.6	3.2	2.8	2.5	2.2	2	1.8
8	7	6.3	5.6	5	4.5	4	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6
7	6.3	5.6	5	4.5	4	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6	1.4
6.3	5.6	5	4.5	4	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6	1.4	1.3
5.6	5	4.5	4	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6	1.4	1.3	1.1
5	4.5	4	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6	1.4	1.3	1.1	1
4.5	4	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6	1.4	1.3	1.1	1	.9
4	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6	1.4	1.3	1.1	1	.9	.8
3.6	3.2	2.8	2.5	2.2	2	1.8	1.6	1.4	1.3	1.1	1	.9	.8	.7
3.2	2.8	2.5	2.2	2	1.8	1.6	1.4	1.3	1.1	1	.9	.8	.7	
2.8	2.5	2.2	2	1.8	1.6	1.4	1.3	1.1	1	.9	.8	.7		
2.5	2.2	2	1.8	1.6	1.4	1.3	1.1	1	.9	.8	.7			
2.2	2	1.8	1.6	1.4	1.3	1.1	1	.9	.8	.7				
2	1.8	1.6	1.4	1.3	1.1	1	.9	.8	.7					
1.8	1.6	1.4	1.3	1.1	1	.9	.8	.7						
1.6	1.4	1.3	1.1	1	.9	.8	.7							
1.4	1.3	1.1	1	.9	.8	.7								
1.3	1.1	1	.9	.8	.7									
1.1	1	.9	.8	.7										
1	.9	.8	.7											
.9	.8	.7												

ND Filter Selector Chart

Stop for correct exposure					1.4	2	2.8	4	5.6	8	11	16	23	32	45	64	90	128	180	256
	Stops	Factor	% Trans	ND Filter																
↑	⅓	1.26	80	.10	1.3	1.8	2.5	3.6	5	7	10	14.3	20	28	40					
	⅔	1.6	63	.20	1.1	1.6	2.2	3.2	4.5	6.3	9	12.7	18	25	36					
⅓ stop steps	1	2	50	.30	1	1.4	2	2.8	4	5.6	8	11	16	23	32	45				
	1⅓	2.5	40	.40	.9	1.3	1.8	2.5	3.6	5	7	10	14.3	20	28	40				
	1⅔	3.2	32	.50	.8	1.1	1.6	2.2	3.2	4.5	6.3	9	12.7	18	25	36				
↓	2	4	25	.60	.7	1	1.4	2	2.8	4	5.6	8	11	16	23	32	45			
↑	3	8	12.5	.90		.7	1	1.4	2	2.8	4	5.6	8	11	16	23	32	45		
one	4	16	6.25	1.2			.7	1	1.4	2	2.8	4	5.6	8	11	16	23	32	45	
stop	5	32	3	1.5				.7	1	1.4	2	2.8	4	5.6	8	11	16	23	32	45
steps	6	64	1.6	1.8					.7	1	1.4	2	2.8	4	5.6	8	11	16	23	32
	7	128	0.8	2.1						.7	1	1.4	2	2.8	4	5.6	8	11	16	23
↓	8	256	0.4	2.4							.7	1	1.4	2	2.8	4	5.6	8	11	16

The columns to the left of the "ND Filter" show the filter factor both numerically and in lens stops and the percent transmission of each. Up to 0.6ND, increments are in ⅓ stop steps. From 0.6ND to 2.4ND the increments are in full stops. Densities may be added: (0.6ND plus 0.9ND equals 1.5ND). If correct exposure indicates a very small stop beyond the calibration of the lens AND/OR: If it is desired to open the lens to a wide aperture to throw the background out of focus: Select the *desired* lens stop in the column under the *indicated* stop, and use the corresponding ND Filter from the left shaded column. (For B&W photography, account for the factor of any color filter also).

CONVERSION FILTERS FOR COLOR FILMS

Filter Color	Filter Number	Exposure Increase in Stops*	Conversion in Degrees K	Mired Shift Value
	80A	2	3200 to 5500	−131
Blue	80B	1⅔	3400 to 5500	−112
	80C	1	3800 to 5500	−81
	80D	⅓	4200 to 5500	−56
	85C	⅓	5500 to 3800	81
	85	⅔	5500 to 3400	112
Amber	85N3	1⅔	5500 to 3400	112
	85N6	2⅔	5500 to 3400	112
	85N9	3⅔	5500 to 3400	112
	85B	⅔	5500 to 3200	131

*These values are approximate. For critical work, they should be checked by practical test, especially if more than one filter is used.

KODAK LIGHT BALANCING FILTERS

Filter Color	Filter Number	Exposure Increase in Stops*	To obtain 3200 K from:	To obtain 3400 K from:	Mired Shift Value
	82C + 82C	1⅓	2490 K	2610 K	−89
	82C + 82B	1⅓	2570 K	2700 K	−77
	82C + 82A	1	2650 K	2780 K	−65
Bluish	82C + 82	1	2720 K	2870 K	−55
	82C	⅔	2800 K	2950 K	−45
	82B	⅔	2900 K	3060 K	−32
	82A	⅓	3000 K	3180 K	−21
	82	⅓	3100 K	3290 K	−10
	No Filter Necessary		**3200 K**	**3400 K**	—
	81	⅓	3300 K	3510 K	9
	81A	⅓	3400 K	3630 K	18
Yellowish	81B	⅓	3500 K	3740 K	27
	81C	⅓	3600 K	3850 K	35
	81D	⅔	3700 K	3970 K	42
	81EF	⅔	3850 K	4140 K	52

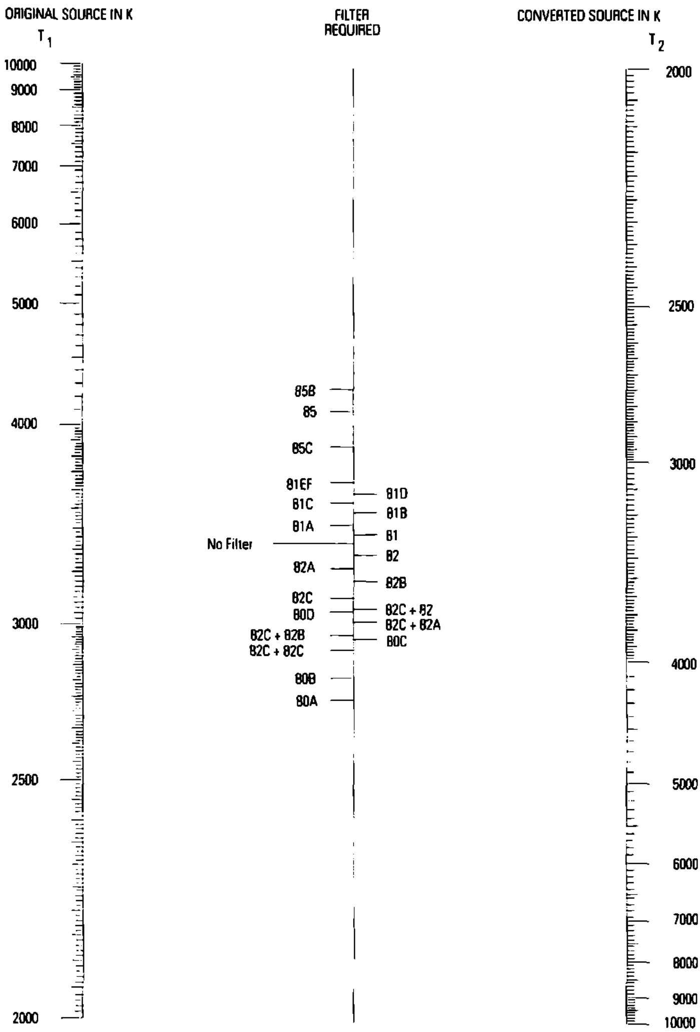
KODAK COLOR COMPENSATING FILTERS

Peak Density	Yellow (Absorbs Blue)	Exposure Increase In Stops*	Magenta (Absorbs Green)	Exposure Increase In Stops*	Cyan (Absorbs Red)	Exposure Increase In Stops*
.05	CC-05Y	—	CC-05M	⅓	CC-05C	⅓
.10	CC-10Y	⅓	CC-10M	⅓	CC-10C	⅓
.20	CC-20Y	⅓	CC-20M	⅓	CC-20C	⅓
.30	CC-30Y	⅓	CC-30M	⅔	CC-30C	⅔
.40	CC-40Y	⅓	CC-40M	⅔	CC-40C	⅔
.50	CC-50Y	⅔	CC-50M	⅔	CC-50C	1

Peak Density	Red (Absorbs Blue and Green)	Exposure Increase In Stops*	Green (Absorbs Blue and Red)	Exposure Increase In Stops*	Blue (Absorbs Red and Green)	Exposure Increase In Stops*
.05	CC-05R	⅓	CC-05G	⅓	CC-05B	⅓
.10	CC-10R	⅓	CC-10G	⅓	CC-10B	⅓
.20	CC-20R	⅓	CC-20G	⅓	CC-20B	⅔
.30	CC-30R	⅔	CC-30G	⅔	CC-30B	⅔
.40	CC-40R	⅔	CC-40G	⅔	CC-40B	1
.50	CC-50R	1	CC-50G	1	CC-50B	1⅓

*These values are approximate. For critical work, they should be checked by practical test, especially if more than one filter is used.

NOMOGRAPH FOR LIGHT SOURCE CONVERSION



The nomograph can be used to find the approximate filter for a particular conversion by placing a straightedge from an original source (T1) to a second source (T2). The approximate filter can be found on the center line.

Exposure Meters

by Jim Branch

The usual final adjustment of a motion-picture camera for exposure control is made with the iris diaphragm in the camera lens. While this is a very simple adjustment, a great deal depends upon its accuracy. Much thought has gone into the objectives to be attained by the adjustment of the diaphragm, and the means to obtain a correct adjustment.

It is recognized that a prime object of exposure control in motion-picture photography is to obtain consistent and uniform images of the principal subjects. It is very important to obtain flesh tones which will be consistent from one scene to the next. It is undesirable to have flesh tones which will be light in one scene, dark in the next without reason, and again light in the next scene. Correct exposure control will provide negatives which are consistent from scene to scene and can be printed on a very narrow range of printer lights.

Modern exposure control is based on the use of a good light meter. The light meter measures the effective intensity of the light, taking into account the sensitivity of the film in the camera and the exposure time. The exposure time is a result of the frames-per-second rate at which the camera operates, and the angle of the shutter opening. Professional cinematographers usually think in terms of 24 frames per second and a 175-degree shutter, which give a basic exposure time of 1⁄50 second. The light meter combines all of the foregoing factors to give an answer in terms of the appropriate camera lens stop.

Light meters are of two types. Some measure the incident light which illuminates the subject. Others measure the light which is reflected from the scene. The results obtained from the two different types may be quite different. It is important therefore to understand the differences between the two types.

Incident Light Meters

These meters are normally used at the location of the photographic subject. They measure the light which is effective in illuminating the subject. They give an answer in terms of f-stop or T-stop for the camera lens. The camera lens diaphragm opening is then set to match the effective intensity of the prevailing illumination.

When the film is exposed, the various reflectances presented by the subject will then each fall into a given place in the film acceptance range. For example, a face tone of 30% reflectance will fall into the 30% reflectance position in the film acceptance range. This method thus provides consistently uniform face tones from scene to scene.

The incident light meter accomplishes its purpose by doing two things. It measures the incident light intensity at the location of the photographic subject. It also takes into account the conditions of illumination geometry; that is, whether the subject has front key light, side key light, or a back key light. The meter combines these factors and gives an answer in terms of the correct setting for the camera lens diaphragm.

There are several makes of incident light meters which use a three-dimensional light collector. The hemispherical light collector allows these meters to perform automatically the dual function described above.

These incident light meters are normally used at the position of the principal subject, with the hemisphere pointed at the camera lens. The hemisphere then acts as the miniature face of the subject. All illumination which will be effective on the subject, including key light, fill light, line light, hair light, eye lights, etc., will be received, evaluated and integrated by the meter. The meter will then indicate directly the correct f-stop or T-stop for the camera lens. Incident light meters are particularly useful because they may be used on a scene before the principal subject appears. They may also be carried through a scene, with the hemisphere always pointed at the camera lens, to detect uneven illumination, and particularly hot spots, into which the subject may move during the action. This allows the scene illumination to be suitably balanced before the principal subject is at hand.

In the case of outdoor photography, it is not always necessary to take the meter to the location of the principal subject. Under such conditions the illumination is usually uniform over considerable areas. If the illumination is the same at subject location and at camera location the meter may be used at camera location. Care should be exercised to point the meter in the proper direction, as though it were at the subject location.

Exposure meters, in general, are either analog (with a needle) or digital. The introduction of the analog incident meter with the 3-D light-collecting hemisphere revolutionized the method of determining proper exposure for the cinematographer.

Today, a number of companies throughout the world manufacture exposure meters employing the basic incident type principles in their design, but all due credit should be given for the invention to Don Norwood, ASC, who patented it, and Karl Freund, ASC, who was instrumental in its development. Most incident meters are provided with suitable adapters so that they may be converted for use as a reflected light meter if the occasion should so indicate. The reflected light adapter can be used in a situation where the cinematographer encounters difficulty in putting the meter into a position to read either the illumination directly on the subject, or illumination similar to that on the subject. Such a situation, for example, might be encountered when taking a picture out of the window of an airliner in flight. The reflected light attachment can also be used in other situations to evaluate the relative brightness of a background.

Special Effects

When a special effect is desired, the cinematographer may use the incident light meter to first determine normal exposure for the subject. Then he may then deliberately modify that value, up or down, to achieve the desired effect. This can be done with considerable confidence because the incident light meter will give a firm foundation upon which to base the desired modification.

Specific Situations

There are some situations, occasionally encountered in outdoor photography, which require special attention.

1. Unusually light or dark backgrounds are cause for consideration. When a scene includes an unusually light background, the cinematographer may wish to first use the meter as an incident light meter to determine the basic exposure for the principal subject in the foreground. Then he can convert the meter to a reflected light meter in order to measure the brightness of the unusual background. The second reading is then used to modify somewhat the basic incident light reading. The same procedure could be followed in the case of an unusually dark background.

2. Outdoor scenes that include a subject in the foreground as well as distant objects, such as mountains, in the background, usually also include considerable aerial haze, which may be invisible or only partly visible to the eye, but strongly visible to the camera. A frequent photographic result is a recording of the aerial haze overlaid on the scene background. This would give the appearance of an overexposed background. It is recommended that in such a situation a haze-cutting filter be used to improve the background. In addition, use the procedure previously described for the case of an unusual lighting background.

3. Scenes consisting of a mixture of sunshine and shade areas, with the principal subject in a shade area, can be handled by: (a) using the meter in the sunshine area, or (b) opening up the lens by ½ to ⅔ f-stop from the meter indication.

Reflected Light Meters

Reflected light meters can be classified into two groups, according to function. The meters in each group may give exposure readings which are substantially different from those given by the meters in either of the other two groups. This is due to differences in basic principle of operation.

Group 1. These are the meters which are designed to measure the average brightness of an entire scene. Such meters are usually used at camera location and pointed at the scene. For a discriminating observer, this method appears to give acceptable results only in the case of a very limited category of scenes, those which have front-lighting and a foreground subject of medium tone as well as a background of medium tone. In other types of scenes, which include side-lighting or backlighting, or very bright or dark backgrounds, or large areas of sky, the exposure results are questionable. This is because the meter, when used by this method, is affected not only by the unit brightness of each portion of the scene, but also by the relative area of each. Thus a large area of sky would influence the meter to dictate a small lens aperture which might result in an underexposure of the face of the principal subject in the foreground. Any backlight may strike directly into the meter cell and cause an unduly high reading on the meter. This also would result in underexposure of the foreground subject. Large bright backgrounds tend to cause meter readings which result in underexposure of foreground subjects.

Large dark backgrounds tend to cause meter readings which result in overexposure of the foreground subject. If this method is used it should be considered only as a very rough guide, subject to considerable modification according to the experience of the cameraman.

It is interesting to note that this method is the one generally used in the built-in automatic exposure control systems of amateur motion-picture and still picture cameras. It has been noted by many that the photographic results do not meet the high standards of professional cinematography.

Group 2: These are the spot meters. A spot meter may be used at camera location and aimed at a selected spot in the scene. The effectiveness of the meter is heavily dependent on the operator's judgment in the selection of the spot. The selected spot must be precisely representative of the particular combination of elements which compose the scene. In the use of such a meter the operator must be particularly careful when confronted with a scene that presents strong contrasts between the selected spot and the scene background. An example of such a situation would be a case where a person in the foreground is in front of a very light background, such as sky or white buildings, etc. In such a case the operator should modify the spot reading provided by the meter according to his own estimate of the situation. When the use of a reflected light meter is required, the results of determining the exposure can be greatly improved by using a "Kodak Neutral Test Card."

This card is a piece of sturdy 8" X 10 " cardboard that is neutral gray on one side and white on the other. The gray side reflects 18% of the light falling on it, and the white side reflects approximately 90%. Also, the gray side has a protective lacquer overcoat that reduces specular reflectance and resists damage due to fading, fingerprints, soil, etc. To a light meter, an average scene is one in which the tones when averaged form a tone brightness that is equivalent to middle gray — a tone that reflects 18% of the light illuminating it (the same tone and reflectance of the gray card). When a scene is not average the gray card as a reference helps you make the proper exposure judgments. A Kodak Gray Card is manufactured under close tolerances to provide a neutral gray-side reflectance of 18% (± 1%) and white-side reflectance of approximately 90%.

Testing

Small errors may exist in meters, lens calibrations, emulsion speeds and development. These small errors will frequently cancel out without undue harm to the final picture. It is when these errors add up in the same direction that their cumulative effect is serious. It is wise, therefore, to test equipment, film and meters under simulated production conditions so that errors may be detected and corrected before production begins. It is always a good idea to "tune up to the variables."

Exposure Meters

Cinemeter II

Type: Hand-held digital/analog incident meter.

Light Sensor: Large area, blue enhanced silicon photo sensor. Swivel head 270 degrees.

Measuring capability: Direct readout of photographic exposures in full f-stops or fractional f-stops. Also measures illuminance level in footcandles and Lux.

Measuring Range: Direct-reading multiple-range linear circuit incorporates a high quality CMOS integrated amplifier whose bias current is compensated against drift up to 70° C. Dynamic range 250,000 to one. Digital f-stop: f/0.5 to f/90 in ⅒-stop increments. Analog f-stop: f/0.63 to f/36 in ⅓-stop increments. Photographic illuminance: 0.20 to 6400 footcandles, 2 to 64,000 Lux.

Display: Vertical digital/analog bar graph which consists of 72 black liquid-crystal bars (6 bars per f-stop), that rise and fall depending on the light intensity. The scale can be used in three different display modes (Bar, Floating Zone and Dedicated Zone), and in three different measurement modes (f-stops, footcandles and Lux).

Display Modes:

1. Bar mode is similar to a needle-reading meter, except that the movement is up and down instead of left to right.

2. Floating Zone mode: a single flashing bar forms a solid bar that graphically indicates the range of illumination in the scene. It can also be used for the measurement of flickering or blinking sources.

3. Dedicated Zone mode is used to save up to five separate measurements.

Display Range:

ISO film speed: 12 to 2500 in ⅓-stop increments.

Camera speed: 2 to 375.

Shutter Angle: 45° to 90° in 1/9 f-stop increments, 90° to 205° in 1/12 f-stop increments.

Filter factors: ⅓ f-stop to 7 f-stops.

Resolution: Digital: ⅙ f-stop. Analog: ⅙ f-stop.

Accuracy: Digital ⅙ f-stop.

Additional Functions: Memory store and recall.

Lamp: Electroluminescent backlit liquid crystal display.

Power consumption: Operating reading 5 mA with backlight on.

Power Source: One 9-volt battery.

Dimensions: 6⅝" X 3" X 1 3/16"

Weight: Approximately 10 ounces.

Minolta Luminance ft-1°, nt-1° & nt-⅓°

Type: Reflex-viewing spot-reading automatic/manual luminance meter.

Light Sensor: Silicon Photovoltaic cell with 1° (⅓° in model nt-⅓°) of acceptance.

Viewing System: Focusing through-the-lens reflex type. Objective lens 85mm f/2.8. Angle of view: Circular 9° with central 1° (⅓° in model nt-⅓°) marked circle. Magnification: 2.96X focused at infinity.

Measuring Capability: Direct readout of illuminance level in footlamberts or candelas.

Measuring Range:

Model ft-1°: 0.01 to 99900 ft-L (0.01 step)

Model nt-1°: 0.1 to 99900 cd/m^2 (0.1 step)

Model nt-⅓°: 1.0 to 99900 cd/m^2 (0.1 step)

Display Range: Red (+) LED's at the right of the number display indicates 10X and 100X the display reading.

Accuracy: Within ±4% of C.I.E. standard ±1 digit in last display position.

Screen-flicker accuracy: Within 1% of average luminance with projection cycle of more than 72 Hz and duty of 7% (projector at 24 fps).

Analog Output: Output voltage: 1V over full scale. Output impedance: 10 kilo-ohms.

Power Consumption: 6 mA in analog mode. Meter can monitor changes in luminance for a period up to 40 hours.

Power Source: One 9-volt battery (Eveready 216 or equivalent).

Estimated Battery Life: Approximately 1 year with normal use.

Dimensions: 2 ⅞" X 6⅜" X 4$^{11}/_{16}$"

Weight: 18⅛ ounces, without battery.

Spectra Cinespot 1° Spot Meter

Type: Through-the-lens viewing spot-reading automatic/manual luminance meter.

Light Sensor: Silicon Photovoltaic cell with 1° angle of acceptance.

Viewing Optics: 1.6X magnification, erect system with focusing eyepiece.

Measuring Capability: Direct readout of illuminance level in foot lamberts or candelas.

Measuring Range: Low Range 0-30 fL (or 0-100 cd/m^2) readings legible down to 0.5fL. High Range 0-300 fL (or 0-1,000 cd/m^2), upper limit may be increased by use of accessory 10X or 100X attenuators.

Spectral Response: Within $\pm$4% (by area) of CIE Photopic Luminosity Function.

Accuracy: $\pm$1% of full scale or $\pm$5% of reading (whichever is greater).

Error Due To Chopped Light: $\pm$ 0.5 % at 24 cycles/second.

Power Source: One 6-volt battery. (Eveready 544 or equivalent).

Estimated Battery Life: Approximately 1 year with normal use.

Dimensions: 5" X 2" X 6.4"

Weight: 15 ounces.

Spectra Professional IV

Type: Hand-held exposure meter for measuring incident and reflected light.

Light Sensor: Silicon Photovoltaic cell, computer selected glass filters tailored to spectral response of the film. Swivel head 270 degrees.

Measuring Capability: Direct readout of photographic exposures. Also measures illuminance level in foot-candles and Lux.

Measuring Range: One million to one (20 f-stops) direct-reading multiple-range linear circuit controlled by microcomputer.

Display Range: ISO film speed: 3 to 8000 in ⅓ stop increments.

Camera speed: 2 to 360 frames per second.

Resolution: Digital: 0.1 f-stop. Analog: 0.2 f-stops.

Accuracy: Digital: 0.05 f-stop.

Additional Functions: Memory store and recall.

Lamp: Optional electroluminescent lamp for backlit liquid crystal display.

Power Consumption: Operating (reading) 5mA. Data retention 5uA.

Power Source: One 6-volt battery. (A544, PX28L or PX28).

Estimated Battery Life: Approximately 1 year with normal use.

Dimensions: 5½" X 2½" X 2".

Weight: Approximately 6 ounces.

Much of the material in this section of the manual is basic, but reference should be made to Don Norwood, ASC and Eastman Kodak Company for the gray card information.

Crystal-Controlled Cordless Camera Drive System

by Edmund M. DiGiulio
ASC Associate Member
Cinema Products Corporation

When recording sound simultaneously with filming, it is necessary to provide some means of guaranteeing that the soundtrack will be in perfect synchronism with the film. In single-system filming, where the sound is recorded directly on the film in the camera, on either a magnetic strip or optical sound track, this is automatically accomplished. In double-system filming, however, speed variations of camera and recorder, as well as the elasticity of the magnetic recording tape, require some positive means of keying the dialogue to its appropriate film frame.

The inclusion on the sound recorder of a second, parallel sync or "Pilotone" track is the most common method in use today. The sync pulse is typically a sine wave of 50 to 60 Hz with an RMS amplitude of approximately 1 volt. Back in the lab, a "resolver" transfers the sound track onto oxide-coated sprocketed film stock using the sync track as a reference so that the transferred sound track will correspond, frame for frame, with the camera negative. Until the introduction of crystal sync systems, this sync pulse was derived from the camera by another means.

If, for example, the camera was being driven by a DC motor, with some sort of governor control to hold it fairly accurate at 24 fps, a sync pulse generator geared to the movement or motor shaft could be employed to provide the sync pulse output. A cable conducts the sync pulse from camera to sound recorder. (See Fig. 1.)

An alternate method, used most commonly on soundstages but also on location, was for the camera to be driven by a synchronous motor operating from AC mains, or on location from an AC generator. In this case the recorder used the mains or alternator as a sync pulse source (Fig. 2).

In crystal drive systems, a crystal oscillator of extremely high accuracy at (or in) the recorder provides the sync pulse. The camera is in turn driven by a specially designed DC motor and control circuit which is capable of operating in exact synchronism with a self-contained crystal oscillator of comparable accuracy (Fig. 3). The crystal-controlled motor operation is analogous to that of a sync motor operating in synchronism with AC mains. In the case of AC synchronous operation, both camera and recorder are tied to the AC source as a common reference. In the case of crystal operation both camera and recorder reference to self-contained crystal oscillators which are so accurate that the effect is the same as if they had been tied together.

Since the reference is absolute, any number of cameras can be operated simultaneously, in perfect synchronism, with a single recorder. The basic advantage to the crystal drive system, however, is that it eliminates the need for power cables and any umbilical connection between the camera and recorder. Most crystal motors commonly in use today employ some means of indicating when the motor is running out of synchronism. This is usually a beep tone or a blinking light. This is a reliable indicator of good synchronous operation and is a corollary benefit.

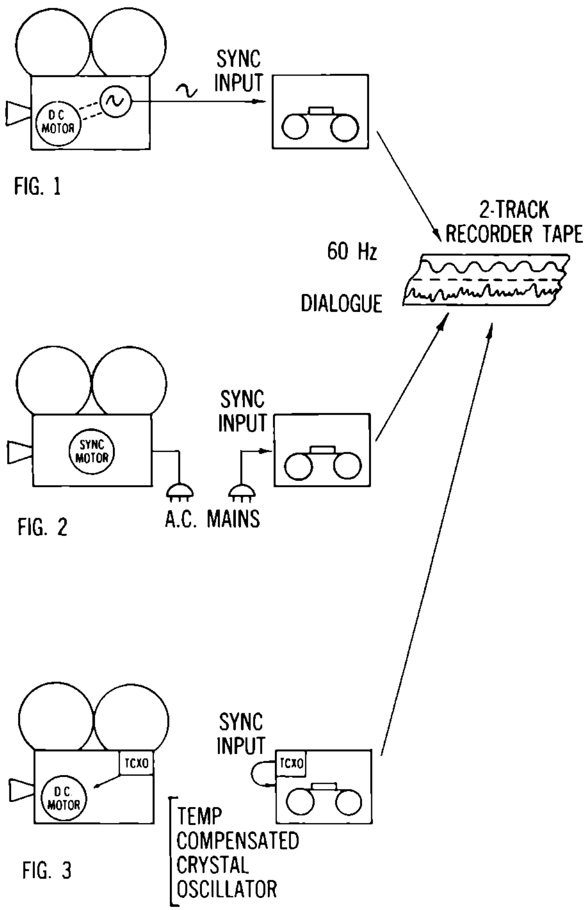
Time Code

While the cordless crystal drive system guarantees synchronous operation between camera and recorder, it does not provide a start mark. Slating, therefore, must be done either with a conventional clapstick, or by wireless transmission of start and scene information.

A more promising approach is that of absolute time reference or "crystal clock." In this system we use an extremely accurate crystal time-base generator (or clock) capable of marking the film at regular intervals with a precise time reference and other pertinent production data. A similar or identical clock would also be plugged into the recorder to mark the sound record in identical fashion. It is only necessary for both crystal clocks to be time-synchronized at the beginning of the day and then be plugged into the camera and the recorder, so that for the rest of the day's shooting, the mark made on the film and on the sound record would always occur at precisely the same time. The effect would be the same as if we operated clapsticks at regular intervals of one second or more during the entire day. As in the case with crystal-controlled synchronization, any number of cameras could be tied to one recorder or several recorders.

The EBU (European Broadcasting Union) proposed such a time-code system in the early '70s. It involved the

METHODS OF SYNCHRONIZING CAMERA AND RECORDER



recording of time information optically on the film in the form of 16 binary-coded decimal digits per second. In accordance with this proposal, a number of European equipment manufacturers designed and offered for sale equipment incorporating the ability to record or read the EBU time code. This approach did not have much success in the marketplace, however, as the only function it served was to permit the automatic syncing of dailies. Accomplishing this single task did not prove to be cost-effective.

Starting in the late '70s, SMPTE in the United States began exploring the possibility of recording the SMPTE time code that had already been established for use with videotape, on both picture and soundtrack. By using the same code that was already a standard for videotape (uniquely identifying every frame), it was felt that a further and more important function could be served than just syncing up dailies. By transferring the picture and also the SMPTE time code from film to tape, one could realize the tremendous efficiencies of videotape editing and then use the SMPTE time code as the means of conforming the edit decisions from the tape to film.

From the first experiments by EBU through the early efforts by SMPTE, the proposed method for recording time code in the camera was optical. This approach has the advantage of being permanent and easily duplicated in the printing process. This technology is changing rapidly and the most up-to-date information can be obtained from manufacturers' representatives.

Camera Supports

Cranes

Louma Crane by Samcine

The Louma Crane is a modular crane which incorporates a remotely-controlled pan and tilt camera mounting system. It may be fitted to any suitable dolly, including Elemack Cricket, Hornet or Rolls types.

The complete crane, excluding individual weights, is packed in 10 Samcine rigidized cases. Maximum weight of any single part is 116 pounds.

In largest configuration, arm with reinforcement stays: Arm length 26', weight tubes 10' 10". Maximum height of optical axis with limited pan (fulcrum 10' high): 31' 4 ½". Maximum height of optical axis with 360° pan (fulcrum 8' 4"): 25' 3". Maximum dimension of reinforcement stays: 5' 8 ½" wide, 2' 11" above tube axis. Weight excluding dolly, 990 pounds. Smaller configuration without extension stays: arm length 15' 7" or 3' 5".

Maximum angle of tilt upward with 360° panning: 45°; downward: 65°. Maximum angle of tilt upward with limited pan: 60°.

Minimum dimension of an aperture through which crane head will pass while supporting a Panaflex camera: 1' 7 ¼" wide x 2' 3" high. Minimum height of optical axis of Panaflex camera above under-side of platform: 7 ¼".

The Louma Crane command console consists of an electronically-operated remote camera pan and tilt system operated by two handles exactly as if it were a regular geared camera head like a Panahead, Samcine Moy or Worrall. The command center incorporates a television monitor connected to the TV viewfinder system of the camera. A second closed-circuit TV camera is used to relay lens calibration information to the focus assistant, who is able to remotely control the focus, aperture and zoom (if fitted) functions of the lens.

The Crane by Matthews

Portable folding crane system. Can be mounted on three types of wheels: pneumatic, hard, or flotation. (Special track is available.)

Basic kit:
Largest dimension of a disassembled module is 8 feet.
Transport weight: 2000 pounds with weights
Set up: Pedestal 64" x 64"
Maximum lens height: 16' 6" with typical camera.
Minimum height: 2' 6"
Reach: 144"
Recommended load: 550 pounds

Junior kit:
Transport weight: 140 pounds
Maximum height: 108"
Minimum height: Floor (Fulcrum height 36")
Reach: 120"

Extension kit:
Transport weight: 100 pounds
Maximum height: 24'
Minimum height: Minus 19'4"
Reach: 18'4"

Maxi Extension Kit:
Transport weight: 105 pounds

MC 88 Crane

Designed exclusively for use with Cam-Remote and other remote-control devices. The boom length is adjustable and requires no support cables.

Boom lengths:
Short boom: 10'
Medium boom: 18' 6"
Long boom: 22' 6"

Nettman Cam-Remote by Matthews

A remotely controlled head for film and television production cameras. The head is precisely controlled over a continuous 360° range in both pan and tilt. All lens functions are controlled via powerful and accurate motors. The system can be used on camera cars, lighting grids by Matthews, the MC88 Crane or any other production cranes. User friendly controls employing "Worrall-type" hand wheels or joystick systems are provided for the operator. The head is normally controlled via cables but may be controlled via a serial link system.

Chapman-Super Nova Mobile Crane

Location and stage crane.

Width:	7' 7" (232 cm)
Length:	20' (589 cm)
Length with battery pack:	21' 6"
Minimum Height:	9' 3" (282 cm)
Lens Height (without risers):	27' (823 cm)
Drop Down:	8' (244 cm)
Maximum Reach:	17' 3" (526 cm)
Maximum with 12' extension:	29' 3" (884 cm)
Traveling Weight:	28,500 lbs.
Vert. Travel of Boom above grnd.:	23' (701 cm)
(with hydraulic riser):	27' (823 cm)
Vert. Travel of Boom below grnd.:	2' 7"
Boom Length fully extended:	30'11"
Max Length Boom & chassis:	37' 4"
Tread:	6' 4"
Wheel Base:	13'10"
Maximum Speed (batteries):	12' per sec
Minimum Turn Radius:	23' 3"
Maximum lifting capacity:	1,750 lbs.

Mercury Balancing Automatic leveling system.
Patented Feathering valves.
860 DC Ampere hours available.
Two 72-volt systems used in series or paralleled, total 144 volts.
Six wheel drive, six wheel steering.

Chapman-Titan II Mobile Crane

Location and stage crane.

Width:	7' 7" (232 cm)
Length:	20' (589 cm)
Length with spare tire:	21' 5"
Minimum Height:	9' 3" (282 cm)
Lens Height (without risers):	27' (823 cm)
Drop Down:	8' (244 cm)
Maximum Reach:	17' 3" (526 cm)
Maximum with 12' extension:	29' 3" (884 cm)
Traveling Weight:	26,000 lbs.
Vert. Travel of Boom above grnd.:	23' (701 cm)
(with hydraulic riser):	27' (823 cm)
Vert. Travel of Boom below grnd.:	3' 7"

Boom Length fully extended:	30' 11
Max Length Boom & Chassis:	37' 4"
Tread:	6' 4"
Wheel Base:	13′ 10"
Maximum Speed (batteries):	12' per sec
Minimum Turn Radius:	23' 3"
Maximum Lifting Capacity:	1,500 lbs.

Mercury Balancing.
Automatic leveling system, Patented Feathering valves.
Six-wheel drive, six-wheel steering.

Chapman-Super Apollo Mobile Crane

Location and stage crane.

Max. Lens Height:	19' 5"
Maximum Reach Beyond Chassis:	18' 9"
Vert. Travel of Boom above grnd.:	15' 5"
Vert. Travel of Boom below grnd.:	10.5"
Chassis Width:	7' 7.5"
Tread:	6' 4"
Wheel Base:	10' 6.5"

860 DC Ampere hours available.
Mercury Balancing.
Patented Feathering valves.

Maximum lifting capacity:	1,700 lbs.
Chassis Length:	15' 11"
Minimum Chassis Height:	8' 4"
Traveling Weight:	19,500 lbs.
Maximum Speed (batteries):	12' per sec
Minimum Turn Radius:	21' 2"

Four-wheel drive and four-wheel steering.

Chapman-Zeus Stage Crane

Lens Height:	16' 2"
Maximum Reach:	14' 6"
Vert. Travel of Boom above grnd.:	12' 2"
Vert. Travel of Boom below grnd.:	3' 0"
Chassis Width:	4' 0"
Chassis Length:	7' 10"
Minimum Chassis Height:	5' 8"
Maximum length boom + chassis:	19' 4"
Crane operating weight:	7,200 lbs.
Tread:	44"

Wheel Base:	5' 7"
Maximum Speed:	11.2' per sec
Minimum turn radius:	7' 9"
Maximum lifting capacity:	1,500 lbs.

Chapman-Electra I Stage Crane

Lens height:	11'
Minimum height:	ground
Reach:	7'
Max. reach (with 3' extension):	10'
Chassis width:	41"
Chassis length :	81"
Minimum chassis height:	4' 10"
Weight:	3,000 lbs.
Maximum lifting capacity:	1,500 lbs.
Minimum turning radius:	7' 3"

*Equipped with solid wheels only.

Chapman-Nike/Electra II Stage Crane

Lens height:	14'
Maximum reach:	14' 6"
Vert. Travel of Boom above grnd.:	10'
Vert. Travel of Boom below grnd.:	2'
Chassis width:	44"
Chassis length:	7' 3"
Minimum chassis height:	5' 3.5"
Maximum length boom & chassis:	16' 9"
Crane operating weight:	5,600 lbs.
Tread:	40"
Wheel base:	5'
Maximum speed:	9' 9.6" per sec.
Minimum turn radius:	6' 3"
Maximum lifting capacity:	1,500 lbs.

Dollies

Chapman-Sidewinder Dolly

For indoor or outdoor use. For television or motion picture productions.

Lens height (w/o added risers):	9'
Low lens height (with extension):	22"
Lifting capacity:	900 lbs.

Max. horizontal reach (w/extension):	38"
Chassis length:	64"
Chassis width:	38.75"
Minimum Chassis height:	41"
Weight:	1,450 lbs.

Crab or Conventional steering.
Electric drive, full 24 hours of use with each charge.
Dual rocker system, three point suspension.

Elemack Cricket Dolly

Convertible three or four wheel dolly with center hydraulic pedestal.

Basic Unit (Collapsed size):	25½" x 25½" x 25¾"
Lens height:	5' 11"
Low lens height:	3' 11"
Lifting capacity:	260 lbs.
Width (wheels spread:	27 7/16"
Minimum Tracking Width:	17"
Weight:	300 lbs.

Crab or Conventional steering.
Accessories: Electro hydraulic lift drive.
Several configurations of mini cranes.
Seats and brackets; running boards.
Curved and straight track sections in two gauges.
Articulated bogey wheels for track use.

J. L. Fisher Crab Dolly

Four-wheel dolly.

Chassis width:	30"
Chassis length:	67"
Weight:	446 lbs.
Max. Height:	61"
Max. Height (w/ low level head):	50"
Min. Height:	14"
Min. Height (for storing or shipping):	20"
Min. Height (with low level head):	3"

Elevation: AC, DC, or manual.
Camera mount ahead of wheels.
Full crab-brakes in rear wheels.
Four or two wheel selection for crab or steering shots.
Solid or pneumatic tires.

FGV Panther

Column drive may be operated manually or its ascent and descent phases may be stored and recalled using built-in computer memory.

Minimum size for transport:	
Length:	29" (73.6 cm)
Width:	26.8" (68 cm)
Height:	28" (71 cm)
Total weight for transport:	260 lbs. (118 kg)
Maximum tracking width:	24.4" (62 cm)
Minimum tracking clearance:	14" (36 cm)
Minimum Battery performance per charge, column moves:	200
Max. load using column drive:	551 lbs. (250 kg)
Max. w/column retracted:	1,763.7 lbs (800 kg)
Input voltage tolerance:	18-28 V
Maximum power consumption:	24 A
Battery unit specifications:	24 V 9.5 Ah
Charge cycle standard charger:	10 hours
Charge cycle charge/ballast unit:	5 hours
Max. lens height (Arri 35 BL on Sachtler Studio Head):	74.8" (190 cm)
Min. lens height (35 BL on Sachtler Studio Head+adapter):	17.7" (45cm)
Column range:	27.6" (70 cm)
Max. lens height w/Super-Jib (35 BL on Sachtler+50cm Bazooka):	118" (300 cm)
Max. lens height w/Lightweight-Jib (35BL on Sachtler Studio Head):	106" (270 cm)

Kombi-Wheels for track or floor use.
Program stores up to 5 drive sequences.
Integrated battery maintains program memory.
Continuously variable speeds.
Modular quick-change circuit cards.

Camera Stabilizing Systems

by John Jurgens
Cinema Products Corporation

Modern camera stabilizing systems enable a camera operator to move about freely and make dolly-smooth hand-held shots without the restrictions or the resultant image unsteadiness encountered with prior methods. These systems transfer the weight of the camera unit to the operator's body via a support structure and weight distribution suit. This arrangement frees the camera from body-motion influences. It allows the camera to be moved by the operator through an area generally defined by the range through which his arm can move.

Camera smoothness is controlled by the "hand-eye-brain" human servo system that we use to carry a glass of water around a room or up and down stairs. Viewing is accomplished through the use of a video monitor system that displays an actual through-the-lens image, the same image one would see when looking through a reflex viewfinder. The advantage of these camera stabilizing systems is that the camera now moves as if it were an extension of the operator's own body, controlled by his internal servo system, which constantly adjusts and corrects for body motions whether walking or running. The camera moves and glides freely in all directions — panning, tilting, booming — and all movements are integrated into a single fluid motion which makes the camera seem as if it were suspended in mid-air and being directed to move at will. These camera stabilizing systems turn any vehicle into an instant camera platform.

As with remotely controlled camera systems, servo controls may be used for control of focus, iris and zoom on the camera lens.

Cinema Products Steadicam (Universal Model III)

The Steadicam system consists of a stabilizing support arm which attaches at one end to the camera operator's vest and at the other end to a floating camera mounting assembly which can accept either a 16mm, 35mm or video camera. The comfortable, adjustable, padded, close-fitting camera operator's vest is an effective and sophisticated weight distribution system. It transfers and distributes the weight of the Steadicam system (including camera and lens) across the operator's shoulders, back and hips. The arm mounting plate may be quickly reversed to mount the stabilizer arm on the right or left side of the front plate.

The stabilizer support arm is an articulated support system which parallels the operator's arm in any position, and almost completely counteracts the weight of the camera systems with a carefully calibrated spring force. The double-jointed arm maximizes maneuverability with an articulated elbow hinge, which frees the arm to move 380 degrees horizontally from the elbow. One end of the arm attaches to either side of the vest front plate, allowing the operator to change for left- or right-handed operation. A free-floating gimbal connects the stabilizer support arm to the camera mounting assembly.

The camera mounting assembly consists of a central support post, around which the individual components are free to rotate as needed. One end of the post supports the camera mounting platform, while the other end terminates in the electronics module. The film or video camera can rotate 180 degrees to left or right on its platform. The video monitor is attached to a pivoting bracket which may also slide up, down or around the post. There are scale markings on each of the components so that adjustments for various modes of shooting may be documented and repeated. The video viewfinder monitor features a kinescope tube of high brilliance with multiple layer coatings to eliminate reflections and permit viewing in sunlight. An electronic level indicator is visible on the CRT viewing screen in the bottom of the picture area. Electronically generated frame lines can be adjusted to accommodate any aspect ratio. Positions of the components may be reversed to permit "low mode" configuration. The Steadicam unit is internally wired to accept wireless or cable-controlled remote servo systems for lens control. A quick-release mechanism permits the operator to divest himself of the entire Steadicam unit in emergency. A 12V/3.5A NiCad battery pack mounts on the electronics module to supply the viewfinder system and film or video camera.

Panavision Panaglide

The Panavision Panaglide system is an integrated stabilizer system incorporating specially lightened cameras: 35mm Panaflex for sync sound, 35mm Pan-Arri for non-sound, 65mm Hand-held Reflex and 16mm Panaflex Elaine; a Panacam model supports a video camera.

The support consists of a reinforced padded vest to which an adjustable articulated suspension arm is pivoted. The arm uses either a pneumatic/spring or a spring/cable shock-absorbing system. A vertical telescoping staff attached to the suspension arm carries a camera platform on one end and an electronics/battery unit on the other. The unit can be inverted, with the camera mounted either at top or bottom of the staff. All swing joints and spring tensions are adjustable.

The viewfinder uses video reflexed from the camera lens, a 3½" high brightness monitor, flexibly positioned for convenience, and superimposed frame lines. Image can be electronically deanamorphosed or can be reverse-scanned for over-the-shoulder shooting.

The Panaglide also features remote focus and iris controls; illuminated level indicator; 24V battery; crystal sync or variable camera speeds; digital fps and footage counter; and a quick-release vest for safety of operator.

Aerial Mounts

Continental Camera (Door, Belly and Outside mounts)

Door mounts for video/16mm/35mm are Master & Magnum mounts (cameras up to 30 lbs) and the Magnum Elite (cameras up to 100 lbs). Belly mount can accommodate cameras up to 40 lbs; 180° field-of-view, tilts up 10°, down 90°. Can be mounted with camera looking fore or aft, and will accommodate zoom lenses, though useful only at wide-angle portion of lens. Huffy mount is a belly mount for cameras up to 100 lbs; will allow 160° field-of-view. Both belly mounts attach to skid tubes of Bell 206/206L helicopters, fitted with standard or high skids. Outside mount attaches to Hughes 500 C or D model helicopters; must be flown with specially qualified pilot. 337 FAA inspection required for belly mounts, STC approvals for door mounts. Also unique body stabilizer, remote head and periscope lens.

Gyrosphere (Gyro-Stabilized)

Two Gyrosphere systems were built in the mid-80's using earlier Wescams as their starting point; the extensive upgrade and redesign work represented many "firsts": Vertical reference gyros to automate ability to hold level horizon; integration of the Speed Aperture Computer with an aerial system; improved stabilization and camera steering enabled faster and more accurate pans/tilts with less lag; improved ergonomics with hand-held joysticks; prime lens capability. Mixed analog and digital electronics. Vertical slit curved plexiglass window.

Camera: Modified Mitchell Mk 2 (3-36 fps) with underslung XR-35 magazine. Also available with *Empireflex* VistaVision camera from ILM (2-48 fps) or Vistacam from BCS (2-48 fps).

Spacecam (Gyro-Stabilized)

Unique gyro-system using heavier gyro wheels spinning at greater RPMs. Patented powered main cardin-joint allows more responsive and faster pans/tilts. Digital electronics allow many abilities (i.e., dutching in sync with helicopter turns). The lens looks through a windowless port. Unique brackets for modified Hughes 500 helicopter includes nose position as well as sides; unique nose and tail position brackets for JetRanger helicopters.

Camera: custom built light-weight body and magazine utilizing Mitchell NC movement (0-36 fps), as well as modified Mitchell Mk 2 (0-60 fps); VistaVision (0-90 fps) and Showscan (0-72 fps). All cameras incorporate patented SpaceCam fiberoptic video assist system with superior low-light capability.

Tyler Camera (Door and Nose mounts)

Middle-Mount II for video/16mm/35mm; Major-Mount for Arri 35-3, Arri BL or Mitchell Mk 2 (with special horizontal magazine adapter), as well as larger formats up to Imax. Tilting nose mount (35mm/16mm/video) can be used with prime lenses for Arri 35-3 as wide as 9.8mm. Tilts from up to include rotor blades to upside-down/rearward; also can be mounted with camera looking aft. Does not accommodate zoom in 35mm, but allows zoom (if limited to wide end of lens) for video/16mm cameras. Attaches to nose of Bell 206/206L helicopters fitted with standard or high skids; can be fit to A-Stars/Twin-Stars if aircraft owner has special adapter brackets installed. Available large format tilting nose-mount for cameras up to Imax; same tilt range as standard nose mount; designed to attach to skid tubes of Bell 206/206L helicopters, fitted with standard or high skids. FAA STC approvals for all mounts. Also unique crane-mount, gyro-stabilized boat mount and jib arm. Exterior gyro-stabilized mount allows fast pan/tilt rates, fast lens changes; uses Arri 3 with custom 1000' top-loaded magazine allowing low lens position for on-the-ground applications. Tilt range to inverted 90 degrees. Color video tap as well as bore-sighted video camera for low-light viewing. The lens looks through a windowless port. Ability to lock off camera to mimic "banking horizon look" of nose mount.

Wescam (Gyro-Stabilized)

The original (early 1960's) gyro-stabilized camera mount. Current generation features all digital electronics with unique abilities and may be remotely operated at the end of a 500′ cable or by radio link. The lens looks through an optically flat anti-reflection coated glass window which tracks with the lens during pans/tilts. This patented window system minimizes internal reflections from back or side light; also permits use of polarizing filter, not possible with curved plexiglass, which creates a rainbow of interference lines. FAA STC approvals for all mounts. 120 Video units worldwide on Goodyear blimps, etc. Unique mounting brackets for Super Puma, MBB-105, 206L and Huey helicopters, as well as boats. Also specialized track for on-the-ground moves up to 26 mph using radio link control.

Camera: Modified Mitchell Mk 2 (1-60 fps) with underslung Arri BL magazine. Also available with *Empireflex* VistaVision camera from ILM (2 - 48 fps).

Preparation of Motion Picture Camera Equipment

by
Marty Ollstein,
Michael Hofstein & Tom 'Frisby' Fraser

All motion-picture camera equipment must be periodically inspected and maintained to insure proper performance in production. Camera rental facilities employ skilled technicians to service and repair equipment after each use. Once the equipment leaves the rental house, however, the camera crew must service that equipment throughout the production. The camera assistant must be prepared with the right knowledge, skills, tools, and reference materials to properly maintain all equipment in the camera package.

The following is a list of procedures for the preparation of camera equipment needed to photograph a motion picture. It is the responsibility of the camera assistant to assure that all equipment and supplies needed and requested by the director of photography are present, in working order, at the start of production.

Inventory

1) Basic equipment, from the ground up: Spreader, hi-hat, tripods, tripod head, camera body, batteries, all necessary cables, magazines (small & large), lenses and housings, zoom motor and control, follow-focus unit, matte box, filters and holders, changing bag.

2) Additional accessories often requested by the director of photography: Adapter plates (quick-release, dovetail/balance, riser, tilt); speed control (for HMI lights, TV monitors, or other requirements); set of hard mattes, eyebrow, French flag; hand-held accessories (matte box, follow-focus, shoulder pad, viewfinder, magazines); viewfinder extender, leveler, heater; barneys, rain shields; obie light, 'assistant' light; videotap, monitor, recorder.

3) Supplies to be purchased by the production company: Raw stock, camera reports, film cores, empty film cans, black labpack bags, labels, cloth camera tape, paper tape, lens tissue, lens cleaning solvent, cleaning swabs, orangewood sticks, slate, spare camera fuses, rags, air cans,

felt markers, grease pencils, pens and pencils, chamois, chalk, disposable batteries.

Invoice Check

Examine the rental invoice or work order, and confirm that all equipment ordered by the director of photography is included. Make sure that all support accessories and supplies needed by the assistants to properly perform their tasks are also included. When the equipment is first received, use the rental invoice to check that all equipment and supplies that have been ordered and billed for have indeed been delivered. Confirm that the serial numbers listed on the invoice match those engraved on the equipment.

Equipment Checkout

Set up and test each piece of equipment to determine whether it is in working order. Label each case with cloth tape and marker. When a case is not being used, keep at least one latch locked to prevent an accident. Start from the ground up and build the camera system. Thoroughly check the entire package for completeness, compatibility, and proper functioning. The equipment should be clean and properly lubricated. Immediately return any piece of equipment that does not perform to your satisfaction.

The following list suggests standards by which to judge each piece of equipment. They are to be used in conjunction with the appropriate camera operation manual.

Some of the procedures described, such as testing the flange focal depth or magazine clutch and brake tension, require specialized test equipment. If the test equipment is not available, or if you encounter any other questions or problems, speak to the camera technician who prepared the package at the rental house. It is likely that he has performed the tests himself and can give you the results.

1) Spreader

a) Runners slide smoothly and lock in all positions.
b) End receptacles accommodate the tripod points and spurs, and hold them securely.

2) Tripods

a) Each leg extends smoothly and locks in all positions.

b) Top casting accommodates the base of the tripod head (flat Mitchell, ball, or other).
c) Hinge bolts that attach each leg to the top casting are adjusted to proper tension: each leg swings easily away from top casting and remains at selected angle.
d) Wooden tripods (baby, sawed-off, standard): Legs are solid and have no splits or breaks.
e) Metal or fiber tripods (baby, standard, 'two-stage'): Legs are straight and have no burrs or dents.

3) Tripod Head

a) Base (Mitchell, ball, or other) fits and locks into tripod topcasting.
b) Ball base (only) adjusts smoothly and locks securely in any position.
c) Camera lockdown screw fits into camera body, dovetail base with balance plate, riser, or tilt plate;

OR

d) Top plate of head includes a quick-release (touch-and-go) base, which accommodates a quick-release plate that bolts to camera body or any of the adapter plates.
e) Eyepiece leveler bracket and frontbox adapter on the head accommodate the leveler rod and frontbox being used.
f) Friction or Fluid Head:
    1. Pan and tilt movement is smooth.
    2. Both brake levers lock securely in all positions.
    3. Both drag knobs easily adjust the tension of movement from free movement to the tension required by the operator.
g) Gear Head:
    1. Pan and tilt movement is smooth.
    2. Both brake levers engage properly (gears may move under stress).
    3. Gears shift smoothly between low and high speeds.

4) Camera Body

a) Accommodates and locks securely to tripod head, balance plate, riser, tilt plate and shoulder pod with camera lockdown screw.
b) All rollers move freely.

c) Camera interior is clean — no emulsion buildup or film chips.
d) Camera oil and grease has been applied to lubrication points as recommended by camera manufacturer. Clean off any excess.
e) All fuses are intact and properly seated. Carry spare fuses.
f) Movement of the shutter, pull-down claw, and registration pins is synchronized. Check by carefully scribing a frame in the gate, then inching the motor back and forth manually. The film should remain stationary as long as the shutter stays open.
g) Movement of shutter and mirror is synchronized. (Check only on certain cameras, including Panavision.)
h) The "glow" that illuminates the ground glass is synchronized with the shutter — the light turns off before the shutter opens the gate. (Check only on certain cameras, including Arriflex.)
i) Camera speed holds steady at all speeds required for the production. Thoroughly test all speed control accessories being used in camera package.
j) Pitch and loop adjustments operate properly (certain cameras).

5) Aperture

a) Film gate has the correct aspect ratio.
b) Gate is clean and properly seated. To confirm this:
   1. Remove the gate and pressure pad.
   2. Clean both with a chamois, and if necessary, a proper solvent.
   3. Clean channels and holes with an orangewood stick.
c) Flange focal depth is set to manufacturer's specifications. Confirm by measurement with depth gauge.
d) Plastic gels have been removed from the gel holders.

6) Batteries and Cables

a) All batteries and cables are compatible — male pairs with female, the number of pins in connectors match.
b) Batteries hold charge and cables conduct properly. Check with voltmeter.
c) Camera motor runs film steady at desired speed while under the load of all other current drawing ac-

cessories required for the production. These may include a zoom motor, assistant light, video tap, eyepiece heater, and viewfinder "glow." Check with each battery.

7) Lamps

Lamps that require bulbs may include an out-of-sync monitor lamp, running lamp, start-marking lamps (older cameras), and others. All lamps must light at the proper time. Replace all defective bulbs.

8) Variable Shutter

Mechanism operates through the full range of openings. Set shutter at opening selected by the director of photography.

9) Viewfinder

a) Ground glass is properly seated. Ground glass depth is within manufacturer's specifications. Check with portable collimator.
b) The image is clear and clean. If necessary, remove ground glass and carefully clean with proper solvent and lint-free lens tissue.
c) Ground glass is marked for the aspect ratios requested by the director of photography.
d) Eyepiece focuses easily to the eye of the operator (adjust diopter until the grains of the ground glass appear sharp).
e) Viewfinder extender fits properly between camera body and eyepiece. Magnifier and ND filter operate properly.
f) Viewfinder extender leveling rod attaches securely to extender and to bracket on tripod head. Rod extends smoothly and locks in all positions.
g) Viewfinder illumination, or "glow", is synchronized with the shutter.

10) Lenses

a) Each lens and lens housing is compatible with — and seats securely in — the mount in the camera body.
b) Front and rear elements are clear and clean, free of large chips and scratches, or any fingerprints or dirt. Blow off loose material with a blower bulb, clean off

grease with lint-free lens tissue and proper lens cleaning solvent.

c) Iris leaves are flat and fall properly in place as they are closed from the full open position.
d) Follow-focus assembly mounts properly. Focus gears thread properly on the lenses.
e) Lens focus distance markings are accurate. (See Lens Focus Calibration.)

11) Zoom Lens

a) Zoom mechanism is aligned properly and tracks smoothly.
b) The cross-hairs on the ground glass remain centered on a point throughout the zoom.
c) Lens focus distance markings are accurate at all focal lengths. (See Lens Focus Calibration.)

12) Zoom motor

a) Motor mounts securely and threads properly on the lens.
b) Zoom control unit operates motor smoothly at all speeds.
c) All cables connecting the camera, zoom control and zoom motor conduct properly when checked with a voltmeter.

13) Lens Housing

Distance and f-stop strips fit properly and match the markings on the lens.

14) Filters

a) Both surfaces of each filter are clear, clean, and free of major flaws.
b) Filters are the proper size:
   1. Filters cover entire image area of each lens being used.
   2. Filters fit properly into filter holders — on lens, lens housing, matte box, filter tray, or separate holder.
c) Filter mounting accessories accommodate all lenses used, and mount the number of filters on each lens required by director of photography.
d) Rotating mount for polarizing filter turns smoothly and locks in any position.

e) Sliding mount for graduated filters moves smoothly and locks in any position.
f) Prepare labels for each filter (tape or velcro) for display on the side of the matte box.

15) Matte Box

a) Mounts securely to camera body and extends smoothly along the supporting rods.
b) No light passes between the matte box and the lens. If necessary, acquire additional rings, filter trays or rubber 'doughnuts' to block light leaks.

16) Magazine

a) Fits snugly into the camera body.
b) Magazine doors fit and lock securely.
c) On co-axial magazines, label each "Feed" and "Take-up" door with tape.
d) Throat, film channels, and interior are clean, clear of dust or film chips.
e) Loop adjustment operates properly (certain cameras).
f) Magazine gear timing is properly adjusted — film runs smoothly and quietly through the magazine.
g) Clutch tension and friction brake tension have been measured with the proper tools and are correct.

17) Video Assist: video camera, monitor and recorder (optional)

a) Video camera (or tap) mounts securely on the camera body.
b) All cables are compatible and operate the tap, monitor and recorder.
c) The iris and focus controls adjust smoothly and produce an adequate image on the monitor.
d) The image can be centered on the monitor so that the entire film frame is visible and level.

Lens Focus Calibration

(see "Photographic Testing and Evaluation")

1) Prime Lenses
   a) 40mm or wider: set camera at 3 feet from Focus Chart. Focus lens visually, compare with lens dis-

tance markings. For more critical testing, shoot film tests of each lens.

b) Longer than 40mm: set camera at 7 feet from Focus Chart. Focus lens visually, compare with lens distance markings.

c) All lenses — focus on distant object to test sharpness at infinity.

2) Zoom Lenses: Use calibration procedure described for Prime Lenses, and repeat for several focal lengths — at 3 feet for the wide end, 7 feet for the long end, and a distant object to test infinity for both ends.

3) Note: Other lens-to-chart distances may be used, as long as the selected distance is marked on the lens barrel. The chart should fill the frame as much as possible.

4) When the eye focus differs from the scale focus:

a) Consistent from lens to lens

1. Check ground glass seating and depth measurement.
2. Check lens mount.
3. Check measurement technique and tape measure for accuracy.

b) Single discrepancy

1. Return lens for collimation.
2. If needed immediately, encircle lens barrel with chart tape and mark the correct distances.

Scratch Test

Run a scratch test for each magazine to determine if there are any obstructions in the camera or magazine mechanism that might damage the film. Load a short end of virgin raw stock in the magazine and thread it through the camera. Turn on the camera motor and run the film through for several seconds. Turn off the motor. Remove the film from the take-up compartment of the magazine without unthreading the film from the camera. Examine the film with a bright light and magnifying glass. If any scratches or oil spots appear on the emulsion or base, mark the film, still threaded in the camera body, with a felt pen at the following points:

a) where it exits the magazine feed rollers;
b) just before it enters the gate;
c) just after it exits the gate;
d) where it enters the magazine take-up rollers.

Then carefully unthread the film and examine it to determine where the damage originates. Once the problem area has been identified, check that area for dust, film chips, emulsion buildup, or burrs. Remove burrs with emery paper, and any removable obstructions with an orange-wood stick.

Make periodic scratch tests on magazines and camera during production to avoid damage to the negative.

Steadiness Test

Test steadiness of camera movement by double-exposing image.

1) Prepare chart: simple cross of one-inch white tape on black card.
2) Mark start frame in film gate with felt pen.
3) Roll 30 seconds of the chart at 50% exposure.
4) Backwind film, or rewind film in darkroom, to place start frame back in film gate (so as to thread on the same perforation).
5) Offset chart by the width of the tape, and double-expose chart.
6) Process and project to evaluate steadiness.

Daily Preparation for Shooting

1) Clean the aperture. Suggested methods:
   a) Pull the aperture plate and clean with proper solvent.
   b) Remove the lens and blow air through the lens port with blower bulb.
   c) Sight through the lens (possible with a lens 40mm or longer).
   d) Remove hairs and dust from the gate with an orange-wood stick.
2) Warm up the camera:
   a) Run the camera for several minutes without film.
   b) In cold situations, run the camera for the amount of time it would take to run one full magazine through the camera at standard speed.
3) Load proper film stock in magazines.
4) Prepare slate and camera reports.

Film Tests

(See "Photographic Testing and Evaluation.")

Film tests are requested by the director of photography. Following is a list of tests that may be useful in preparation for a production. A standard gray scale and color chip chart are often used for such tests, as well as models that resemble the subjects of the film to be photographed.

1) Lens sharpness and color balance (particularly important if lenses of different manufacturers are used on the same production): Test each lens to ensure consistent sharpness and color balance when lenses are changed. Photograph the identical subject with each lens and compare on a one-light print.

2) Film stock and emulsion batch: Test each different film stock and emulsion batch to be used on the production for color balance and exposure latitude.

3) Laboratory Processing: normal, forced, flashed. Test processing at film laboratory selected by the production. This is particularly important for determining the degree of forced processing or flashing that is desired.

4) Filters: Test the effects of various filters on chosen subjects to facilitate a selection of filters for the production.

5) Lighting: Test the look of new lighting instruments, color gels, and diffusion materials on selected subjects.

6) Makeup: Test makeup on actors under the lighting conditions planned for the production.

Tools

A proper set of tools and supplies is essential to the preparation and maintenance of motion-picture equipment. Although the production company should provide the expendable supplies, a camera assistant's personal set of tools should include most of the following items:

- blower bulb - large (6")
- lens brush - camel's hair or soft sable (1"; use only for lenses, keep capped)
- magazine brush - stiff bristles (1"-2")
- lens tissue - lint free
- cotton swabs
- lens-cleaning solvent
- 50' flexible measuring tape
- lighter fluid
- scissors - straight blade, blunt tip (2")
- tweezers forceps - curved dissecting forceps or hemostat
- ground glass puller
- ARRI SW2 - 2mm hex (for variable shutters)
- magnifying glass

small flashlight
orangewood sticks
tape:
cloth (1") black, white, and colors
paper (½") white, colors
chart (1⁄16") white - for lens barrel markings
velcro - (1") white, male & female
chalk - thick, dustless
felt marking pens
'rite-on/wipe-off' pens for plastic slates
powder puffs (to clean rub-off slates)
grease pencils - black and white
pens and pencils
film cores
camera fuses
multimeter
soldering iron
16-gauge solder
solder wick desoldering spool
folding knife
emery paper (600 grip - ferric-oxide coated)
razor blades (single-edge industrial)
rope - nylon line (⅛" x 10' long)
camera oil
camera grease
oil syringe and needle (one fine, one wide)
bubble level - small, circular
ATG-924 (snot tape)
black cloth - 2' square
set of jeweler's screwdrivers
set of hex wrenches (1⁄32" - 3⁄16" and metric)
combination pliers (6")
needlenose pliers (6"), miniature (1")
crescent wrench (6")
vice-grip pliers (4") diagonal cutters (4")
wire strippers (4")
screwdrivers (⅛", 3⁄16", ¼", 5⁄16")
Phillips screwdrivers #0, #1, #2
Arri screwdrivers #1, #2, #3

Optional Items

Additional tools are often useful — each assistant collects his or her own personal set. Following is a list of optional items that many have found to be valuable.

insert slate
color lily (gray scale and color chip chart)
gray card
electrical adapters:
    U-ground plug adapter
    screw-in socket adapter
WD-40 oil
assistant light
compass
depth-of-field charts
depth-of-field calculator
footage calculator
circle template (for cutting gels)
extra power cables
magnetic screwdriver
variable-width screwdriver
wooden wedges (to level camera)
small mirror (to create a highlight)
dentist's mirror (aids in cleaning)
alligator clips
graphite lubricant
⅜" x 16 bolt - short and long
2 one-inch C-clamps
black automotive weather stripping
small wooden plank (for mounting camera)

The Camera Assistant

The position of camera assistant requires a wide range of skills. The assistant must have technical knowledge of the camera, lenses, and a myriad of support equipment. He or she must be physically fit, capable of total concentration, and be able to retain a sense of humor under stressful conditions.

Putting the Image On Film

The section on "Exposure" together with the adjacent tables is intended as a quick-reference condensation of material explained in more detail in "Lighting," "Filters," and elsewhere in the manual.

Exposure

Most exposure meters incorporate some sort of calculator; some simple, some sophisticated. An exposure meter measures amounts of light, either incident or reflected. The calculator helps you decide how to use the measurement. There are six specific variables entering the calculation:

Variables:	Expressed as:
Film exposure index	EI, ASA/ISO
Camera Speed	FPS (frames per second)
Shutter Opening	Degrees
Lens Aperture	T-stop
Filter	Filter factor
Light	Meter reading:
	Footcandles
	Foot Lamberts

T-Stops

The "T" stop number is defined as being the true "f" stop number of a lens if it completely free from all reflection and absorption losses. The T (transmission) number represents the f-stop number of an open circular hole or of a perfect lens having 100% axial transmission. The T-stop can be considered as the "effective" f-stop. It is from this concept that the means arises for standardization of T-stop calibration. T-stops are calibrated by measuring the light intensity electronically at the focal plane, whereas f-stops are calculated geometrically. Thus f-stops are based on the light that enters a lens. T-stops are based on the intensity of the light that emerges from the rear of the lens and forms the image.

There is no fixed ratio, however, between T-stops and f-stops which applies to all lenses. The difference actually represents light losses within the elements of a given lens due to reflection from the glass-air surfaces and from absorption within the glass itself. Consequently, this factor is variable and cannot be incorporated into an exposure meter, since the meter must function in connection with many different lenses calibrated in both f-stops and T-stops.

Many cinematographers do not understand why lens and exposure tables are presented in f-stops when all professional cine lenses are calibrated in T-stops. The f-stops are required for all calculations involving object-image relationships, such as depth of field, extreme close-up work with extension tubes, etc. Such tables are based on the size of the "hole" or diameter of the bundle of light rays which the lens admits to form the image. The diameter of the f-stop will normally be the same for all lenses of similar focal length set at the same aperture. The T-stop, however, is an arbitrary number that may result in the same T-stop setting varying in aperture diameter with different lenses.

It is recommended that all professional cine lenses be calibrated in both T-stops and f-stops, particularly for color work. T-stop calibration is especially important with zoom lenses, the highly complex optical design of which necessitates a far greater number of optical elements than is required in conventional lenses. A considerable light loss is encountered due to the large number of reflective optical surfaces and absorption losses. A zoom lens with a geometrical rating of f/2, for example, will transmit considerably less light than a conventional fixed focal length lens of similar rating with fewer elements.

Exposure tables are generally based on "effective" f-stops, (which are, in fact, T-stops). Small variations in emulsion speed, processing, exposure readings, etc., tend to cancel out. Cinematographers should shoot tests with their particular lenses, meter, light and film to find best combinations for optimum results.

Other variables, such as direction and contrast of the light, are factors calculated from the experience of the cinematographer, aided by such things as photospheres and spot readings. Finally, manipulation of all the above, plus off-normal negative processing to achieve a desired "look," is from the mind of the cinematographer.

The laboratory and choice of film are closely tied to exposure. It is important to keep exposure within limits satisfactory both to the selected film and to the printing range of the laboratory.

The tables will aid exposure calculation for meters which lack settings for some of the factors or will aid in calculating constant exposure control when one factor varies from another.

Incident Key Light/T-Stop

(Foot candles)

EI/ASA	2000	1600	1250	1000	800	650	500	400	320	250
T-stop 1.4	1.25	1.5	2	2.5	3	4	5	6	8	10
1.6	1.5	2	2.5	3	4	5	6	8	10	12
1.8	2	2.5	3	4	5	6	8	10	12	16
2	2.5	3	4	5	6	8	10	12	16	20
2.2	3	4	5	6	8	10	12	16	20	25
2.5	4	5	6	8	10	12	16	20	25	32
2.8	5	6	8	10	12	16	20	25	32	40
3.2	6	8	10	12	16	20	25	32	40	50
3.6	8	10	12	16	20	25	32	40	50	64
4	10	12	16	20	25	32	40	50	64	80
4.5	12	16	20	25	32	40	50	64	80	100
5	16	20	25	32	40	50	64	80	100	125
5.6	20	25	32	40	50	64	80	100	125	160
6.3	25	32	40	50	64	80	100	125	160	200
7.1	32	40	50	64	80	100	125	160	200	250
8	40	50	64	80	100	125	160	200	250	320
9	50	64	80	100	125	160	200	250	320	400
10	64	80	100	125	160	200	250	320	400	500
11.3	80	100	125	160	200	250	320	400	500	650
12.7	100	125	160	200	250	320	400	500	650	800
14.2	125	160	200	250	320	400	500	650	800	1000
16	160	200	250	320	400	500	650	800	1000	1290
18	200	250	320	400	500	650	800	1000	1290	1625
20	250	320	400	500	650	800	1000	1290	1625	2050
22.6	320	400	500	650	800	1000	1290	1625	2050	2580

Most cinematography is at 24 frames per second. The table is calculated for foot candles incident light on a fully lighted subject at 1/50 second exposure (172.8° precisely, but 170° to 180° varies from this by less than a printer point for normally processed color negative). For photography at 1/60 second (30 frames per second, 180° shutter; or 24 frames per second, 144° shutter), use one-third wider lens stop or one

200	160	125	100	80	64	50	40	32	25
12	16	20	25	32	40	50	64	80	100
16	20	25	32	40	50	64	80	100	125
20	25	32	40	50	64	80	100	125	160
25	32	40	50	64	80	100	125	160	200
32	40	50	64	80	100	125	160	200	250
40	50	64	80	100	125	160	200	250	320
50	64	80	100	125	160	200	250	320	400
64	80	100	125	160	200	250	320	400	500
80	100	125	160	200	250	320	400	500	650
100	125	160	200	250	320	400	500	650	800
125	160	200	250	320	400	500	650	800	1000
160	200	250	320	400	500	650	800	1000	1290
200	250	320	400	500	650	800	1000	1290	1625
250	320	400	500	650	800	1000	1290	1625	2050
320	400	500	650	800	1000	1290	1625	2050	2580
400	500	650	800	1000	1290	1625	2050	2580	3250
500	650	800	1000	1290	1625	2050	2580	3250	4100
650	800	1000	1290	1625	2050	2580	3250	4100	5160
800	1000	1290	1625	2050	2580	3250	4100	5160	6500
1000	1290	1625	2050	2580	3250	4100	5160	6500	8200
1290	1625	2050	2580	3250	4100	5160	6500	8200	
1625	2050	2580	3250	4100	5160	6500	8200		
2050	2580	3250	4100	5160	6500	8200			
2580	3250	4100	5160	6500	8200				
3250	4100	5160	6500	8200					

column to the right (one ASA step lower) on the incident light table. For exposure indexes less than tabulated (which are uncommon at this time) find the column which is ten times the desired index and multiply the light by ten. Example: For EI 10, use the column under EI 100. For exposure at T stop 2, multiply 50 by 10 and the light level desired will be 500.

T-Stop Compensation for Camera Speed (constant shutter)

fps	**6**	7.5	9.5	**12**	15	19	**24**	30	38	**48**
ft/min	**22.5**	28	36	**45**	56	71	**90**	112	142	**180**
	2.8	2.5	2.2	**2**	1.8	1.6	**1.4**	1.3	1.1	**1**
	3.2	2.8	2.5	2.2	2	1.8	1.6	1.4	1.3	1.1
	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6	1.4	1.3
	4	3.6	3.2	**2.8**	2.5	2.2	**2**	1.8	1.6	**1.4**
	4.5	4	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6
	5	4.5	4	3.6	3.2	2.8	2.5	2.2	2	1.8
	5.6	5	4.5	**4**	3.6	3.2	**2.8**	2.5	2.2	**2**
	6.3	5.6	5	4.5	4	3.6	3.2	2.8	2.5	2.2
	7	6.3	5.6	5	4.5	4	3.6	3.2	2.8	2.5
	8	7	6.3	**5.6**	5	4.5	**4**	3.6	3.2	**2.8**
	9	8	7	6.3	5.6	5	4.5	4	3.6	3.2
	10	9	8	7	6.3	5.6	5	4.5	4	3.6
	11	10	9	**8**	7	6.3	**5.6**	5	4.5	**4**
	12.7	11	10	9	8	7	6.3	5.6	5	4.5
	14.3	12.7	11	10	9	8	7	6.3	5.6	5
	16	14.3	12.7	**11**	10	9	**8**	7	6.3	**5.6**
	18	16	14.3	12.7	11	10	9	8	7	6.3
	20	18	16	14.3	12.7	11	10	9	8	7
	23	20	18	**16**	14.3	12.7	**11**	10	9	**8**
	25	23	20	18	16	14.3	12.7	11	10	9
	28	25	23	20	18	16	14.3	12.7	11	10
	32	28	25	**23**	20	18	**16**	14.3	12.7	**11**
	36	32	28	25	23	20	18	16	14.3	12.7
	40	36	32	28	25	23	20	18	16	14.3
	45	40	36	**32**	28	25	**23**	20	18	**16**

60	76	**96**	120	150	**192**	240	300	**384**	484
225	285	**360**	450	562	**720**	900	1125	**1440**	1815
.9	.8	**.7**							
1	.9	.8	.7						
1.1	1	.9	.8	.7					
1.3	1.1	**1**	.9	.8	**.7**				
1.4	1.3	1.1	1	.9	.8	.7			
1.6	1.4	1.3	1.1	1	.9	.8	.7		
1.8	1.6	**1.4**	1.3	1.1	**1**	.9	.8	**.7**	
2	1.8	1.6	1.4	1.3	1.1	1	.9	.8	.7
2.2	2	1.8	1.6	1.4	1.3	1.1	1	.9	.8
2.5	2.2	**2**	1.8	1.6	**1.4**	1.3	1.1	**1**	.9
2.8	2.5	2.2	2	1.8	1.6	1.4	1.3	1.1	1
3.2	2.8	2.5	2.2	2	1.8	1.6	1.4	1.3	1.1
3.6	3.2	**2.8**	2.5	2.2	**2**	1.8	1.6	**1.4**	1.3
4	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6	1.4
4.5	4	3.6	3.2	2.8	2.5	2.2	2	1.8	1.6
5	4.5	**4**	3.6	3.2	**2.8**	2.5	2.2	**2**	1.8
5.6	5	4.5	4	3.6	3.2	2.8	2.5	2.2	2
6.3	5.6	5	4.5	4	3.6	3.2	2.8	2.5	2.2
7	6.3	**5.6**	5	4.5	**4**	3.6	3.2	**2.8**	2.5
8	7	6.3	5.6	5	4.5	4	3.6	3.2	2.8
9	8	7	6.3	5.6	5	4.5	4	3.6	3.2
10	9	**8**	7	6.3	**5.6**	5	4.5	**4**	3.6
11	10	9	8	7	6.3	5.6	5	4.5	4
12.7	11	10	9	8	7	6.3	5.6	5	4.5
14.3	12.7	**11**	10	9	**8**	7	6.3	**5.6**	5

Shutter Angle/f.p.s./T-stop change
(for 24 or 30 f.p.s. projection)

f.p.s.	**24**	22	20	**19**	18	16	**15**	14	**12**	**9.5**	**7.6**	**6.**	**4.8(5)**	**3.8(4)**	**3**	**2.4**
f.p.s.	**30**	27	25	**24**	22	20	**19**	17	**15**	**12**	**9.5**	**7.6**	**6.**	**5(4.8)**	**4(3.8)**	**3**
Exposure change in T-stops	0			**⅓**			**⅔**		**1**	**1⅓**	**1⅔**	**2**	**2⅓**	**2⅔**	**3**	**3⅓**
Maximum Shutter																
	235°	215°	196°	**188°**	176°	157°	**147°**	137°	**118°**	**93°**	**74°**	**59°**	**47°**	**37°**	**29°**	**24°**
	200	183°	167°	**158°**	150°	133°	**125°**	117°	**100°**	**79°**	**63°**	**50°**	**40°**	**32°**	**25°**	**20°**
	180	165°	150°	**143°**	135°	120°	**113°**	105°	**90°**	**71°**	**57°**	**45°**	**36°**	**29°**	**23°**	**18°**
	170	156°	142°	**135°**	128°	113°	**106°**	99°	**85°**	**67°**	**54°**	**43°**	**34°**	**27°**	**21°**	**17°**
	150	138°	125°	**119°**	113°	100°	**94°**	88°	**75°**	**59°**	**48°**	**38°**	**30°**	**24°**	**19°**	**15°**
	140	128°	117°	**111°**	105°	93°	**88°**	82°	**70°**	**55°**	**44°**	**35°**	**28°**	**22°**	**18°**	**14°**
	135	124°	113°	**107°**	101°	90°	**84°**	79°	**68°**	**53°**	**43°**	**34°**	**27°**	**21°**	**17°**	**14°**

If it is desired to slow the camera without varying the lens stop but maintain constant exposure:

If it is desired to reduce exposure without varying the lens stop:

If it is desired to reduce the exposure time per frame without reducing exposure:

This table gives shutter angles in one-third T stop exposure intervals (bold columns) as well as for some camera speeds in less than one-third stop intervals.

Color Balancing for Existing Fluorescent Lighting

©David L. Quaid, ASC

Common fluorescent lights	Using existing fluorescent lighting unfiltered							Filtering fluorescent lights to match photo lights			
(See page 242 for comprehensive listing)	Camera filters (Kodak or equivalent)				Photo lamp filters (Rosco Cinegel or equivalent)			Camera filter: None (Tungsten negative or reversal)		Camera filter: Tungsten Negative: #85 Daylight film: None	
	3200K film	EI	5500K film	EI	3200K	EI	5500K	To match 3200K	EI	To match 5500K	EI
Cool white	CC50R +#81A +CC05M +#85B	1⅔	CC30M	⅔	Full blue 50 +Plusgreen +Quarter blue +¼Plusgreen	⅔	Plusgreen +Third blue	Fluorfilter +½Minusgreen	0	Minusgreen	0
Cool white deluxe	#85C +CC05M	⅔	#82C +CC05M	1⅓	Half blue +¼Plusgreen +Eighth blue	⅓	MT54 +Eighth Blue +UV Filter	Sun ½ CTO +¼Minusgreen +Quarter blue	- ⅓	Quarter blue +¼Minusgreen +Eighth blue	0
Warm white	CC30M +#81EF	1⅓	CC50B +CC15M	1⅔	Half blue +Plusgreen +Quarter blue	0	Plusgreen +½Plusgreen +Sun ⅛ CTO	Minusgreen +¼Minusgreen +Sun ¼ CTO	- ⅓	Half blue +Minusgreen +Eighth blue	⅓
Warm white deluxe	CC10M +#81	⅔	#80B +CC05G	1⅔	¼Plusgreen +Quarter blue +UV Filter	⅓	Sun ½ CTO +UV Filter	¼Minusgreen	0	Full blue 50 +½Minusgreen	- ⅓

Balancing Daylight Windows on Location Interiors

Emulsion Balance	Exposure Index	Camera Filter	Photographic Lights/Filter	Practical/Existing Lights/Filters	Window Filters
Balancing Interior to Daylight					
3200K Daylight	Daylight Daylight	85 Neg. 85B Rev. None	3200K/Full Blue 50 or Dichroic White flame arc/Y-1 HMI, CID/Y-1*	Tungsten/Full Blue 50 Cool White Fluor/Minus green	ND as required
Balancing Ambient Lighting to 3200K					
3200K	3200K	None	3200K/None Yellow flame arc/YF101 HMI, CID/Y-1+MT2*	Tungsten/None Cool White Fluor/ Fluor filter + ½ Minus green AC discharge/	CTO or Sun 85 plus ND as required

Balancing to Match Existing (Ambient) Interior Lighting					
Cool White Fluorescent					
3200K	3200K -1⅔ stop	CC50R + #81A +CC05M +85B	3200K Full Blue 50 + Plus green + Quarter blue + ¼ Plus green	Cool White Fluor/None	Plus green + Third Blue
Daylight	Daylight -⅔ stop	CC30M	White Flame Arc / HMI, CID * — Plus Green + Third Blue	Tungsten/same as Photo 3200K	plus ND as required
Other AC Discharge Commercial Lighting—see pg 242 for filters					
Tungsten					
See "Balancing Ambient Lighting to 3200K" above. This would be an unusual situation. Either accept the difference between 3200K and ambient lighting or drop voltage on 3200K photo lamps and add ⅛ CTO to 5500K lighting. Inefficient electrically.					
***HMI and CID may vary. See pg 218 and check with 3C meter.**					

The Cinematographer and the Laboratory

Laboratories routinely use the film manufacturers' recommended specifications for processing, modified to meet their particular equipment. (The entire system — type of film, manufacturers' EI recommendation, laboratory printing and processing range — is calibrated to produce a pleasing rendition of fully lighted flesh tones under normal projection conditions.) In addition to producing normal results on the screen, most laboratories can on request modify the screen results to produce a particular effect or look.

Printer Points

The laboratory controls print density and color balance by increasing or decreasing the intensity of each primary color of light in steps called printer points. Since the development of the B & H model C printer most manufacturers have standardized on a range of 50 light points in 0.025 Log E increments. In addition to the light points each printer usually also has 24 trim settings (0.025 Log E) , giving an available total of 74 lights.

The ideal settings for scene-to-scene timing would be at mid-scale (Trim 12 + Tape 25 = 37 lights). In actual practice the available range is considerably less. Printer lamps are usually operated under their rated voltage. This reduces the light intensity in all three colors. For example, lowering the voltage from 120 to 90 volts on a BRN 1200-watt lamp results in a relative change in printer points equal to minus 12 Red, 13 Green, 17 Blue. The trims are usually used to balance the printer for a given print film emulsion. A typical emulsion might require 16 Red, 13 Green, 10 Blue, or in terms of the ideal, plus 4 Red, plus 1 Green, minus 2 Blue. Other factors influencing the available printer points are the operating speed of the printer, and the use of neutral-density filters in the individual channels and the main light beam.

The sum of these variables explains why a given negative might be printed Red 28, Green 29, Blue 22 at one laboratory and Red 36, Green 32, Blue 36 at another laboratory to produce matched prints. It is important to understand that printer points relate only to how the printer exposes film. A one-stop .30 Log E change (12 printer points X .025 Log E) is equal to a one-stop exposure in the camera only if the film in the camera has a gamma of approximately 1.0. The current negative films, both black & white and color, have gammas of approximately .65. Therefore, in correlating camera and printer exposure, one stop equals ⅔ x 12 = 8 printer points per stop.

Exposure Reporting

It has become the normal practice for laboratories to furnish "one light" rather than timed daily rush prints. This does not mean that all negatives are printed at the same light points. The laboratory establishes a day exterior, day interior, night exterior and night interior light for a cinematographer when he/she starts a picture, based on testing or on the first few days of shooting. Each laboratory establishes it own method, but basically all try to keep usable negative within the 1 to 50 light point scale. Eastman Kodak proposes the LAD (Laboratory Aim Density) system, which keeps the printer scale constant by adjusting printer trims to compensate for process and stock variables, and places a "normal" scene at mid-scale. (Laboratories do not necessarily agree on the numerical value of the preferred mid-scale light point, but this is not critical as long as you know which system your laboratory uses.) Conference with your laboratory technician will establish methods that fit your style of photography. After that, variation in your exposure will show as variation in the density of your dailies. Bear in mind that if subject matter or style of photography requires a solid black in any area of the print, exposure must be kept at center of the printer scale or higher.

Negative raw stock from different manufacturers may or may not have the same base density, maximum density, or density/exposure characteristic ("curve shape"), although these differences are usually small. A rush print made by the LAD control method shows the density and color ratio at mid-scale on the printer. Negative from two manufacturers, both exposed correctly, may or may not look the same at this printer point. If necessary, an adjustment to the printer point may be made for the difference in raw stock and this new light point used for printing dailies on the subject.

Special Processing

If special processing is requested, a conference with the laboratory representative and experimentation (or experience) is desirable. If special processing is requested, or the cinematographer is using high or low exposure for effect, it is desirable to test the effect by going through the entire release-print technique, including the interpositive/duplicate negative generations, and to view the result as nearly as possible under the anticipated release-print viewing conditions. (Don't ignore the fact that most pictures are also released in one of the television formats.) If the scene to be photographed will be used in an optically printed special effect, it is wise to confer with the appropriate special-effects people.

Release-Printing Procedures

After the picture negative and soundtrack negative have been assembled in their final form, the laboratory will analyze the picture negative for scene-to-scene color and density variations and make a print known as the "first trial composite." As many trial prints are made as are necessary to resolve all printing data. The final trial is also often known as an "answer print." With the data thus obtained, one or more intermediates are printed and from these the release prints are made. Modern film stocks used to make the intermediate positives and intermediate or duplicate negatives are of excellent quality, but they do entail added printing generations. The appearance of scenes involving effects such as off-normal film exposure or processing can suffer if they exceed the extremes the system can handle. (See also "Testing and Evaluation.")

Color Reversal Films

Most of the above also applies to color reversal films; however, color reversal films are now usually used only when it is intended to project the original. Exposure latitude is short compared to that of color negative films. Proper exposure is therefore critical in order to keep all scenes at a usable density.

Black & White Negative and Reversal Films

The above also applies to black & white reversal films. Black & white negative films, however, are an exception. Both their contrast and density can be more strongly affected by developing time than color negative films. While there is much more latitude in exposure with black & white negative films as compared to color negative films, both grain and acutance are affected by exposure variations. Deviation from the manufacturers' recommended EI (exposure index) should be tested and evaluated.

Forced Development of Color Films

With the color films most commonly used today, it is possible to compensate for underexposure by extended development or "pushing." Similar to the principles of traditional black & white sensitometry, forced development of these color films increases their contrast, graininess and the fog level.

Therefore, forced development can never yield the same image quality possible when films are exposed and processed strictly according to the manufacturer's recommendations. In many instances, however, the image quality obtained with underexposure and overdevelopment is entirely satisfactory, and a cinematographer may want to take advantage of this fact when shooting under adverse light conditions. What "pushing" means, in effect, is that the cinematographer can deliberately underexpose the film (sometimes by as much as two stops) and request that the laboratory compensate in development.

With the introduction of high-speed color negative emulsions, there is less call for pushing the moderate speed films, except for a special "look" or when underexposure is unavoidable and high-speed negative is not at hand. It is possible to push one stop in development without appreciable loss in image quality. The scenes produced in this manner can be intercut with scenes exposed and processed normally.

If color negative is pushed two stops in development, the increase in the graininess and the fog level is substantial, but the results are acceptable for scenes involving night-for-night photography or available-light photography under exceptional circumstances.

Extending development beyond two stops does not appreciably contribute to the image; rather, it increases the grain and fog level and should not be attempted even as an emergency measure. It should be realized that with color films the sensitometric balance of the three emulsion layers is only achieved with normal processing and that forcing the development does not accomplish a true compensation for underexposure. Forced development does not result in a substantial increase in Exposure Index of the negative as measured by accepted scientific methods. Nevertheless, it cannot be denied that the technique proves to be of some practical value if it brings the underexposed negative into an acceptable printing range.

Reversal films, unlike negative, derive their projection density from the camera exposure. Forced processing of underexposed film can bring up the projection density to normal. Eastman Ektachrome Films 7240 and 7250 and Fujicolor RT8427 and 8428 (all tungsten balanced), as well as Ektachrome 7239 and 7251 (daylight balanced) can be "pushed" one stop with acceptable results. In emergency situations they can be pushed up to three stops with some loss in quality. The ability to underexpose these films and still obtain on film a usable image should by no means be regarded as a suitable substitute for additional lighting when it can be provided.

If a cinematographer anticipates the need for deliberate underexposure during a production, he or she should, if possible, shoot careful tests in advance using the same emulsion to be used for the production and have them processed by the lab that will be processing the production film. The results can then be analyzed with the help of a laboratory representative. Needless to say, underexposed rolls should be clearly marked with instructions as to how much they should be pushed when they are sent to the laboratory.

Flashing

Flashing may be described qualitatively as subjecting the negative film to a weak, controlled uniform fogging exposure prior to development either before, during or after photographing the desired subject. There is no measurable difference in the effect if the flashing takes place before or after the principal exposure. As a result, because of various unfavorable factors (such as not being able to control the time interval between the flash exposure and the time that development will actually take place, and not knowing the actual conditions of photography in advance), pre-flashing is generally avoided in favor of post-flashing. Simultaneous flashing during actual photography by means of a special device attached to the front of the camera lens is described under "VariCon." A device called a "Panaflasher" can also be used for simultaneous flashing on Panavision cameras. The Panaflasher can be used pre- or post-exposure.

Since color negative consists basically of three emulsion layers sensitive to red, green, and blue light, the spectral composition of the light used for flashing can be a neutral equivalent to tungsten light (3200K) or daylight (5500K) which, depending on the film, would affect all three emulsion layers equally. The fundamental reasons for using a neutral flash are to reduce the contrast of the image and to increase shadow detail. This effect is accomplished because the flashing exposure affects principally the shadow region of the negative image.

Another reason for flashing is to achieve certain creative effects by using a non-neutral flashing exposure which would then alter the normal color rendition of the developed negative.

Flashing is also used sometimes to reduce contrast of positive or reversal films when such films are to be used for special effects duplication purposes, such as projection backgrounds or aerial image compositing with animation.

VariCon Adjustable Contrast Filter

The Arri VariCon is a compact, variable contrast-control system which quickly and easily slides into the dual filter stage closest to the lens of any regular 6.6"X 6.6" matte box. The VariCon differs from low-contrast filters in that it provides for a continuously adjustable contrast over the entire photometric range of the film without any loss of resolution, and without any effect on the highlights. It differs from standard flashing (pre- or post-exposure) of the negative in the lab or in the film camera magazine in that it adds a controlled, even amount of light during the exposure, and permits the cinematographer to set the desired contrast reduction while observing the results in the viewfinder, in relationship with the actual scene to be photographed. The VariCon also provides for coloring of shadow areas in the image without affecting the highlights. This feature can be very helpful in situations when extreme contrast compression would result in extreme color desaturation.

The system consists of a light source, the VariCon Glass Emitter, the 6.6" X 6.6" VariCon frame that holds the Emitter (with a built-in slot for an ND filter), a digital meter for precise setting of contrast ranges, and a dual-level output Power Supply. With the VariCon placed in the 6.6"X 6.6" stage closest to the lens, it will cover virtually all wide-angle and long focal-length prime lenses, and most zooms. With the VariCon in position and switched OFF, it will not affect image quality or require f-stop compensation.

Adjusting the VariCon

VariCon's contrast-range adjustment is simple: turn a single control knob (located on its left side), or turn a single flexible extension shaft that plugs directly into the VariCon just above the control knob, to adjust contrast up or down. The amount of contrast reduction can be seen through the finder, or be measured via the digital meter for accuracy and repeatability. Set the meter for the camera's f-stop, the film stock's exposure index, and the required contrast range in values ⅛,½, 1, 2, 3, 4 or 5. (A value of 1 is equal to 20% flashing.) The effective range of VariCon covers situations from F1.4 with 800 ASA to F22 with 100 ASA.

Changing the coloration of the VariCon is done with a gel placed in the VariCon's slide-in gel filter holder. A light sensor built into the VariCon works in conjunction with the meter to compensate for the light reduction of the gel filter. VariCon can also be used in conjunction with other filters to enhance their effects.

NOTE: When using the VariCon, exposing the gray scale/slate with the Varicon switched ON is recommended; it's helpful for the lab timer.

Lens Coverage:

Standard Aspect Ratio:

Zoom lenses: 18mm on up

Prime lenses: 10mm, 12mm, 16mm on up

Super 35 Aspect Ratio:

Zoom lenses: 20mm on up

Prime lenses: 12mm, and 16mm on up

Power Sources:

Varicon has two 50W, 12V 'BRL' Ushio halogen bulbs, powered by 110V AC through a 12V AC adaptor, or from

12V or 24V batteries. (Cables for 24V batteries are available only through special order.)

Power consumption: 96 Watts (8A @ 12V, 4A @ 24V)

Dimensions:

Upper light source: 9 X 2 X 1.75 inches

Slide-in emitter section: 8 X 6.5 X 0.5 inches

Weight: 3 lbs.

Photographic Testing and Evaluation

by Fred Detmers

Photographic testing and experimenting aid the cinematographer in evaluating equipment, new films and processing, and techniques of lighting. This article is intended as a checklist and brief on the techniques of testing and evaluation.

Each of the factors in creating a photographic image relates to several other factors; it is important in evaluation to vary one factor at a time, and continually to compare, when possible, with a known result. In this way, a bank of information is acquired which can be drawn on and expanded.

Before proceeding to photographic testing it is necessary to establish the conditions under which the tests will be evaluated. It is of no value to photograph a test and then view it under anything less than first-class conditions. Standards and recommended practices have been set up by the SMPTE and ANSI, and test films are available from the SMPTE for evaluation of projection conditions. If these conditions are not optimum, the value of the test is compromised. Users of 16mm and Super 8 should be particularly alert to this condition because there are so many substandard projectors and lenses in use.

Through adaptation and fatigue the eye can change its sensitivity to color, density, or subjective sharpness. When possible use two projectors and two screens. Make direct comparisons rather than subjective evaluations. If in doubt, switch films on the two projectors and re-evaluate.

Some of the testing referred to below may be performed on black & white film even if the subject is to be color, thereby saving some of the cost. If the test is mechanical rather than photographic, the negative itself may be projected for evaluation instead of going to a print.

I. Equipment

A. Steadiness check: Particularly when composite photography is contemplated (but valuable in any case), a check for image steadiness is advisable. The subject matter may be simple; for instance, a black background with a simple cross made of adhesive tape. Photograph 20 or 30 seconds of the cross, cover the lens, backwind to the beginning, uncover the lens, offset the chart by the width of the tape, and double-expose the chart. Any unsteadiness will readily show between the offset lines (Do not re-thread on a different perforation — this introduces the possibility of unsteady perforations and compromises the camera test.) After photographing and processing this and before projecting, examine the negative for perforation damage and scratches.

B. Optical: Lenses should have been calibrated at the factory or by the distributor for exposure and focus and the distributor should have checked the ground glass position with reference to the film plane. If you trust your supplier there is no need for extensive testing. If, however, the equipment is unfamiliar or it is necessary to field test the equipment, following are suggested procedures:

1. Focus and ground glass/film plane:

(a) Set up a focus/definition chart (obtainable from camera equipment suppliers) with center and corner targets; set up at a distance from the camera corresponding to a scale-calibrated distance, filling the aperture as much as possible. Check the eye focus versus scale focus. Repeat for each lens. Repeat at a mid-distance (15 to 25 feet) scale calibration. With a zoom lens, check at several zoom settings.

A consistent discrepancy suggests either ground glass or index error. A discrepancy on one lens suggests error in the setting of the scale ring. (When using Panavision wide-angle lenses, read and follow the Panavision instructions.) In either case, photographic or collimator tests are required to confirm the source of error. (If you have a rental or a newly acquired camera/lenses, send it/them back for correction.)

(b) Set up the definition chart at a scale distance closest to filling the frame. If the index and/or focus scale rings are provided with secondary index marks for adjustments, use these marks as a guide; otherwise:

On a piece of tape on the index, make four additional temporary marks at equal intervals above and below the index. Space the marks to indicate 0.001 in travel of the lens for each interval (see "Lens Formulas"), and label those away from the film "plus" and those closer to the film "minus."

At a wide-open aperture, using either the temporary marks or the permanent secondary marks mentioned above, photograph a short take (just enough to get up to speed) at each index mark: "plus," "N," "minus." Develop and examine with a 10X magnifier. The N exposure should be noticeably sharper than the plus or minus. If it is not, repeat the test to confirm.

Check all lenses, and check also at another mid-distance (say 15 feet), always at a scale-calibrated mark. If any lens is consistently "off the mark" or if there is a pattern of failure between lenses, send the camera/lenses back for recalibration or, in the field, be guided by the focus test results.

2. Sharpness (See also "Lens Selection."):

Because sharpness is a subjective judgment based on the composite of resolution, acuteness, contrast, flare and aberration, a full test of each lens would encompass photography in a number of different situations. A simple comparison may be made between lenses, however, by photographing a definition chart and a simple scene with each lens and comparing them with identical exposures made with a lens of known photographic performance.

(a) The definition chart should preferably be one made for lens testing (available from camera supply distributors) and should have targets in the corners as well as in the center. Exposure should be made at a wide-open aperture, a mid-aperture (one at which you would be most likely to photograph interiors), and at a very small aperture, each lighted for normal exposure. The wide-open exposure should show up aberration and distortion, particularly in the corners, should they be present. The small aperture exposure will tell you (in comparison with the "mid-aperture" exposure) if there is lower definition because of diffraction; a lack of definition at wide-open or small apertures can affect apparent depth of field as well as intrinsic sharpness.

(b) The test scene should include a white area, a light area (with detail such as lace), and a dark area with detail, as well as a person or object showing detail in mid-tones. There should be a normal exposure and one each one stop over and underexposed. When printed alike in the midtones and compared, this will show up contrast, and if the lens has a tendency to flare, the overexposed scene will be flatter than the normal and will show flare from the white area into the surrounding area. Care should be taken not to exceed the printer scale.

(c) Comparison of (b) normal exposure with a like exposure made with a known lens is a subjective sharpness test.

3. Exposure (T-stop), color shift:

Photograph a short length of film of a gray scale at the same T-stop and illumination with each lens. The negative gray scale may be read with a densitometer, if available, to determine uniformity. If a print is made of the negative it may be projected to see if there is a color shift between lenses. In most instances small differences in color can be corrected in printing and will affect only the rush prints. If you are photographing on reversal film, you may wish to use color correcting filters to balance the lenses.

II. Laboratory/Process/Printer Scale/ Emulsion Batch

Generally these tests should be comparative. We should compare for sharpness, grain, contrast, detail in highlights and shadows and off-color highlights or shadows. Prints should be made for best appearance in faces and/or mid-tones and comparative prints should be made to match in these tones. A gray scale included in the scene is helpful.

Comparative tests should be made at the same T-stop. Where an exposure range is made, exposure should be varied with shutter and/or neutral density filters. Clear filters should be used to substitute for neutral densities so the same number of filters are always in place. While the scene used above for lens comparisons can also be used in these tests, it is helpful also to include a high-key and a low-key scene.

A. Testing new film stocks:

Photograph a range of exposures of each scene from the new film and on a known film, from normal to plus and minus 2 lens stops. If forced processing is intended (see below) add a set at minus 3 stops.

B. Testing for off-normal processing (including push processing and flashing):

1. Because there are now three variables — exposure, flash level, and developing time — unless a wide range of combinations is budgeted, it might be well to separate tests for flash and processing, observe the result, and then confine tests of combinations to levels likely to be useful to the desired look. Always compare to a normally exposed and developed scene.

2. Before committing to forced developing, compare with a properly printed, underexposed, normally developed take. In some instances, the only thing forced developing does is raise the printer points.

3. Make a print of a minus-one-stop exposed, "push one" developed take at the same lights as the normally exposed, normally developed take. Comparison will show just what is accomplished by "push-one" developing.

4. If the desired look is obtained but the print is made below printer point 10 or above 40, be cautious because you have limited your latitude.

C. Testing a new emulsion batch for compatibility:

If the new emulsion batch is incompatible, it is more likely to be so in off-normal densities or processes. Follow the same general procedure as in testing a new film; the exposure range need not be as great. If the printer lights vary 2 or 3 points between scenes photographed the same on the two batches of emulsion no harm will be done. If there is a marked difference in shadow or highlight color when faces match, caution is warranted.

III. Visual Effects: Lighting, Filters, Image Modification

This is a subjectively judged area in which the cinematographer and laboratory technician must work together closely. Unless based on experience, it is advisable to start with a print at center scale. If the visual appearance is then not correct, the decision can be made whether to vary the photographic conditions or vary the printing conditions.

Varying both without conference between the cinematographer and laboratory technician can only lead to confusion. If the desired effect can only be achieved by off-normal printing or negative processing, it is advisable to go a step further and evaluate the result after making either a duplicate negative or a CRI to simulate release-print conditions. The result should then be viewed with as large a screen magnification as is anticipated, for the release print. If television use is anticipated the result should also be viewed under television conditions.

Emulsion Testing

by Steven Poster, ASC

The object of this series of tests is to determine the best working exposure index and the dynamic range for your original camera negative. This system takes into account any processing techniques, print stock and further duping of the original camera negative.

Judging these tests should be done visually, although densitometer readings should be taken for later reference. It is more important to train your eye to see the various characteristics of the chain of events that result in the presentation of images that we create during production than to know scientifically all of the sensitometry that goes into the imaging system.

Calibration

1. The basic physical nature of the film stock (i.e., how much density there is in the negative without any exposure) must be calibrated. If you are going to test or use other film stocks and/or processing techniques these should also be calibrated at this time.

The lab should process a short length of unexposed negative. If the negative is going to be pushed or pulled or flashed, these special treatments should be done in the proscribed way at this time as well. You can measure the specific densities of the base density plus fog levels on a densitometer for reference. (This reference can be used later if there is an emulsion change, lab change or just as a simple check on your standard emulsion.)

We know that this specific density will be used to reproduce a black tone on the final print. If this density on the negative is not printed deep enough to reproduce a desirable black on the print stock there will be no black tones in the final print and the images will be appear to have been underexposed. If this is the case the images can also develop a grainy appearance and will not dupe well.

At this point you have a piece of unexposed processed negative that reflects any special processing techniques done to that negative. You should also have noted reference densities of that negative. This leads us to the second part of the test.

2. In order to determine the specific amount of light needed to print your test negative to a desirable black tone, we must test the print stock and any printing techniques (flashing the print stock, ENR, bleach suppression or optical printing, for example). This is done by printing your piece of unexposed processed film stock at a succession of printer lights increasing by 2 to 4 points of density (8 printer points equals 1 stop, 4 points equals ½ stop, etc.). If you are planning to use any unusual printing techniques or print processing techniques, they should be applied at this point. Any subsequent printing for these series of tests should have these techniques applied as well.

A trick that I have often used to help me judge my optimum black density is to punch a hole in the negative with a single-hole paper punch (not in the center of the frame) before it is printed. This will give you a reference to zero density in the frame, which can help determine the optimal visual black tone that you want. Your desired black tone will never be as black as the portion printed through the hole, but the reference helps to determine what density you will want to achieve with your processing and printing techniques.

If your lab has strip projectors which they use for timing proposes, this is a very good way to view these tests. Two identical prints can be made which can be viewed side by side on these projectors, allowing you to study the results and compare different densities. If no strip projectors are available,the length of each exposure should be enough to allow you time to view it sufficiently on the screen during projection.

Once you have determined which density you would like to represent black in your final print, it should be read on the densitometer and used for later reference. You can also read the densities of each level of printer lights to see where reciprocity sets in, although this is not actually necessary because this density will probably be deeper than you will actually be printing at.

A test for no-density print highlights can also be done at this time by printing a piece of opaque leader at the determined printer lights and reading the resulting density. The difference between your chosen black density and the resulting white density will determine the dynamic range of the print stock. In order to determine the speed and working range of your negative in relation to that print stock, further testing is necessary.

You should now have a optimum black density and a reference to the printer lights that it will take at your lab to result in that density with your chosen negative stock. This includes any unusual processing methods and any variation in printing techniques that you choose to use. This brings us to the third part of the test.

3. This will be the first camera test which will determine the working speed or exposure index (EI) that will allow you to judge the exposure necessary to represent the values that are photographed as normal tones on the final print when that print is made using the recommended density determined by the first two parts of these tests. You must determine the amount of light that it will require to properly photograph a mid-gray tone when the negative is printed to the benchmark density.

There are several points worth mentioning at this stage about testing methods. Everyone has their own method of measuring light values. There are probably as many methods as there are people taking exposure readings. If your meter and method of reading works for you it is correct.

I prefer to use a Minolta 1° spot meter and take my neutral readings off of a Unicolor Permanent Gray Card. I feel that this gives me a consistent and accurate way of judging not only the light falling on a subject but the reflectance of that subject as well. I also like to vary the amount of light falling on the subject rather then changing the T-stop on the lens. This gives me a more accurate series of exposures because there is no reliable way to vary the stop by fractions, due to the variables and tolerances of the lens iris.

Lighting for these tests requires flat, even illumination over the surface of the subject, similar to copy light (light from two sides of the subject at a 45° angle from the camera). The color temperature of the light should be as close to 3200° Kelvin possible except in tests of daylight film, when 5400° Kelvin should be used.

If you are planing to use filtration, such as diffusion of some kind, these filters should be used in all subsequent tests, because some of these filters can have some light-absorption qualities. Even though this effect will be very slight, it can affect the results of your tests by as much as two-thirds of a stop.

Make a series of exposures of an 8" x 10" gray card and a face with neutral skin tone at a series of stops based on variations in the manufacturer's recommended exposure index. Start the series at one stop under the EI and increase the exposure by one-third of a stop until you reach one stop over the recommended speed.

For instance, if you were testing Kodak's 5296, the recommended speed is 500. You would start your test at an EI of 1000 and proceed to an EI of 250 in one-third -stop increments, resulting in seven different exposures.

Remember, don't vary the T-stop. Change the amount of light to give the proper exposure at the T-stop you are using.

Print the negative at the benchmark density arrived at in the second part of the test, adjusting the printer ratio (color balance) to reproduce a neutral gray. Read the print density of the gray in each exposure. A proper mid-gray print density for theater viewing should be R/1.09 G/1.06 & B/1.03 (status A filters).

View the print to determine which print is closest to that recommended density. Look carefully at the quality of the color balance of the skin tones in relation to the gray card. If an emulsion cannot reproduce skin tones properly when the gray card is printed correctly (or vice versa), this is a good indication that there are problems with either the emulsion or the lab processes that have taken place. If this is the case, when the skin tones are printed properly in the final print there will always be problems getting the proper color balance in the shadows.

The print that is chosen as the best representation of the gray card and skin tone will become the mid-point in the dynamic range of your negative. Check which exposure index was used for this test. This EI will become your empirical emulsion speed. Most often I have found that the EI that is derived will be within one-third of a stop of the manufacturer's recommended speed, unless some form of processing modification is used (such as push or pull processing).

4. This is the part of the testing process that will determine the usable dynamic range of your negative when exposed, processed and printed using the information gathered in the previous tests.

Make a series of exposures using a Macbeth Color Checker color chart, an 8"x10" gray card, a small gray scale and a face with neutral skin tone. Mount the color chart vertically with the gray card in the middle and the scale vertically next to the gray card, all on one piece of card. Mount this card on a grip stand and place it over the head of the model. This allows you to fill the frame with the cards and then tilt down to see the face. Shoot the chart and the face each for a minimum of ten seconds (more if you can afford the film) so that you will have enough time to study the results on the screen. If you are comparing emulsions or processing techniques, repeat these tests for each variation.

Using the EI that you derived from the last test, start the series of exposures at normal and underexpose successively until you reach five stops underexposed. Do the same with overexposure.

For example:

First Series	Second Series
normal	normal
1 stop under	1 stop over
1 ⅓ stops under	2 stops over
1 ⅔ stops under	3 stops over
2 stops under	3 ⅓ stops over
2 ⅓ stops under	3 ⅔ stops over
2 ⅔ stops under	4 stops over
3 stops under	4 ⅓ stops over
4 stops under	5 stops over
5 stops under	

The use of uneven increments of exposure is based on experience. I know that the first shadow detail will fall somewhere within the range of 2 and 3 stops underexposed and that the last highlight detail will fall between 4 and 5 stops over. I also know from experience that the increments between 1 and 2 comprise very useful shadow densities to have a visual reference to.

Print these tests again at the benchmark densities. View the work print to make sure the color ratios are correct. If possible, at this point an interpositive, dupe negative and final print should be produced using any special printing techniques intended for the final release (such as ENR or flashing the interpositive). This will allow you to view the results as they would be viewed in the theater. If this is not possible, enough useful information can be learned by viewing the work print.

When you view the results projected, either in motion or on strip projectors, you will begin to see the effects of exposure on different tones and colors. If you are comparing different emulsions or processing techniques, the results should be viewed side by side for proper comparison.

The exposure difference between first shadow detail and last highlight detail and their relation to mid-gray will determine the empirical dynamic range of the negative, processing and printing combination.

Conclusion

It is important to remember that these tests are not scientific but empirical. They are meant to train your eye to the dynamic range of your emulsion under working conditions. The tests should be a good working reference. In fact, I have often taken frames of each exposure and mounted them in slide mounts for viewing on the set if I want to know exactly where to place a specific tone on the scale so that it will be represented exactly as I want in the final print. To do this you will need a small light box properly color-corrected and with an illumination of 425 FC +/- 10%.

It is most important to learn to trust your eye rather than relying on too many exposure readings. These tests should give you a better understanding of the results of exposing, processing and printing your original camera negative so that you can predict exactly what the images you make will look like. With this knowledge you should be able to make more consistent dramatic images to help tell the story of your motion picture.

16mm FOOTAGE TABLE

24 F.P.S. Sound Speed (1 foot = 40 frames)

SECONDS						MINUTES			
SECONDS	FEET	FRAMES	SECONDS	FEET	FRAMES	MINUTES	FEET	MINUTES	FEET
1		24	31	18	24	1	36	31	1116
2	1	8	32	19	8	2	72	32	1152
3	1	32	33	19	32	3	108	33	1188
4	2	16	34	20	16	4	144	34	1224
5	3		35	21		5	180	35	1260
6	3	24	36	21	24	6	216	36	1296
7	4	8	37	22	8	7	252	37	1332
8	4	32	38	22	32	8	288	38	1368
9	5	16	39	23	16	9	324	39	1404
10	6	10	40	24		10	360	40	1440
11	6	24	41	24	24	11	396	41	1476
12	7	8	42	25	8	12	432	42	1512
13	7	32	43	25	32	13	468	43	1548
14	8	16	44	26	16	14	504	44	1584
15	9		45	27		15	540	45	1620
16	9	24	46	27	24	16	576	46	1656
17	10	8	47	28	8	17	612	47	1692
18	10	32	48	28	32	18	648	48	1728
19	11	16	49	29	16	19	684	49	1764
20	12		50	30		20	720	50	1800
21	12	24	51	30	24	21	756	51	1836
22	13	8	52	31	8	22	792	52	1872
23	13	32	53	31	32	23	828	53	1908
24	14	16	54	32	16	24	864	54	1944
25	15		55	33		25	900	55	1980
26	15	24	56	33	24	26	936	56	2016
27	16	8	57	34	8	27	972	57	2052
28	16	32	58	34	32	28	1008	58	2088
29	17	16	59	35	16	29	1044	59	2124
30	18		60	36		30	1080	60	2160

16mm FOOTAGE TABLE

25 F.P.S. European Television Film Sound Speed
(1 foot = 40 frames)

SECONDS						MINUTES					
SECONDS	FEET	FRAMES	SECONDS	FEET	FRAMES	MINUTES	FEET	FRAMES	MINUTES	FEET	FRAMES
1		25	31	19	15	1	37	20	31	1162	20
2	1	10	32	20		2	75		32	1200	
3	1	35	33	20	25	3	112	20	33	1237	20
4	2	20	34	21	10	4	150		34	1275	
5	3	5	35	21	35	5	187	20	35	1312	20
6	3	30	36	22	20	6	225		36	1350	
7	4	15	37	23	5	7	262	20	37	1387	20
8	5		38	23	30	8	300		38	1425	
9	5	25	39	24	15	9	337	20	39	1462	20
10	6	10	40	25		10	375		40	1500	
11	6	35	41	25	25	11	412	20	41	1537	20
12	7	20	42	26	10	12	450		42	1575	
13	8	5	43	26	35	13	487	20	43	1612	20
14	8	30	44	27	20	14	525		44	1650	
15	9	15	45	28	5	15	562	20	45	1687	20
16	10		46	28	30	16	600		46	1725	
17	10	25	47	29	15	17	637	20	47	1762	20
18	11	10	48	30		18	675		48	1800	
19	11	35	49	30	25	19	712	20	49	1837	20
20	12	20	50	31	10	20	750		50	1875	
21	13	5	51	31	35	21	787	20	51	1912	20
22	13	30	52	32	20	22	825		52	1950	
23	14	15	53	33	5	23	862	20	53	1987	20
24	15		54	33	30	24	900		54	2025	
25	15	25	55	34	15	25	937	20	55	2062	20
26	16	10	56	35		26	975		56	2100	
27	16	35	57	35	25	27	1012	20	57	2137	20
28	17	20	58	36	10	28	1050		58	2175	
29	18	5	59	36	35	29	1087	20	59	2212	20
30	18	30	60	37	20	30	1125		60	2250	

16mm FOOTAGE TABLE
29.97 F.P.S. U.S. Television Film Sound Speed
(1 foot = 40 frames)

SECONDS						MINUTES					
SECONDS	FEET	FRAMES	SECONDS	FEET	FRAMES	MINUTES	FEET	FRAMES	MINUTES	FEET	FRAMES
1	0	30	**31**	23	9	**1**	44	38	**31**	1393	24
2	1	20	**32**	23	39	**2**	89	36	**32**	1438	22
3	2	10	**33**	24	29	**3**	134	35	**33**	1483	21
4	3	0	**34**	25	19	**4**	179	33	**34**	1528	19
5	3	30	**35**	26	9	**5**	224	31	**35**	1573	17
6	4	20	**36**	26	39	**6**	269	29	**36**	1618	15
7	5	10	**37**	27	29	**7**	314	27	**37**	1663	13
8	6	0	**38**	28	19	**8**	359	26	**38**	1708	12
9	6	30	**39**	29	9	**9**	404	24	**39**	1753	10
10	7	20	**40**	29	39	**10**	449	22	**40**	1798	8
11	8	10	**41**	30	29	**11**	494	20	**41**	1843	6
12	9	0	**42**	31	19	**12**	539	18	**42**	1888	4
13	9	30	**43**	32	9	**13**	584	17	**43**	1933	3
14	10	20	**44**	32	39	**14**	629	15	**44**	1978	1
15	11	10	**45**	33	29	**15**	674	13	**45**	2022	39
16	12	0	**46**	34	19	**16**	719	11	**46**	2067	37
17	12	29	**47**	35	9	**17**	764	9	**47**	2112	35
18	13	19	**48**	35	39	**18**	809	8	**48**	2157	34
19	14	9	**49**	36	29	**19**	854	6	**49**	2202	32
20	14	39	**50**	37	19	**20**	899	4	**50**	2247	30
21	15	29	**51**	38	8	**21**	944	2	**51**	2292	28
22	16	19	**52**	38	38	**22**	989	0	**52**	2337	26
23	17	9	**53**	39	28	**23**	1033	39	**53**	2382	25
24	17	39	**54**	40	18	**24**	1078	37	**54**	2427	23
25	18	29	**55**	41	8	**25**	1123	35	**55**	2472	21
26	19	19	**56**	41	38	**26**	1168	33	**56**	2517	19
27	20	9	**57**	42	28	**27**	1213	31	**57**	2562	17
28	20	39	**58**	43	18	**28**	1258	30	**58**	2607	16
29	21	29	**59**	44	8	**29**	1303	28	**59**	2652	14
30	22	19	**60**	44	38	**30**	1338	26	**60**	2697	12

35mm FOOTAGE TABLE

24 F.P.S. Sound Speed (1 foot = 16 frames)

SECONDS						MINUTES			
SECONDS	FEET	FRAMES	SECONDS	FEET	FRAMES	MINUTES	FEET	MINUTES	FEET
1	1	8	31	46	8	1	90	31	2790
2	3		32	48		2	180	32	2880
3	4	8	33	49	8	3	270	33	2970
4	6		34	51		4	360	34	3060
5	7	8	35	52	8	5	450	35	3150
6	9		36	54		6	540	36	3240
7	10	8	37	55	8	7	630	37	3330
8	12		38	57		8	720	38	3420
9	13	8	39	58	8	9	810	39	3510
10	15		40	60		10	900	40	3600
11	16	8	41	61	8	11	990	41	3690
12	18		42	63		12	1080	42	3780
13	19	8	43	64	8	13	1170	43	3870
14	21		44	66		14	1260	44	3960
15	22	8	45	67	8	15	1350	45	4050
16	24		46	69		16	1440	46	4140
17	25	8	47	70	8	17	1530	47	4230
18	27		48	72		18	1620	48	4320
19	28	8	49	73	8	19	1710	49	4410
20	30		50	75		20	1800	50	4500
21	31	8	51	76	8	21	1890	51	4590
22	33		52	78		22	1980	52	4680
23	34	8	53	79	8	23	2070	53	4770
24	36		54	81		24	2160	54	4860
25	37	8	55	82	8	25	2250	55	4950
26	39		56	84		26	2340	56	5040
27	40	8	57	85	8	27	2430	57	5130
28	42		58	87		28	2520	58	5220
29	43	8	59	88	8	29	2610	59	5310
30	45		60	90		30	2700	60	5400

35mm FOOTAGE TABLE

25 F.P.S. European Television Film Sound Speed
(1 foot = 16 frames)

SECONDS						MINUTES					
SECONDS	FEET	FRAMES	SECONDS	FEET	FRAMES	MINUTES	FEET	FRAMES	MINUTES	FEET	FRAMES
1	1	9	31	48	7	1	93	12	31	2906	4
2	3	2	32	50		2	187	8	32	3000	
3	4	11	33	51	9	3	281	4	33	3093	12
4	6	4	34	53	2	4	375		34	3187	8
5	7	13	35	54	11	5	468	12	35	3281	4
6	9	6	36	56	4	6	562	8	36	3375	
7	10	15	37	57	13	7	656	4	37	3468	12
8	12	8	38	59	6	8	750		38	3562	8
9	14	1	39	60	15	9	843	12	39	3656	4
10	15	10	40	62	8	10	937	8	40	3750	
11	17	3	41	64	1	11	1031	4	41	3843	12
12	18	12	42	65	10	12	1125		42	3937	8
13	20	5	43	67	3	13	1218	12	43	4031	4
14	21	14	44	68	12	14	1312	8	44	4125	
15	23	7	45	70	5	15	1406	4	45	4218	12
16	25		46	71	14	16	1500		46	4312	8
17	26	9	47	73	7	17	1593	12	47	4406	4
18	28	2	48	75		18	1687	8	48	4500	
19	29	11	49	76	9	19	1781	4	49	4593	12
20	31	4	50	78	2	20	1875		50	4687	8
21	32	13	51	79	11	21	1968	12	51	4781	4
22	34	6	52	81	4	22	2062	8	52	4875	
23	35	15	53	82	13	23	2156	4	53	4968	12
24	37	8	54	84	6	24	2250		54	5062	8
25	39	1	55	85	15	25	2343	12	55	5156	4
26	40	10	56	87	8	26	2437	8	56	5250	
27	42	3	57	89	1	27	2531	4	57	5343	12
28	43	12	58	90	10	28	2625		58	5437	8
29	45	5	59	92	3	29	2718	12	59	5531	4
30	46	14	60	93	12	30	2812	8	60	5625	

35mm FOOTAGE TABLE
29.97 F.P.S. U.S. Television Film Sound Speed
(1 foot = 16 frames)

SECONDS						MINUTES					
SECONDS	FEET	FRAMES	SECONDS	FEET	FRAMES	MINUTES	FEET	FRAMES	MINUTES	FEET	FRAMES
1	1	14	**31**	58	1	**1**	112	6	**31**	3484	0
2	3	12	**32**	59	15	**2**	224	12	**32**	3596	6
3	5	10	**33**	61	13	**3**	337	3	**33**	3708	13
4	7	8	**34**	63	11	**4**	449	9	**34**	3821	3
5	9	6	**35**	65	9	**5**	561	15	**35**	3933	9
6	11	4	**36**	67	7	**6**	674	5	**36**	4045	15
7	13	2	**37**	69	5	**7**	786	11	**37**	4158	5
8	15	0	**38**	71	3	**8**	899	2	**38**	4270	12
9	16	14	**39**	73	1	**9**	1011	8	**39**	4383	2
10	18	12	**40**	74	15	**10**	1123	14	**40**	4495	8
11	20	10	**41**	76	13	**11**	1236	4	**41**	4607	14
12	22	8	**42**	78	11	**12**	1348	10	**42**	4720	4
13	24	6	**43**	80	9	**13**	1461	1	**43**	4832	11
14	26	4	**44**	82	7	**14**	1573	7	**44**	4945	1
15	28	2	**45**	84	5	**15**	1685	13	**45**	5057	7
16	30	0	**46**	86	3	**16**	1798	3	**46**	5169	13
17	31	13	**47**	88	1	**17**	1910	9	**47**	5282	3
18	33	11	**48**	89	15	**18**	2023	0	**48**	5394	10
19	35	9	**49**	91	13	**19**	2135	6	**49**	5507	0
20	37	7	**50**	93	11	**20**	2247	12	**50**	5619	6
21	39	5	**51**	95	8	**21**	2360	2	**51**	5731	12
22	41	3	**52**	97	6	**22**	2472	8	**52**	5844	2
23	43	1	**53**	99	4	**23**	2584	15	**53**	5956	9
24	44	15	**54**	101	2	**24**	2697	5	**54**	6068	15
25	46	13	**55**	103	0	**25**	2809	11	**55**	6181	5
26	48	11	**56**	104	14	**26**	2922	1	**56**	6293	11
27	50	9	**57**	106	12	**27**	3034	7	**57**	6406	1
28	52	7	**58**	108	10	**28**	3146	14	**58**	6518	8
29	54	5	**59**	110	8	**29**	3259	4	**59**	6630	14
30	56	3	**60**	112	6	**30**	3371	10	**60**	6743	4

65/70mm FOOTAGE TABLE
24 F.P.S. SOUND SPEED
(1 foot = 12.8 frames)

SECONDS						MINUTES					
SECONDS	FEET	FRAMES	SECONDS	FEET	FRAMES	MINUTES	FEET	FRAMES	MINUTES	FEET	FRAMES
1	1	11.2	**31**	58	1.6	**1**	112	6.4	**31**	3487	6.4
2	3	9.6	**32**	60	0	**2**	225	0	**32**	3600	0
3	5	8.0	**33**	61	11.2	**3**	337	6.4	**33**	3712	6.4
4	7	6.4	**34**	63	9.6	**4**	450	0	**34**	3825	0
5	9	4.8	**35**	65	8.0	**5**	562	6.4	**35**	3937	6.4
6	11	3.2	**36**	67	6.4	**6**	675	0	**36**	4050	0
7	13	1.6	**37**	69	4.8	**7**	787	6.4	**37**	4162	6.4
8	15	0	**38**	71	3.2	**8**	900	0	**38**	4275	0
9	16	11.2	**39**	73	1.6	**9**	1012	6.4	**39**	4387	6.4
10	18	9.6	**40**	75	0	**10**	1125	0	**40**	4500	0
11	20	8.0	**41**	76	11.2	**11**	1237	6.4	**41**	4612	6.4
12	22	6.4	**42**	78	9.6	**12**	1350	0	**42**	4725	0
13	24	4.8	**43**	80	8.0	**13**	1462	6.4	**43**	4837	6.4
14	26	3.2	**44**	82	6.4	**14**	1575	0	**44**	4950	0
15	28	1.6	**45**	84	4.8	**15**	1687	6.4	**45**	5062	6.4
16	30	0	**46**	86	3.2	**16**	1800	0	**46**	5175	0
17	31	11.2	**47**	88	1.6	**17**	1912	6.4	**47**	5287	6.4
18	33	9.6	**48**	90	0	**18**	2025	0	**48**	5400	0
19	35	8.0	**49**	91	11.2	**19**	2137	6.4	**49**	5512	6.4
20	37	6.4	**50**	93	9.6	**20**	2250	0	**50**	5625	0
21	39	4.8	**51**	95	8.0	**21**	2362	6.4	**51**	5737	6.4
22	41	3.2	**52**	97	6.4	**22**	2475	0	**52**	5850	0
23	43	1.6	**53**	99	4.8	**23**	2587	6.4	**53**	5962	6.4
24	45	0	**54**	101	3.2	**24**	2700	0	**54**	6075	0
25	46	11.2	**55**	103	1.6	**25**	2812	6.4	**55**	6187	6.4
26	48	9.6	**56**	105	0	**26**	2925	0	**56**	6300	0
27	50	8.0	**57**	106	11.2	**27**	3037	6.4	**57**	6412	6.4
28	52	6.4	**58**	108	9.6	**28**	3150	0	**58**	6525	0
29	54	4.8	**59**	110	8.0	**29**	3262	6.4	**59**	6637	6.4
30	56	3.2	**60**	112	6.4	**30**	3375	0	**60**	6750	0

— 16mm FILM —
FOOTAGE OBTAINED AT VARIOUS CAMERA SPEEDS

SECONDS	FRAMES PER SECOND														
	1	2	4	8	12	16	20	22	24	32	48	64	96	120	128
5	1/8	1/4	1/2	1	1 1/2	2	2 1/2	2 3/4	3	4	6	8	12	15	16
10	1/4	1/2	1	2	3	4	5	5 1/2	6	8	12	16	24	30	32
15	3/8	3/4	1 1/2	3	4 1/2	6	7 1/2	8 1/4	9	12	18	24	36	45	48
20	1/2	1	2	4	6	8	10	11	12	16	24	32	48	60	64
30	3/4	1 1/2	3	6	9	12	15	16 1/2	18	24	36	48	72	90	96
60	1 1/2	3	6	12	18	24	30	33	36	48	72	96	144	180	192

1 Foot = 40 Frames	1/2 Foot = 20 Frames
4/5 Foot = 32 Frames	2/5 Foot = 16 Frames
3/5 Foot = 24 Frames	1/5 Foot = 8 Frames

35mm FILM FOOTAGE + FRAMES OBTAINED AT VARIOUS CAMERA SPEEDS
(1 Ft = 16 frames)

FRAMES PER SEC	1	2	4	8	12	16	20	22	24	32	48	64	96	120	128
SEC															
5	0′+5fr.	0+10	1+4	2+8	3+12	5+0	6+4	6+14	7+8	10+0	15+0	20+0	30+0	37+8	40+0
10	0+10	1+4	2+8	5+0	7+8	10+0	12+8	13+4	15+0	20+0	30+0	40+0	60+0	75+0	80+0
15	0+15	1+14	3+12	7+8	11+4	15+0	18+12	20+10	22+8	30+0	45+0	60+0	90+0	112+8	120+0
20	1+4	2+8	5+0	10+0	15+0	20+0	25+0	27+8	30+0	40+0	60+0	80+0	120+0	150+0	160+0
30	1+14	3+12	7+8	15+0	22+8	30+0	37+8	41+4	45+0	60+0	90+0	120+0	180+0	225+0	240+0
60	3+12	7+8	15+0	30+0	45+0	60+0	75+0	82+8	90+0	120+0	180+0	240+0	360+0	450+0	480+0

65mm FILM FOOTAGE + FRAMES OBTAINED AT VARIOUS CAMERA SPEEDS
(1 Ft = 12-4/5 frames)

FRAMES PER SEC	1	2	4	8	12	16	20	22	24	32	48	64	96
SEC													
5	0′+5fr.	0+10	1+7	3+2	4+9	6+3	7+10	8+8	9+5	12+6	18+10	25+0	37+6
10	0+10	1+7	3+2	6+3	9+5	12+6	15+8	17+2	18+10	25+0	37+6	50+0	75+0
15	1+2	2+4	4+9	9+5	14+1	18+10	23+6	25+10	28+4	37+6	56+3	75+0	112+6
20	1+7	3+2	6+3	12+6	18+10	25+0	31+3	34+5	37+6	50+0	75+0	100+0	150+0
30	2+4	4+9	9+5	18+10	28+4	37+6	46+11	51+7	56+3	75+0	112+6	150+0	225+0
60	4+9	9+5	18+10	37+6	56+3	75+0	93+10	103+2	112+6	150+0	225+0	300+0	450+0

35mm CAMERA RECOMMENDED PANNING SPEEDS

APPROX. 180° SHUTTER — FOR STATIC SCENES

For 90° Sweep With Various Camera Speeds and Different Focal Length Lenses

EXAMPLE: 24 f.p.s. with 50mm Lens Should Take 23 Seconds to Pan 90° Sweep

CAMERA SPEED FRAMES PER/SEC.	FOCAL LENGTH OF LENS IN MM										
	18 to 20	25 to 28	35	40	50	75	85	100	150	180	300
	PANNING SPEED — Unshaded Numbers: SECONDS; Shaded Numbers: MINUTES										
8	27	45	55	60	1.5	2.0	2.5	3.0	4.0	5.0	7.0
12	18	30	36	42	54	70	1.5	2.0	2.5	3.5	5.0
16	13	23	27	32	41	55	70	1.5	2.0	2.5	3.5
20	11	18	22	25	27	43	60	70	1.5	2.0	3.0
24	9	15	18	21	23	36	50	60	80	1.5	2.5
32	7	11	14	16	20	27	38	45	60	75	2.0
48	4.5	7.5	9	11	13	18	25	30	40	55	75
60	3.5	6	7	8	11	14	20	24	32	40	60
75	3	5	6	7	9	12	17	19	26	35	50
90	2.4	4	5	6	7	10	14	16	21	29	40
120	1.8	3	4	4	5	7	10	12	16	22	30
150	1.4	2.4	3	3.5	4	6	8	10	13	17	25

35mm CAMERA RECOMMENDED PANNING SPEEDS IN DEGREES PER SECOND

(For Static Scenes) Approximately 180° Shutter

For Various Camera Speeds and Different Focal Length Lenses

EXAMPLE: 24 f.p.s. with 50mm Lens Should Be Panned 3.6° Per Second or 36° in 10 Seconds, etc.

LENS FOCAL LENGTH: mm	24 f.p.s.	60 f.p.s.	80 f.p.s.	100 f.p.s.	120 f.p.s.
17	9.9°	25.0°	33.3°	41.6°	49.9°
25	7.0°	17.5°	23.3°	29.1°	34.9°
28	6.3°	15.7°	20.9°	26.1°	31.3°
32	5.5°	13.7°	18.2°	22.9°	27.4°
35	5.0°	12.7°	16.9°	21.1°	25.4°
50	3.6°	8.7°	11.7°	14.6°	17.5°
75	2.4°	6.0°	8.0°	9.9°	12.0°
85	1.7°	4.3°	5.8°	7.2°	8.7°
100	1.5°	3.9°	5.2°	6.4°	7.7°
125	1.3°	3.3°	4.3°	5.4°	6.5°
150	1.1°	2.8°	3.7°	4.6°	5.5°
180	0.95°	2.4°	3.2°	4.0°	4.7°
300	0.58°	1.5°	1.9°	2.4°	2.9°
500	0.36°	0.64°	0.9°	1.07°	1.3°

35mm CAMERA RECOMMENDED PANNING SPEEDS

(For Static Scenes)

180° Shutter & Various Degrees of Sweep

EXAMPLE: 60° Pan with 75mm Lens Should Take 24 Seconds

	FOCAL LENGTH OF LENS IN MM											
PANNING	18 to 20	25 to 28	35	40	50	75	85	100	150	180	300	500
ANGLE IN DEGREES	PANNING SPEED Unshaded Numbers: SECONDS									Shaded Numbers: MINUTES		
30°	3	5	6	7	9	12	18	20	27	32	50	80
60°	6	10	12	14	18	24	36	40	55	60	95	2.5
90°	9	15	18	21	23	36	50	60	80	90	2.5	4.0
120°	12	20	24	28	36	48	65	80	100	2.0	3.5	5.0
150°	15	25	30	35	45	60	80	95	2.0	2.5	4.0	6.5
180°	18	30	36	42	54	72	95	2.0	2.5	3.0	5.0	8.0

Light Sources and Lighting Filters

by Richard B. Glickman, Consulting Engineer
ASC Associate Member

The advent of faster films has changed many of the rules for well-established lighting techniques. Feature-film photography is now routinely accomplished in "natural lighting" situations, and night scenes are photographed with only the light available from street lighting and shop windows. The speed of these new emulsions has made possible a new degree of realism, and greater freedom in selecting locations for photography.

Quality photography still demands consistent lighting. Consistency often depends on an understanding of the characteristics of various light sources. Light sources may be mixed in any lighting situation, so long as care is taken to apply the appropriate filtering to ensure a consistent color balance. The following sections will deal with those requirements.

The use of lighting filters, formerly restricted to a few blues and ambers, has now advanced to the point where relatively refined adjustments can be made in the spectral energy output of the wide variety of sources. The use of this more sophisticated range of lighting filters has been made practical by the development of convenient color temperature meters that produce relatively sophisticated information about light sources.

The actual lighting of a scene is an artistic process which is beyond the scope of this work. Those artistic decisions involve many considerations, such as the type of story being told, the desired mood and the emotional content of the material. The cinematographer's efforts in those directions, and the specific tools he or she uses, are the hallmarks of the work of any given cinematographer.

Characteristics of Light Sources

The predominance of location photography makes a basic understanding of typically encountered light sources essential. Particularly important, due to their widespread use, are the AC enclosed arc discharge lamps such as HMI-types. Today's cinematographer must have a grasp of the basic operational characteristics of these light sources.

COMPARISON OF SOME TYPICAL COMMERCIAL/INDUSTRIAL LIGHT SOURCE CHARACTERISTICS			
Description	Correlated Color Temperature (°Kelvin)	Color Rendering Index	Efficacy (Lumens/Watt)
Fluorescent Types			
Daylight	6500	79	60
Design White	5200	82	50
Cool White	4300	67	70
Deluxe Cool White	4100	86	50
Natural White	3700	81	45
White	3500	62	70
Warm White	3050	55	70
Deluxe Warm White	2950	73	45
Incandescent	2700	90	35
Mercury Vapor Types			
Clear Mercury	5900	17	50
White Deluxe	4000	45	55
Warm Deluxe	3500	62	70
Metal Halide Additive Types			
Multi-arc™; Metal Vapor™	5900	65	80-115
Metalarc C™	3800	70	80-115
High Pressure Sodium			
Lucalox™	2100	25	80-140
Lumalux™			

For a detailed explanation of the parameters of Correlated Color Temperature, Color Rendering Index and Efficacy, reference should be made to page 319.

In this section, a wide range of photographic, commercial and industrial light sources will be dealt with in some detail. The accompanying tables give the reader a brief idea of the range of characteristics to be encountered.

Physical Characteristics of Light Sources

Figure 1 shows the various lamp envelope configurations and the designations that are common to them. The

Comparison of Photographic Light Sources

Description	Correlated Color Temperature (at rated voltage)	Mired Value	Efficacy Lumens/watt
Incandescent			
Standard and tungsten/ halogen	3200K	313	26
CP gas filled	3350K	299	32
Photoflood	3400K	294	34
Daylight blue photoflood	4800K	208	
Carbon arc (225A Brute)			
White flame, Y-1 filter	5100K	196	24
" " no filter	5800K	172	
Yellow flame YF 101 filter	3350K	299	
*Xenon, high pressure DC short arc	6000K	167	35-50
*Metal halide additive AC arc			
HMI	5600K	179	80-102
CID	5600K	179	80
CSI	4200K	238	85

*Need filtering for color photography.

use of this figure reveals the envelope's configuration by simply knowing that the code letters associated with the lamp designation are the dimensional descriptive data.

The following examples are offered to clarify this descriptive process:

a.) R40 — This is a reflector flood ("R" type envelope), which is 40/8ths of an inch in diameter.

b.) PAR 64 — The designation "PAR" refers to the sealed beam lamp type (Parabolic Aluminized Reflector) which is 64/8ths of an inch in diameter.

c.) Q1000 PAR 64 — This is the envelope as in (b.), but the "Q" designates a tungsten halogen lamp of 1000 watts inside. ("Q" is a hangover from the early days of tungsten halogen when these lamps were referred to as Quartz Iodine.)

d) Q1000T3 — A tungsten halogen lamp, 1,000 watts, with a tubular envelope 3/8ths of an inch in diameter.

Another important element in the construction of lamps is the basing. Figure 2 shows the most common base arrangements used on incandescent-type lamps (also applicable to certain discharge types). This figure can be helpful in establishing whether a particular lamp can be mated to a given fixture.

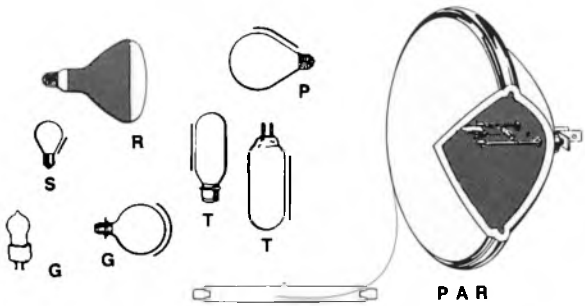


Figure 1. Lamp envelope configurations.

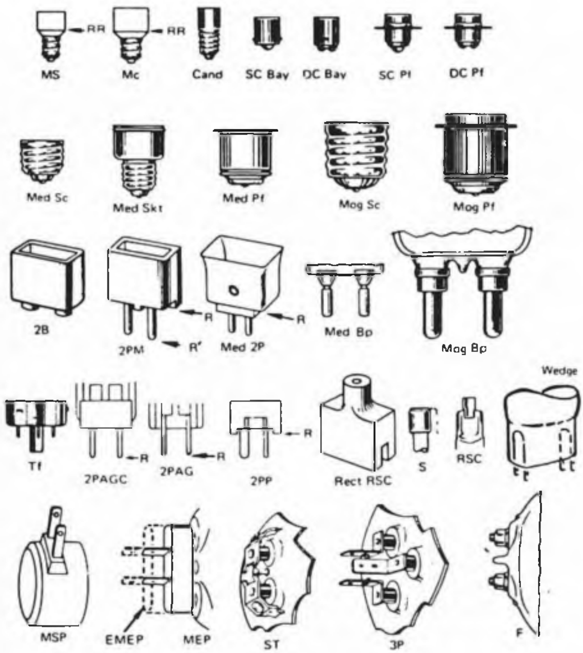
Color Temperature

Color temperature describes the actual temperature of a "black body radiator" and thereby completely defines the spectral energy distribution (SED) of the object. When the object becomes luminous and radiates energy in the visible portion of the spectrum, it is said to be incandescent. Simply stated, this means that when an object is heated to an appropriate temperature, some of its radiated energy is visible.

The color temperature is usually described in terms of degrees Kelvin. This simply refers to a temperature scale, like Fahrenheit or Centigrade (Celsius). It is in fact the absolute Centigrade (Celsius) scale, which is the temperature in degrees Centigrade (Celsius) plus 273 degrees.

When metal is gradually heated, the first visible color is "dull cherry red." As the temperature is raised, it visually becomes "Orange," then "Yellow," and finally "White" hot. The actual effect of increasing color temperature on the spectral energy distribution is best seen in Figure 3.

Strictly speaking, tungsten filaments are not true black bodies. However, from a practical standpoint, both standard incandescent lamps and tungsten halogen types can be so considered.



Cand	candelabra
DC Bay	double-contact bayonet candelabra
DC Pf	double-contact prefocus candelabra
EMEP	extended mogul end prong
F	ferrule contact
Mc	minicam
Med Sc	medium screw
Med Bp	medium bipost
Med Pf	medium prefocus
Med Skt	medium skirted
Med 2P	medium two pin
MEP	mogul end prong (also: extended mogul end prong)
Mog Sc	mogul screw
Mog Bp	mogul bipost
Mog Pf	mogul prefocus
MS	miniature screw (with reference shoulder) (also: Tru-Loc miniature screw)
MSP	medium side prong
Rect RSC	rectangular recessed single contact
RM2P	rim mount two pin
RSC	recessed single contact (also: single contact recessed)
S	metal sleeve
SC Bay	single-contact bayonet candelabra
SCI Pf	single-contact prefocus
ST	screw terminal
TB2P	trubeam two pin
Tf	trufocus (also: four pin)
TLMS	Tru-Loc miniature screw (also: miniature screw with reference shoulder)
Wedge	wedge
2B	two button
2PAG	two pin all glass
2PAGC	two pin all glass (ceramic cover)
2PM	two pin miniature
2PP	two pin prefocus
3P	three prong

Notes: R indicates special reference point for LCL. 'Note below (RR - at 0.531 inch diameter)

Figure 2. Common incandescent lamp bases (not to scale).

One of the most important characteristics of incandescent radiators is that they have a continuous spectrum. This means that energy is being radiated at all the wavelengths in its spectrum. Color temperature is only properly applied to radiating sources that can meet this requirement. Therefore, for example, the application of the term "color temperature" to describe the color of fluorescent tubes is incorrect for the following reasons: Fluorescent lamps do not have continuous spectra, and fluorescent lamps do not emit visible radiation due to incandescence (because of their temperature). In practice the term is applied to many other sources. When it is applied to these non-incandescent sources, it really refers to "correlated color temperature."

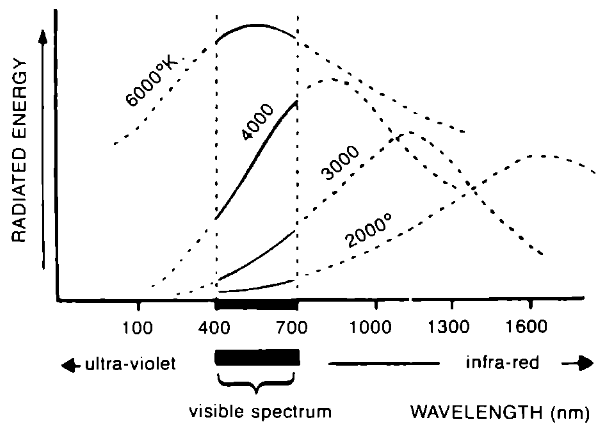


Figure 3. Relative radiant energy distribution for sources at various color temperatures.

Correlated Color Temperature

The term correlated color temperature is used to indicate a visual match where the source being described is not a black body radiator. The term is often abused, an example being its application to such light sources as mercury vapor lamps.

From a photographic standpoint, the correlated color temperature can be extremely misleading. It is important to keep in mind that its connotations are visual. It is a number to be approached with extreme caution by the cinematographer.

Correlated Color Temperature of Typical Light Sources

Artificial Light			
Source			**Mireds**
Match flame	1700K		588
Candle flame	1850K		541
Tungsten-gas filled lamps:		Camera filter	
40-100W	2650-2900K	82B (100W)	317-345
200-500W	2980K	82A	336
1000W	2990K	82A	334
Daylight			
Sunlight:			
Sunrise or sunset	2000K		500
One hour after sunrise	3500K		286
Early Morning, late Afternoon	4300K		233
Average noon, (Wash. D.C.)	5400K		185
Midsummer	5800K		172
Overcast sky	6000K		167
Average Summer Daylight	6500K		154
Light Summer Shade	7100K		141
Average Summer Shade	8000K		125
Partly cloudy sky	8000 -10000K		125-100
Summer skylight	9500 -30000K		105-33

Sunlight should not be confused with daylight. Sunlight is the light of the sun only. Daylight is a combination of sunlight and skylight. These values are approximate since many factors affect the Correlated Color Temperature. For consistency, 5500K is considered to be Nominal Photographic Daylight. The difference between 5000K and 6000K is only 33 Mireds, the same photographic or visual difference as that between household tugsten lights and 3200K photo lamps (the approximate equivalent of ⅓ Blue or ⅛ Orange lighting filters).

The MIRED System

When dealing with sunlight and incandescent sources (both standard and tungsten halogen types), the MIRED system offers a convenient means for dealing with the problems of measurement when adjusting from one color temperature to another. *This system is only for sources that can truly be described as having a color temperature.* The term MIRED is an acronym for Micro Reciprocal Degrees. The MIRED number for a given color temperature is determined by using the following relationship:

$$\text{MIRED Value} = \frac{1{,}000{,}000}{\text{Color Temperature (degrees Kelvin)}} = \left[\frac{10^6}{{}^\circ K}\right]$$

As a convenience, refer to page 323, which is a quick reference for determining the MIRED values for color temperatures between 2000K and 6900K in 100-degree steps.

Filters which change the effective color temperature of a source by a definite amount can be characterized by a "MIRED shift value." This value is computed as follows:

$$\text{MIRED Shift Value} = \left(\left[\frac{10^6}{T_2}\right] - \left[\frac{10^6}{T_1}\right]\right)$$

T1 = Kelvin temperature of the original source.
T2 = Kelvin temperature of the original source as measured through the filter.

MIRED shift values can be positive (yellowish or minus blue filters) or negative (blue or minus red/green filters). *The same filter (representing a single MIRED shift value), applied on light sources with different color temperatures, will produce significantly different color temperature shifts.* Occasionally, the term Decamireds will be found in use for describing color temperature and filter effects. Decamireds is simply MIREDs divided by 10.

Color Rendering Index

The Color Rendering Index (CRI) is used to specify the stated characteristic of a light source as it might be used for critical visual color examinations such as in color matching or inspection of objects. The CRI is established by a standard procedure involving the calculated visual appearance of standard colors viewed under the test source and under a standard illuminant. The CRI is not an absolute number, and there is no particular relative merit to be determined by comparing the CRIs of several sources.

The CRI is of importance photographically only when it is between 90 and 100. This is accepted to mean that such a source has color rendering properties that are a commer-

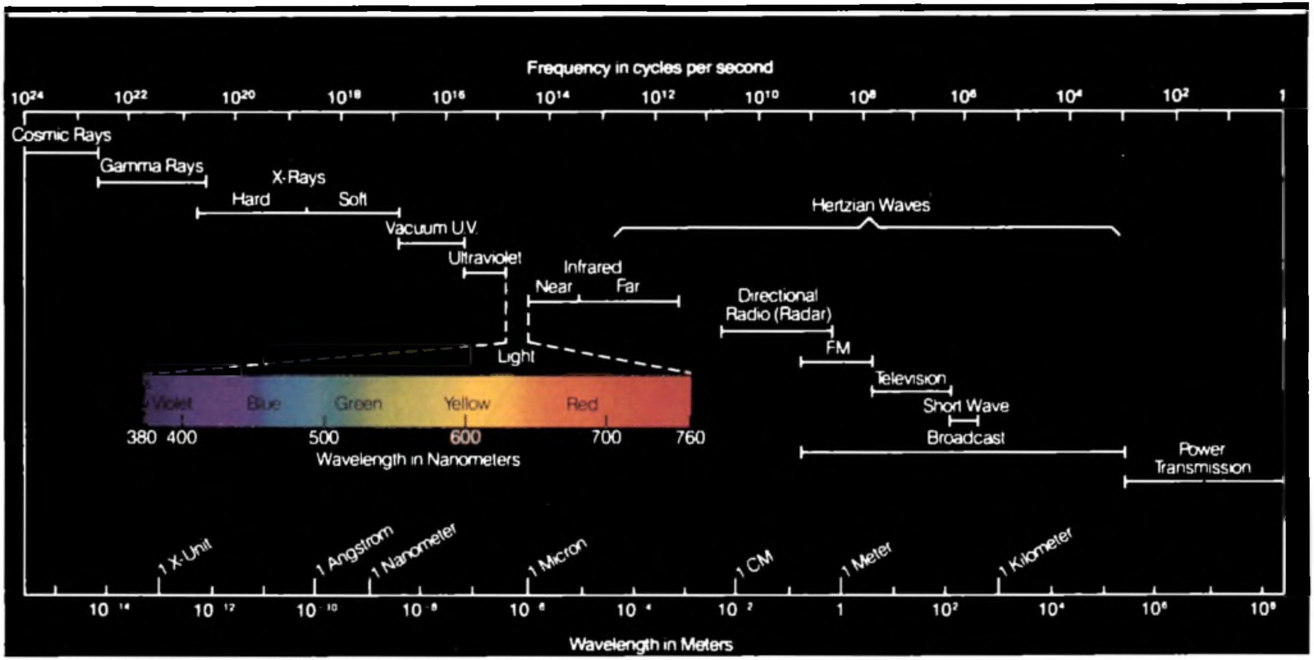


Figure 4. The radiant energy (electromagnetic) spectrum.

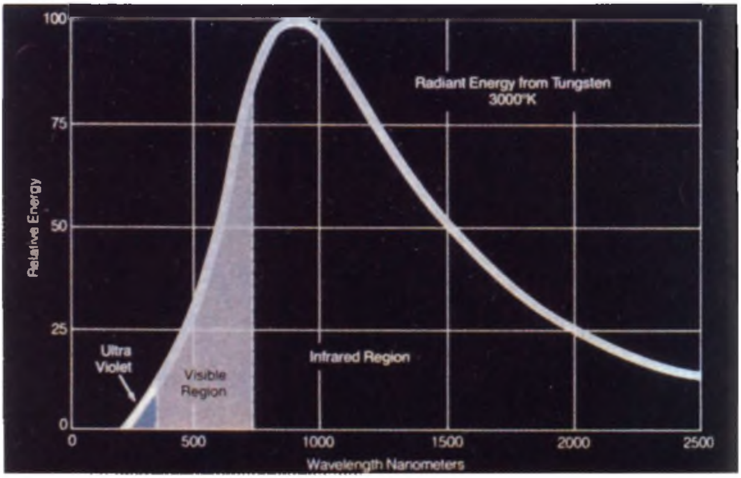


Figure 5. Spectral energy distribution for 1000-watt lamp with approximate color temperature of 3000 degrees K.

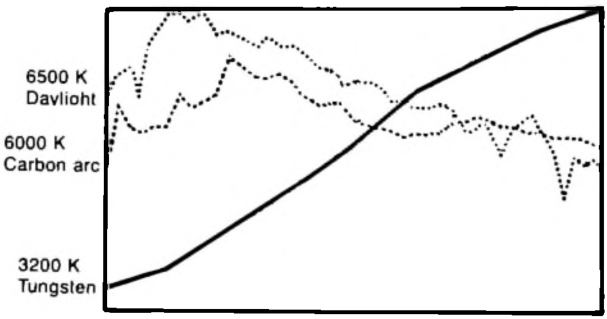


Figure 6. Spectral energy distribution of a tungsten filament lamp at 3200K, a carbon arc at 6000K, and daylight at 6500K.

The visual color response to the energy within particular wavelength bands is described in the following approximate terms:

Color Sensation	Approximate Wavelength Band (nm)
Violet	380–430
Blue	430–490
Green	490–560
Yellow	560–590
Orange	590–630
Red	630–700

EXAMPLES OF MIRED SHIFT VALUE (FILTER) EFFECTS

Initial Source		Filter	Filtered Source		°Kelvin
°K	Mireds	Mired Shift	Mireds	°K	Change
10,000	100	+112	212	4720	5280
6,000	167	+112	279	3600	2400
5,000	200	+112	312	3200	1800
2,600	385	-21	364	2750	150
2,900	345	-21	324	3090	190
3,200	312	-21	291	3440	240

Mired Values of Color Temperatures from 2000–6900°K

°K	+ 0	100	200	300	400	500	600	700	800	900
2000	500	476	455	435	417	400	385	370	357	345
3000	333	323	312	303	294	286	278	270	263	256
4000	250	244	238	233	227	222	217	213	208	204
5000	200	196	192	189	185	182	179	175	172	169
6000	167	164	161	159	156	154	152	149	147	145

cial match to the reference source. For example, the HMI lamps have a CRI of 90 to 93, referred to the D55 standard illuminant (D55 is the artificial match to standard daylight of 5500K).

Spectral Energy Distribution

The spectral energy distribution (SED) is the standard means for exhibiting the relative amounts of energy being radiated by a source as a function of wavelength. This is sometimes called the spectral power distribution (SPD).

The visible spectrum (see Fig. 4), which is also the useful photographic spectrum, comprises the energy whose wavelengths are between approximately 400 and 700 nanometers (nm). Wavelengths shorter than 400 nm are in the ultraviolet region of the spectrum, and those longer than 700nm are in the infrared region.

The electromagnetic radiant energy spectrum is shown in Figure 4. The SED for a lamp at 3000K is shown in Figure 5. A comparison of the spectral energy distributions of 3200K, natural daylight and a carbon arc (white flame carbon) can be seen in Figure 6.

Illumination Data

The purpose of this section is to explain simple general rules for dealing with illumination data. In particular, it will provide the means for interpreting data offered by manufacturers and for interpolating readings based on measurements made by the cameraman.

1. Lighting Quantities — Intensity

Intensity is measured in units of "candelas." An earlier term for this is candlepower. Normally, a value for candelas is also accompanied by directional information. In former times the intensity on axis was referred to as center beam candlepower.

The unique property of intensity relative to the source of light in a given direction is that it is not dependent on distance from the source. The intensity is the same no matter how far away. The only restriction is that it has reduced accuracy if measurements are made closer to the source than approximately ten times the maximum diameter of the lighting unit. For example, for a 12 fresnel lens spotlight, the intensity figures are only accurate at a distance greater than about 10 feet.

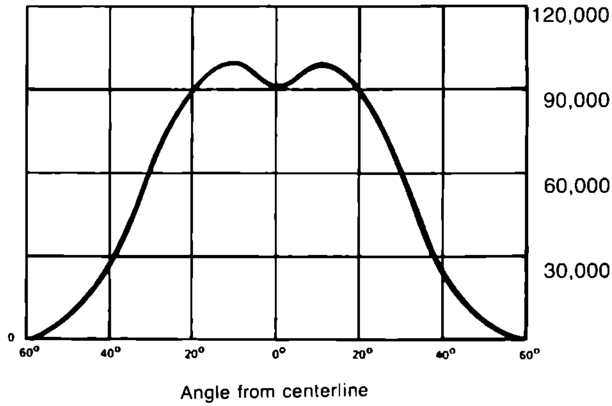


Figure 7. Luminaire intensity distribution—rectangular.

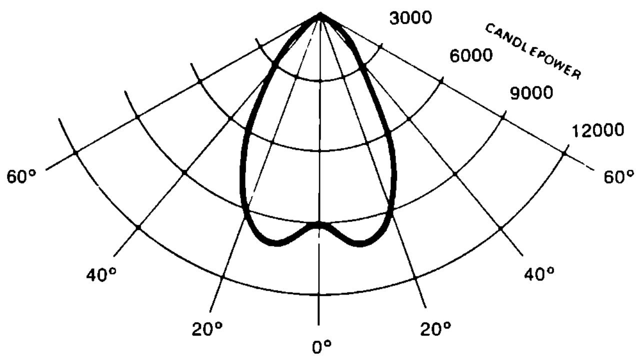


Figure 8. Luminaire intensity distribution—polar.

There are two ways that the intensity information is normally shown. Examples of these are shown in Figures 7 and 8. The only difference between these is that in one case the data is presented in a rectangular coordinate format, and in the other polar coordinates are used. Most lighting manufacturers supplying instruments to the motion-picture industry tend to present their data in a rectangular format. The polar presentation is more likely to be encountered with commercial/industrial type fixtures.

Where the intensity distribution of a lighting source is known, the illumination produced by the unit can be calculated using the inverse square law. This is expressed as follows:

$$\text{Illumination (foot candles)} = \frac{\text{Intensity (candelas)}}{D^2 (D = \text{distance in feet})}$$

$$\text{Illumination (Lux)} = \frac{\text{Intensity (candelas)}}{D^2 (D = \text{distance in meters})}$$

(Example: A fixture is described as having a center intensity (or center beam candlepower) of 50,000 Candelas. What is the illumination at 25 feet? What is the illumination at 10 meters?

$$\text{(a) at 25 feet} = \frac{50{,}000}{25 \times 25} = \frac{50{,}000}{625} = 80 \text{ footcandles}$$

$$\text{(b) at 10 meters} = \frac{50{,}000}{10 \times 10} = \frac{50{,}000}{100} = 500 \text{ Lux}$$

2. Lighting Quantities—Coverage

All lighting fixtures have a lighting distribution which may be visible as projected on a flat wall. Often this is expressed as shown in Figure 9 and defined as an illumination distribution curve. The important standard measuring points for such a distribution are as follows:

Beam Coverage: This is described as the limit of the area covered to within 50% of the maximum intensity.

Field Coverage: This is described as the area covered to within 10% of the maximum intensity.

Of the two areas described above, the beam coverage is the more important photographically. It describes the area that is illuminated at a level that is not lower than 1 stop down from the center intensity. The assumption is made, where a single distribution is shown, that the distribution pattern is essentially circular.

Calculating Coverage from Beam Angle: The following expression allows the computation of the coverage diameter (W) for any distance (D) and a given beam angle (Refer to Figure 10). The expression is:

W = 2 x (D) x [Tangent (½ Beam Angle)]

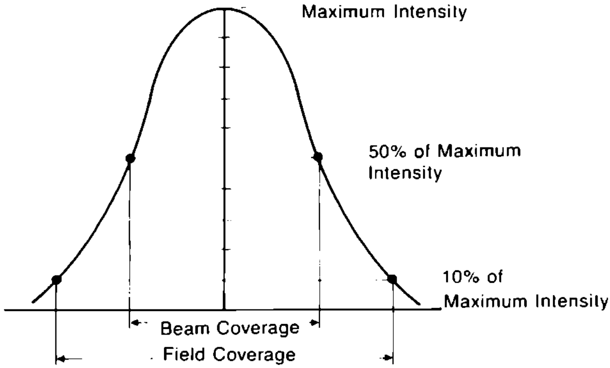


Figure 9. Definition of intensity distribution curves.

(Example: For a distance of 50 feet and a known beam angle of 26 degrees, what is the coverage diameter of the beam (50% of the center)?

D = 50 feet; Beam Angle = 26 degrees.
½ Beam Angle = 13 degrees
Tangent of 13 degrees = .231

W = 2 x 50 x .231 = 100 x .231 = 23.1 feet

3. General Comments on Calculations

Most manufacturers are now offering both candela information and angular coverage. This is actually sufficient information to make some approximations of what to expect from the lighting fixtures using the procedures outlined above.

In the event that it is necessary to convert from footcandles to lux, the value of footcandles should be multiplied by 10.8. To convert lux to footcandles, divide lux by 10.8.

Usually, lux values will be associated with distances measured in meters, and footcandles with distances measured in feet. In the case of the illumination calculations above, the use of feet or meters as the units of distance will automatically yield illumination values in footcandles or lux respectively.

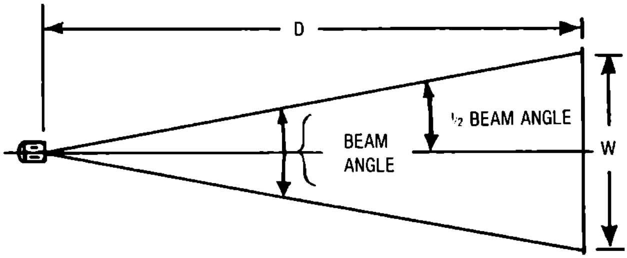


Figure 10. Definition of terms for calculating coverage.

TANGENT FUNCTION							
Angle	Tangent	Angle	Tangent	Angle	Tangent	Angle	Tangent
1	.018	12	.213	23	.425	34	.675
2	.035	13	.231	24	.445	35	.700
3	.052	14	.249	25	.466	36	.727
4	.070	15	.268	26	.488	37	.754
5	.088	16	.287	27	.510	38	.781
6	.105	17	.306	28	.532	39	.810
7	.123	18	.325	29	.554	40	.839
8	.141	19	.344	30	.577	41	.869
9	.158	20	.364	31	.601	42	.900
10	.176	21	.384	32	.625	43	.933
11	.194	22	.404	33	.649	44	.966
						45	1.000

Photographic Light Sources

The sources covered in this section include the more familiar man-made types, such as incandescent, carbon arc and AC arc discharge lamps as well as an exposition on natural daylight.

The general characteristics of each type are delineated in moderate detail, including spectral energy distributions and electrical characteristics. In addition, any special considerations for the cinematographer are carefully noted. Each sub-section on a particular class of light source closes with detailed information on filtering the source.

Natural Daylight

Natural daylight, on a clear day, is the sum of sunlight and skylight. The sunlight is directly from the sun, whose surface is about 6,000K. Skylight is from sunlight that has been scattered and filtered in the earth's atmosphere. Since the shortest wavelengths are the ones least filtered by the atmosphere, this results in the blue sky. Figure 11 represents the spectral energy distribution for the sun compared to a 5400K source.

Daylight conditions are highly varied, from a photographic viewpoint, based on the local atmospheric conditions, location on the earth, time of year, hour of the day and the amount of atmospheric pollutants that may be present. A brief summary of some of the possibilities is presented on page 319.

In addition to color temperature variations, the degree of diffusion in daylight varies from the least to the most diffuse lighting conditions that can be experienced.

Least Diffuse — In clear cloudless sunlight, the sun as the main lighting source (key) is truly a point. This produces the hardest, most distinct shadows. The incident light level from the sun on such a day can be as much as 9,500 footcandles. The skylight contribution (fill) is about 1,500 footcandles. This produces a lighting ratio of about 7:1 (key to fill).

Lighting control in these situations may require booster lighting or the use of certain grip devices such as large overhead scrims.

Most Diffuse — A completely overcast day is essentially shadowless lighting. The entire sky, horizon to horizon, becomes the light source. The incident level may be as low as 200 footcandles.

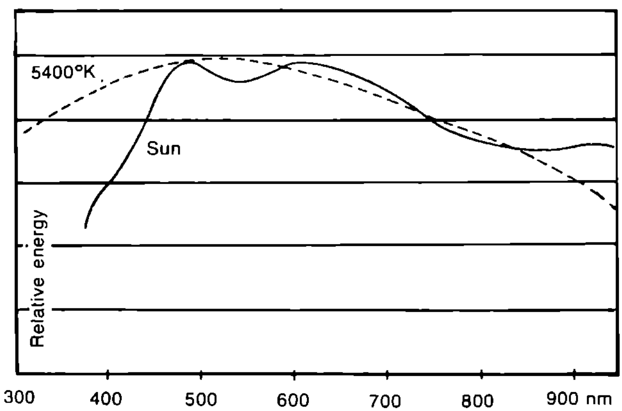


Figure 11. Similarity of sunlight to a theoretical 5400 K light source.

Filters for Control of Natural Daylight

A family of materials, mostly on polyester plastic-based film, are made for light control in these situations. These are normally supplied in rolls that are from 48 to 58 inches wide (122 to 147 cm). In addition, the 85, and ND3, ND6 and ND9 types are also available as rigid acrylic panels, usually 4 by 8 feet in size (1.22 x 2.44 meters).

Reference should be made to pages 323 and 278 in reading this section. Page 323 lists the MIRED shift values for the various materials, and their effect on sources of two different color temperatures. Page 278 summarizes the filter requirements for each element of the lighting system and camera for interior cinematography against daylighted windows.

When properly applied, sharp focus can be carried through windows treated with either the plastic film materials or the acrylic panels. The panels are particularly useful where wind or strong air movement may cause the plastic film to move and produce visible highlights.

Conversion-Type Filters

These materials are intended for application at openings (doors, windows, etc.) where natural daylight is entering an interior which is to be photographed at a 3200K balance. The "full" conversion materials available are known as "CTO" and "85." In USA lighting practice, the "85" has been the type most widely applied (it is really a Wratten 85B equivalent). The European practice has been to use the deeper correction such as the "CTO." The choice of filter will obviously be determined by the actual daylight conditions being dealt with, or by artistic considerations.

Filters which accomplish less than the full correction to 3200K are also available, and are widely used to deal with the variations in daylight conditions that may be encountered. They are also used where the artistic effect wanted is different from "natural" daylight (page 367).

Neutral-Density Filters

Where it is desired to use a daylight balance inside the space in which photography is taking place, the only filter normally indicated for the windows will be neutral density. These are usually required due to the overpowering levels of sunlight which are often encountered in natural settings. Typically these filters are available as either plastic films or as rigid acrylic sheets. Normally they can be obtained in densities which reduce the incident light by ½, 1, 2, or 3 stops (ND.15, ND.3, ND.6, and ND.9).

Combination Filters

Combinations of 85 and neutral density or CTO with neutral density are also available. These are utilized to reduce the number of materials which must be installed in order to accomplish both the conversion and the reduction of lighting level.

Incandescent Light Sources

The incandescent source is characterized by having a filament structure through which current is passed to produce heating.

When the filament is heated to very high temperatures it radiates visible light as a part of its radiant energy output. Figure 12 show the relative spectral energy distributions for some incandescent lamps at various color temperatures.

Incandescent sources, relative to the visible spectrum, radiate at all wavelengths in that spectrum. The proportion

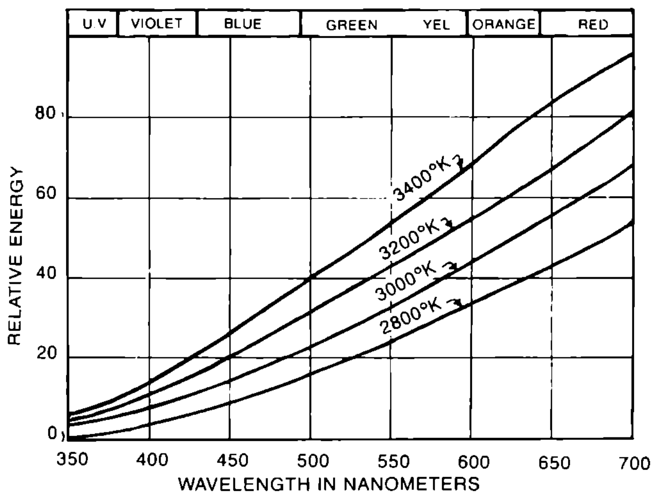


Figure 12. Spectral energy distribution curves for incandescent lamps at various color temperatures.

of energy at the different wavelengths (the spectral energy distribution) is solely dependent on the Kelvin temperature at which the filament is operated. Some of the typical filament configurations encountered in the photographic types of sources are shown in Figure 13. The designations for the various conformations are standard in the USA.

Incandescent sources may be operated on either alternating or direct current. A very wide range of light sources has been designed with nominal operating voltages to meet the requirements of both USA and international requirements. There are two basic subdivisions within the class of incandescent sources.

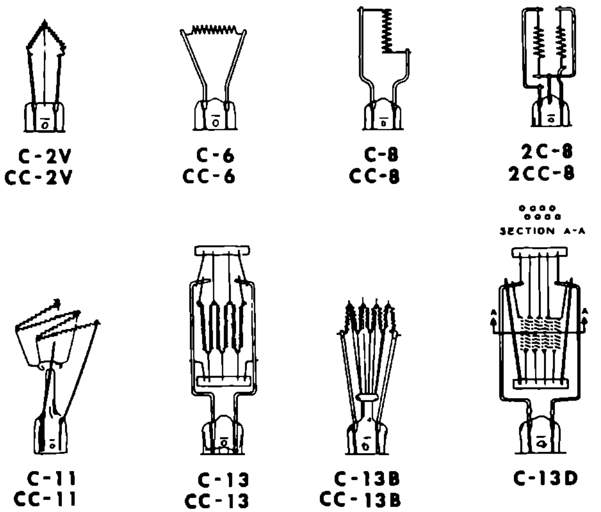


Figure 13. Common incandescent filament forms and their designations.

Standard Incandescent

The standard incandescent source utilizes a tungsten filament in a gas-filled enclosure of commercial glass. These basic lamp types have been available for many years of motion-picture production. It has been traditional to produce two ranges of Kelvin temperature for professional use in these types of lamps. Typically, at the rated voltage (i.e., 120 volts), a 3200K and a 3350K design have been available. 3350K lamps are close to the Photoflood balance of Type

A color film and 3200K lamps are used for all professional color motion picture films.

Tungsten-Halogen Lamps

The tungsten-halogen lamp is an incandescent lamp. Its radiant energy output is based strictly on the temperature of its filament, but it offers an important difference in operating principles when compared to the standard incandescent type.

The addition of a halogen gas in the fill plus the use of high temperature materials in the envelope of the lamp (quartz or fused silica, and recently hard glass), has resulted in a design which does not experience the blackening effect with age that is characteristic of the standard incandescent types. Due to the presence of the "halogen cycle" within the lamp, the tungsten is not permitted to deposit on the bulb walls (as long as the wall temperature is above 250 degrees C). It is, in fact, re-deposited on the filament (See Figure 14). The results of this development have been manifold:

1. Tungsten-halogen lamps have minimal loss in lumen output and no significant shift in color temperature during their entire life.

2. Tungsten-halogen lamps with similar configurations, wattages and initial lumen outputs as standard incandescent types are now produced with substantially longer useful life.

3. Because of the requirement for high bulb wall temperatures, it has been necessary to shrink the envelope size of these lamps, resulting in completely new families of lamps with much smaller external dimensions than the standard incandescent equivalent.

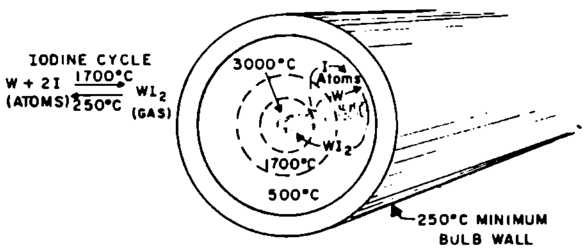


Figure 14. Diagram of Halogen Cycle within lamp.

In all other respects, the tungsten-halogen lamp should be considered the same as the standard incandescent. They may be operated on either alternating or direct current. Care should be taken during installation to prevent finger-marking of the envelope since there is a tendency for some degradation of the envelope to occur if fingerprints or dirt are left on during operation.

Incandescent Lamp Operation

Following are some characteristic curves which will explain more clearly the relationship of various of the parameters associated with incandescent lamp operations. These curves are applicable to both standard incandescent (when the lamp is relatively new) and to tungsten-halogen lamps.

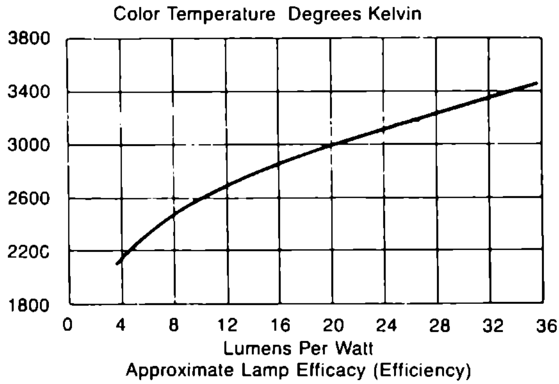


Figure 15. Incandescent lamp efficacy as a function of color temperature.

Lumens are a measure of the total light output of a source. In the case of incandescent lamps the lumen output depends almost entirely on the temperature of the filament and the amount of power. The efficacy of the lamp (lumens/watt) is almost entirely dependent on the temperature of the filament, and because of this relationship the color temperature and lumens per watt (efficacy of the lamp) can be related. This is demonstrated in Figure 15.

The relationship between the lumen output and the operating voltage of the lamp can also be demonstrated as shown in Figure 16. This has been normalized so that the

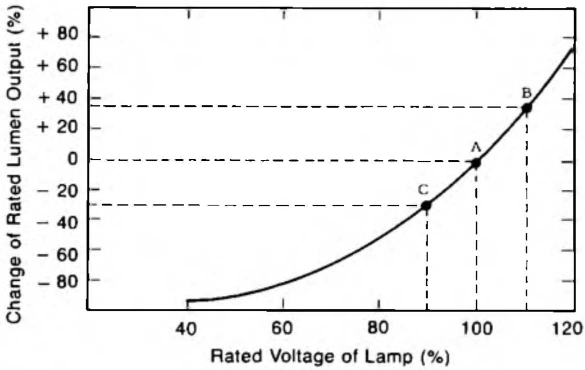


Figure 16. Curve showing change of lumen output of lamp as voltage is changed. This has been normalized so that the percentages of lumen output change to percentage change in rated voltage can be easily related.

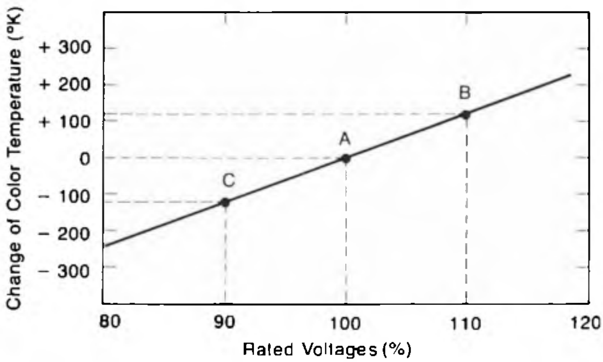


Figure 17. Curve showing change of color temperature (degrees K) as voltage is changed.

percentages of lumen output change to percentage change in rated voltage can be easily related.

There is a direct relationship between the shift in Kelvin temperature and the operating voltage of an incandescent lamp. This is shown in Figure 17 in terms of an absolute change in color temperature for a percentage shift in the rated voltage. The rule of thumb that has been used with 120-volt-rated lamps is that a one-volt change (up or down) results in a 10-degree Kelvin shift. This approxima-

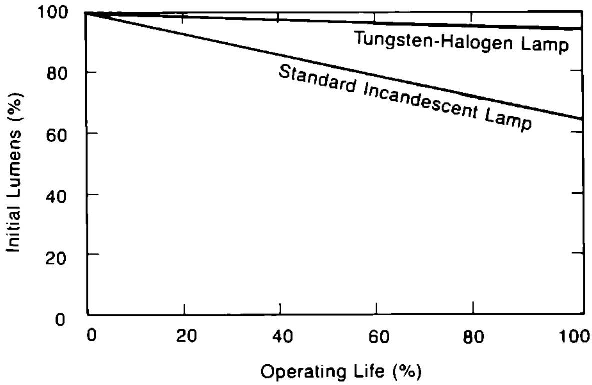


Figure 18. Curve showing lumen output of lamp during life.

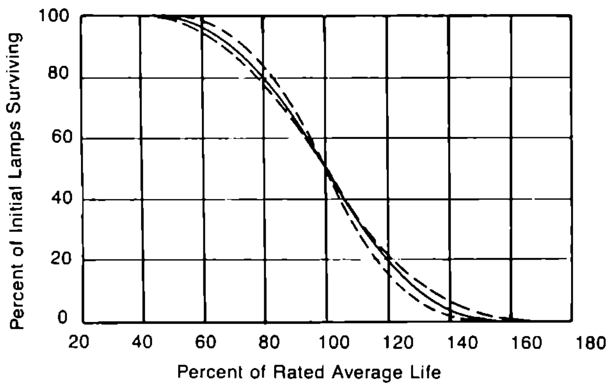


Figure 19. Life expectancy curve for tungsten filament lamps.

tion is reasonably accurate as long as the percentage change in voltage is within 10-15% of the rated value.

Figure 18 compares the percentage of initial lumens versus the percentage of operating life between conventional incandescent and tungsten-halogen lamps. Note that the tungsten-halogen type has only a very nominal shift in the lumen output during the course of its entire life compared with the standard incandescent lamp.

The life rating of all types of incandescent lamps is based on the following concept: if a very large group of lamps is started at the same time, the life rating represents the time at which 50% of the group will still be burning. A standard mortality curve for incandescent lamps is shown in Figure 19.

Boosted-Voltage Operation

It is possible to over-voltage a wide range of standard 120-volt, 2800-2900K lamp types and convert them effectively to photographic lamp types. This system ("Colortran" boosting) was widely in use in many places around the world until the substantial advent of the tungsten-halogen lamp. Although little-used in the USA now, it is still in wide use in other parts of the world and offers some interesting advantages. There are many situations in which this system may be both cost-effective and functionally desirable for particular circumstances.

The system is designed to utilize standard 120-volt-rated tungsten filament lamps whose rated life at 120 volts is 750 hours or more. *The system must not be used with standard tungsten-halogen incandescent types, unless there is a certainty that the lamp has been specifically designed for use in a boosted-voltage system.* Using the standard incandescent types, a very broad range of lamp types, including many of the sealed beams and the "R" series as well as many other standard incandescent lamps, may be utilized and operated at 3200K or higher.

Typically, when lamps are operated at 165 volts, the color temperature should be approximately 3100K to 3200K. It is possible to continue the boosting operation, and some lamp types will actually yield 3300-3400K when operated at approximately 185 volts. Due to the low pressure in the standard incandescent, long-life lamps, this is a safe type of operation.

In the past, equipment was manufactured to accomplish this voltage-boosting function with push-button control of a tapped autotransformer. The Colortran converters usually provide input voltage selection (provision is built in to adjust the unit for input voltages between 100 and 250 volts) and adjustment so that the full boost range was available under any of these input conditions. This permitted the use of the same lamps anywhere in the world. This equipment is still in use in many places, and should be given consideration where economics and function dictate the feasibility.

A further advantage of this system is that the standard incandescent types utilized in it tend to be very much less expensive than the photographic lamp types that are rated at 3200K at the operating voltage. Further, the expected life of many of these lamps at 3200K operation is directly comparable to the life that can be expected from 3200K type photographic lamps operated at their rated voltages.

Filters for Incandescent Lamps

These filters are typically applied to incandescent sources, which may be "quartz," standard incandescent or "boosted" incandescent types. These filters are normally for the purpose of changing the SED to an approximation of daylight. They are referred to as conversion filters (see page 367).

The original standard for this conversion was a glass filter, the MacBeth "Whiterlite" type. This filter transmits only about 35% of the light, and has been largely superseded by the dichroic types which transmit about 50% of the incident light. The dichroic is an interference-type filter, and most of these convert the 3200K source to approximately 5000K to 5200K.

Care must be exercised in the use of the dichroic filters since they do not have the same filtering characteristics for light incident on the filter at widely varying angles. When used on some types of focusing light (particularly some of the open reflector "quartz" types), there may be changes in color as the light is focused. Generally, the light at the edge of the field will show some shift in color on wide-beam floodlights using dichroic filters.

There may also be sufficient difference between dichroics so that if used on multiple keys in the same scene, there could be significant enough differences in the various areas being lit. A three-color type of color meter should be used in making the measurements in such circumstances.

A range of very good conversion filters to meet this requirement is available in the form of sheets and rolls of colored polyester materials. The polyester film shows good heat resistance even when applied to relatively high-powered luminaires. The use of some of the multiple-lamp fixtures (Mini-Brutes), with the requirement for some degree of diffusion material, has resulted in a diffusion material which incorporates the conversion color for this and similar applications. Reference should be made to page 367 for a detailed listing of the filters available.

Conversion filters — 3200K to daylight: The conversion filter is used where it is desirable that the converted

NATIONAL CARBONS FOR STUDIO LIGHTING

<table>
<tr><th>Fixture Type</th><th>Carbon No.</th><th>Positive Description</th><th>Carbon No.</th><th>Negative Description</th><th>Arc D.C. Electrical Amperes</th><th>Rating Volts</th></tr>
<tr><td>Duarc</td><td>1</td><td>8mm x 12 in.
CC MP Studio</td><td>8</td><td>7mm x 9 in.
CC MP Studio</td><td>40</td><td>36</td></tr>
<tr><td>M.R. 90</td><td>2</td><td>13.6mm x 22 in.
H.I. Studio</td><td>9</td><td>7/16 in. x 8½ in.
CC MP Studio</td><td>120</td><td>58</td></tr>
<tr><td>M.R. 170</td><td>3</td><td>16mm x 20 in.
H.I. Studio</td><td>10</td><td>½ in. x 8¼ in.
CC MP Studio</td><td>150</td><td>68</td></tr>
<tr><td rowspan="2">M.R. Brute</td><td>4</td><td>16mm x 22 in.
Super H.I. Studio
Positive-White
Flame</td><td rowspan="2">11</td><td rowspan="2">17/32 in. x 9 in.
Special CC</td><td rowspan="2">225</td><td rowspan="2">73</td></tr>
<tr><td>5</td><td>16mm x 22 in.
Super H.I. Studio
Positive-Yellow
Flame</td></tr>
<tr><td rowspan="2">M.R. Titan</td><td>6</td><td>16mm x 25 in.
Ultrex HIWF
Studio</td><td rowspan="2">12</td><td rowspan="2">11/16 in. x 9 in.
CC MP Studio</td><td>350</td><td>79</td></tr>
<tr><td>7</td><td>16mm x 25 in.
HIYF Special
Studio</td><td>300</td><td>73</td></tr>
</table>

*Union Carbide Corp. Carbon Products Division

color temperature be approximately 5500K. The light loss associated with these types of filters is approximately 1 to 1-⅓ stops These filters are referred to as "full blue 50," "full blue" or "CTB."

Partial Conversion Filters — 3200K to less than daylight: These materials are related to the conversion types, in that they provide a partial conversion. These are made in several grades to permit a range of choices for the cinematographer.

The application of these materials allows for adjustment in light sources due to voltage variation, the fading of dichroic coatings on certain types of lamps, and to achieve desired aesthetic effects which require less than a "full" daylight conversion. These filters may also be used to adjust the spectral energy distribution of the commercial/industrial light sources so that they match standard photographic color balance (3200K or 5500K).

DC Carbon Arc Sources

The open carbon arc remains in wide use, and in particular the 225 ampere "Brute" fresnel lens spotlight. The table summarizes the various carbon arc units, as well as the type of carbons necessary for each type. There is also a summary of the electrical characteristics of these arcs when properly operated.

Electrical Operating Characteristics

All of the carbon arcs described operate from direct current only. The actual arc voltage of these units is typically about 72 volts. They are normally utilized from 120-volt DC sources by using a resistive grid (ballast) to drop the supply voltage 48 volts.

More recently, specially wound or tapped generators have been utilized which produce the arc voltage directly and eliminate the need for the grid or ballast. This is a significantly more efficient mode of operation in terms of power utilization but does require special equipment.

Color Temperature

In the Brute and Titan the carbons are available in both white-flame and yellow-flame positives. The correlated color temperature with white-flame carbon is 5800K. The correlated color temperature with the yellow-flame carbon is 3350K.

Filters

The use of these filters, originally as gelatin-based types, is well-established practice. New, more durable filter materials are now available to accomplish these functions. These filters are used with the different carbons in order to provide light which is a better match to "daylight" or 3200K. In some cases, the arc color is adjusted in order to meet the requirements of matching "daylight" at earlier or later times of the day. The basic conversions are as follows. The designations are the most commonly accepted, although some of the filter manufacturers have chosen to create new codes:

Y-1: Used with white-flame carbon to provide a better match for "daylight." The Y-1 is pale yellow in color, and has about 90% transmission. An LCT Yellow filter may also be used.

MT-2 + Y-1: Used with white-flame carbons to convert to approximately 3200K for color negative. (Filtered light is slightly blue for 3200K reversal types.) The MTY filter is available which combines these two in a single material. An LCT Yellow plus Full CTO may also be used.

Other filters, particularly the ½ MT-2, may be used to "warm" the arc color as deemed necessary by the cinematographer. The CTO series of filters are all applicable to the arc with white-flame carbons for various degrees of adjustment.

Enclosed AC Arcs

These are enclosed light sources which are based on the principle of a medium length mercury arc to which various materials have been added to modify the spectral energy distribution. The additives typically are metal halides.

All of these lamps are operated from alternating current only, and require the use of a high-voltage ignition device to start and to re-strike them when hot, as well as a ballasting device to limit the current.

As a general characteristic, all of these lamps tend to have a light output which is modulated in relation to time. This is due to the fact that the light output follows the current, and these lamps are operated on alternating current. As the current rises through zero and up to a maximum and back down through zero to the opposite polarity peak, the light output tends to modulate between a minimum and a maximum value. The degree of modulation is different for the various sources.

This characteristic is important, since it can be the source of "flicker" problems. With some of the lamps it becomes necessary to be sure that the power source to the lamp and the framing rate of the camera and the shutter angle are held in certain specific relationships. There is a detailed analysis of this phenomenon in a following section (page 376).

Another common characteristic of these sources is that they are approximations of daylight. Typical correlated color temperatures are approximately 5600K. There will be some variation in this, as well as in the manufacturing tolerances for color temperature for the individual lamp types. The following sections will offer more detailed information for each type.

HMI™ Lamps

The most widely used of the new types of photographic enclosed-arc AC discharge lamps are known as HMIs. This term is a trademark of Osram, but has become very much the generic term for this family of lamps. Some of the other trademarked brand names for these sources are BRITEARC, DAYMAX, TRU-ARC, MSR and DiLite. An assortment of these lamps is shown in Figure 20. These are fundamentally mercury arcs with metal halide additives to adjust the color balance. All of the various sizes of this lamp are rated by the manufacturers at approximately 5600K (see Figure 21). This is normally stated as having a plus or minus 400°K tolerance. Color Rendering Index (CRI) of the lamp is greater than 90 for all types. As will be noted from the color temperature and its tolerance, there can be some variation in the color rendering characteristics from lamp to lamp. Also, account must be taken of the age of the lamp since this tends to result in a reduction of the color temperature. In normal daylight fill applications, these variations are probably not significant.

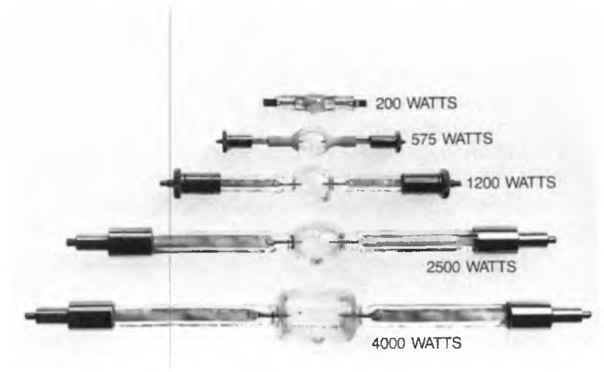


Figure 20. Comparative sizes of some HMI lamps.

Where more than one light will be used as key in a scene, and these are likely to be seen in a single shot, it is strongly recommended that these keys be measured with a three-color type of color-temperature meter. Appropriate filtering materials are available for application to these units that allows correction of green-magenta shifts as well as adjustment of the color temperature. With the proper meter, and the right filter materials at hand, it is literally a matter of minutes to balance lights to an extremely close match. If this practice is not followed, it is possible to have significant variation in color rendering from two keys in the same scene. Refer to the section on "Filters for Arc Sources."

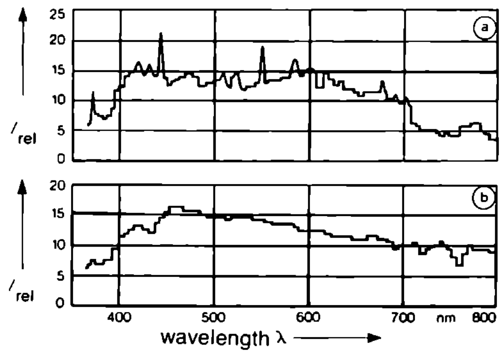


Figure 21. (a) Relative spectral power distribution of radiant energy of HMI 575-W and spectral radiance distribution (b) of daylight at 6500 K.

Page 345 is a brief summary of the electrical and physical characteristics of the lamps comprising the full range of HMI sources. Figure 22 is a graphic presentation of the various parameters of HMI amps expressed in terms of percentage changes in the supply voltage. It is of particular interest to note that the color temperature increases with decreasing voltage.

Like all metal vapor lamps, HMI lamps require a certain period after starting until final operating conditions are reached. The warm-up period varies with the lamp wattage, but typically is of the order of a minute or two from a cold start. Figure 23 shows curves of the electric and photometric data during warming-up of the lamp in operation with a standard inductive ballast. After ignition the lamp current at first increases. Power consumption, operating voltage and luminous flux, however, are lower during the warm-up stage than when in full operation. The warm-up period after igniting a hot lamp is considerably shorter.

Lighting fixtures have been designed specifically for these light sources, due to their particular requirements for cooling and the arrangements for mounting and electrically

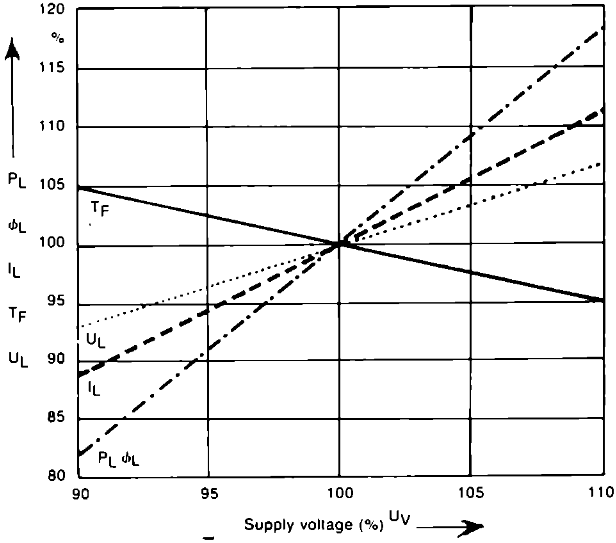


Figure 22. HMI 2500-W power consumption PL, luminous flux OL, current intensity IL, nearest color temperature TF, and operating voltage UL (relative values), as a function of the supply voltage Uv.

connecting these lamps. Also, to utilize the substantial light output of these fixtures with any degree of efficiency requires some special considerations. Fixtures are made by a large number of manufacturers at this point and include conventional fresnel lens spotlights, flood lights and even some softlight configurations.

Normally the lighting units are supplied with a mating ballast, although this equipment can be purchased separately. The ballasting systems are normally conventional inductive types. These ballast types have no effect on the tendency for this light to modulate as a function of time (flicker).

When operated on a *standard inductive type ballast*, this lamp modulates approximately 83%. That is to say, the minimum light output is approximately 17% of the peak value. This modulation characteristic, which is shown in Figure 43 (page 377), is responsible for the "flicker" phenomenon which can occur when proper attention is not paid to the synchronization of the power line frequency for the lamp, the shutter angle and framing rate of the camera. This particular problem is dealt with in some detail in a fol-

HMI LAMPS—SUMMARY OF ELECTRICAL AND PHYSICAL CHARACTERISTICS

Lamp Power Rating (Watts)	**200**	**575**	**1200**	**2500**	**4000**	**6000**	**8000**	**12000**
Minimum Open Circuit A.C. Voltage to the lamp for ignition (Volts)	198	198	198	209	360	220	380	380
Lamp Operating Voltage (Volts)	80	95	100	115	200	135	220	225
Lamp Operating Current (Amperes)	3.1	7.0	13.8	25.6	24.0	55	—	65.0
Luminous Flux (Light output in Lumens)	16,000	49,000	110,000	240,000	410,000	630,000	800,000	1,008,000
Luminous Efficacy (Lumens/Watt)	80	85	92	96	102	105	100	84
Average Life (Hours)	300	750	750	500	500	350	500	—
Burning Position	Horizontal ± 15°	Any	Any	Horizontal ± 15°	Horizontal ± 15°	Horizontal ± 15°	Horizontal ± 15°	Horizontal ± 15°

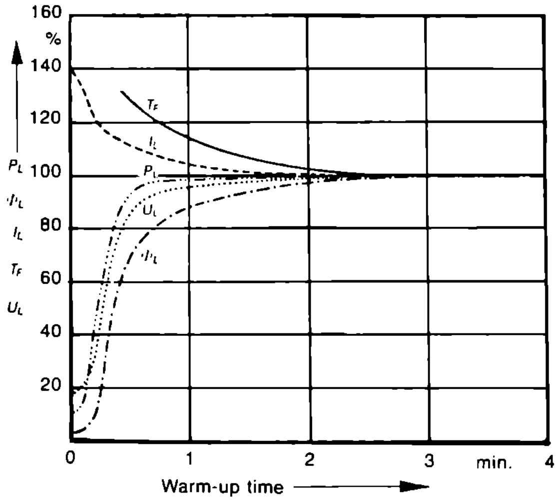


Figure 23. HMI 2500-W power consumption PL, luminous flux OL, current intensity IL, nearest color temperature TR, and operating voltage UL (relative values), as a function of time after starting the cold lamp.

lowing section (page 376). Many types of electronic ballasts are now available for the full range of HMI-type lamps. All of these can be considered "flicker-free" in the normal range of camera operation.

The service life of the HMI type lamps depends to some extent on the number of starts and might even exceed the values given in the table. However it is mainly governed by the permissible tolerances of color temperature (which may very according to application). During lamp life, the color temperature will drop at an average of approximately 1 degree Kelvin per operating hour. The Color Rendering Index will remain unchanged and the decrease of the luminous efficacy and luminous flux will be very low (Figure 24).

HMI lamps that have had long use can, with the use of a three-color color temperature meter and the appropriate correction filters, have their color temperature and green-magenta balance adjusted. This practice will assure that the end life for these lamps is the moment at which they can no longer be started using their specified ignition and ballast equipment, rather than the point at which their unfiltered color balance is no longer acceptable. Adjustments of the color balance of HMI lamps is done with the range of filters described herein. A number of the types of electronic ballasts offer a limited range of "color temperature adjustment." Caution should be exercised in using these controls relative to green-magenta axis shifts, and in particular where applied to keylights.

CAUTION:

1. The HMI source is extremely rich in ultraviolet energy. All commercial fixtures presently sold have been carefully designed to assure that there is no leakage of the ultraviolet energy. There must be a lens or cover glass of appropriate composition over the opening of this fixture in order to screen out this ultraviolet. All of the commercial fixtures in use have interlocking systems which assure that the lamp will not operate if any of the lens openings or access doors are not properly closed. IT IS EXTREMELY IMPORTANT THAT THESE INTERLOCKS BE RESPECTED. SINCE EXPOSURE TO THESE HIGH LEVELS OF ULTRAVIOLET CAN RESULT IN SEVERE SUNBURNING AND PAINFUL EYE BURNS.

2. All commercial systems of HMI equipment are electrically grounded (earthed). This independent ground circuit must be respected, since there are circumstances under which hazardous voltages may be presented to an operator if this connection is omitted. Where HMI equipment is operated from a portable generator, a grounding stake must be used to assure that the generator and its structure are properly grounded. UNDER NO CIRCUMSTANCES SHOULD THIS SYSTEM BE OPERATED UNLESS A COMPLETE GROUNDING CIRCUIT IS CONNECTED.

DCI™ — DC Metal Halide Arc Discharge Lamps

DCI™ lamps are represented as silent and "flicker-free." These are generally very similar in their physical appearance to HMI types, and a number of their operating characteristics are the same. They are rated at 5600 degrees Kelvin, with a Color Rendering Index above 90, and life ratings are very similar to HMI lamps of similar wattage. The electrode configuration is similar to that found in DC

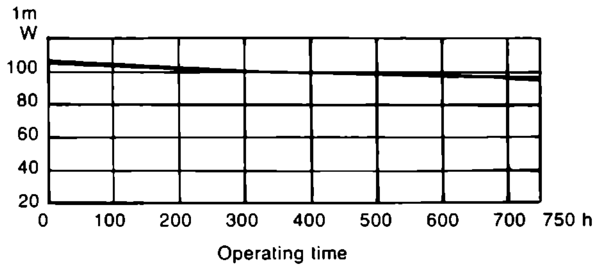


Figure 24. Luminous efficacy of HMI 575-W as a function of operating time.

short arc Xenon lamps. There are, however some significant differences between DCI and HMI:

a.) Due to the fact that the lamp operates on DC, the arc source is located at one electrode all of the time, which yields a smaller effective source size, and should show some improvement in utilizing the lumen output of this source. Further, *because the arc is operating on DC, it can be used at any camera framing rate from 1 to 10,000 frames per second without concern for flicker.*

b.) The DCI lamp ballast will be much simpler, and should therefore more reliable and less expensive than the somewhat complex flicker-free ballasts required for the AC arcs.

c.) The claim for silent operation is based on the DC operation of the lamp as compared to the HMI types when operated on square-wave type ballasts.

This lamp has only recently appeared, and is currently projected to be available in 800W, 1500W, 2500W, 5000W, and 10,000W sizes. At this writing, the lamps have been successfully fitted to existing HMI Fresnel Lens Spotlights.

CSI Lamps

The Compact Source Iodide Lamps (CSI) are also metal halide additive-type lamps. Typically, these are available in either a single-ended configuration or in a PAR 64 (sealed beam) enclosure. The configuration of the various lamps in this series is shown in Figure 25.

This particular lamp has been used more widely in Europe than in the USA. It is specified as having a correlated color temperature of 4200K plus or minus 400K. Clearly it is necessary to do some filtering of the light to use it either in a "daylight" balance situation or for 3200K application. The efficacy of the lamp is high and its initial output represents 90 lumens per watt. Lumen maintenance (the amount by which the light falls off during life) is claimed to be 90%. The tolerance spread for the correlated color temperature (which is not true color temperature) would indicate that the lamp could be anything from 3800K to 4600K as received from the manufacturer.

When operated on a standard inductive type ballast, this lamp modulates approximately 62%. That is to say, the minimum light output s approximately 38% of the peak value. "Flicker" can be a problem under some circumstances, and appropriate precautions should be taken.

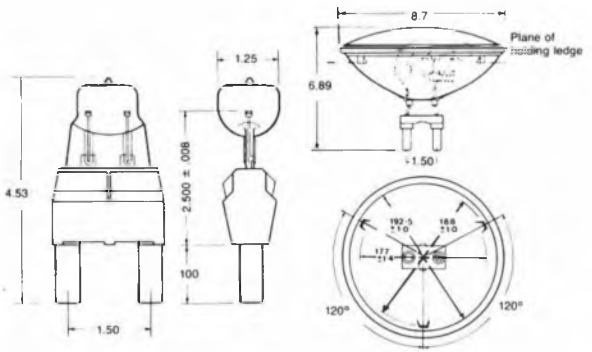


Figure 25. Configurations and dimensions for the 1000-W CSI and CID lamps.

This discharge lamp is available in a sealed-beam (PAR 64) enclosure which affords simple handling and has made it attractive for large area lighting of locations and sports settings for both television and film.

Appropriate filtering for CSI lamps is available from the range of light source correction media listed on page 367. Because of the character of the radiant energy distribution of this source, it is essential that a three-color reading color temperature meter be used in order to assure that

CAUTION: The same cautionary note as shown under the HMI lamp type relative to ultraviolet exposure and to grounding and electrical safety is applicable to the use of these sources. The sealed beam PAR 64 bulb emits no UV provided that the outer bulb is intact.

reasonable corrections are being achieved with these lamps for critical color work.

CID Lamps

This metal halide additive-type lamp utilizes the iodides of tin and indium. The physical configurations are identical to the CSI lamps (see Figure 25), except that in the CID type, a 2500-watt version is also available. This is pictured in Figure 26. The spectral power distribution and transient starting characteristics are shown in Figures 27 and 28.

The correlated color temperature of CID lamps is 5500K plus or minus 400K throughout life. It is claimed that CID lamps can be dimmed to 40% maximum output (using suitable ballast) without affecting color temperature. The claimed lumen maintenance for this source is 90% for all of its types and variations.

When operated on standard inductive ballasts, the lamp modulates to 45%. That is to say, the minimum light output is approximately 55% of the peak. This represents a significant improvement over the basic modulation char-

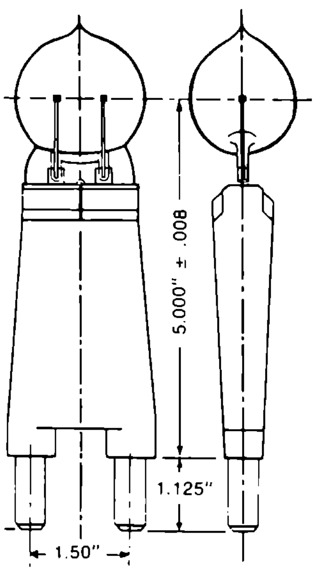


Figure 26. 2500-W compact iodide daylight (CID).

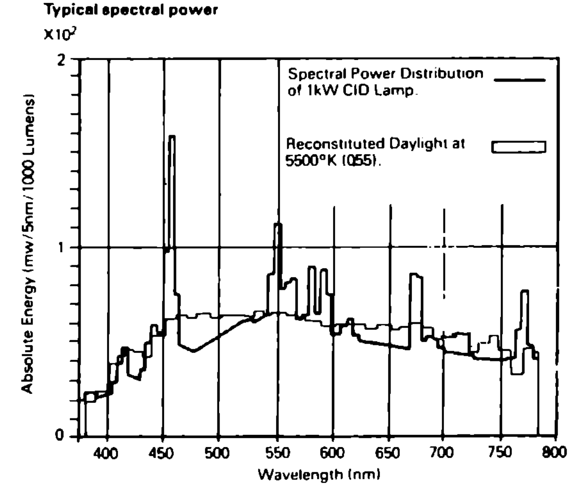


Figure 27. Typical spectral power distribution for CID lamps.

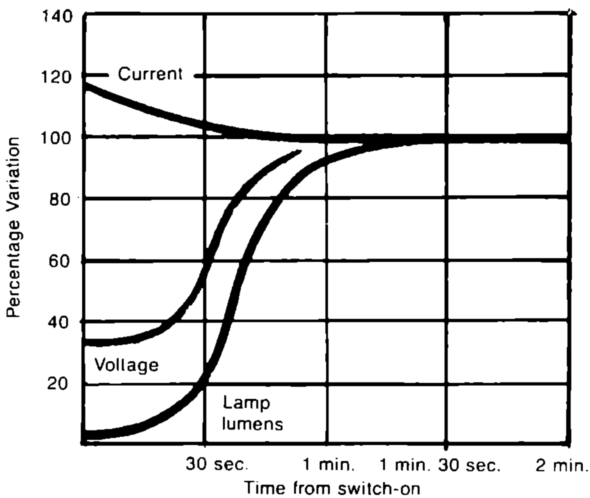


Figure 28. Transient characteristics of lamp from switch-on.

acteristics of the HMI and CSI types, but precautions regarding flicker must still be observed.

Filters for adjusting the spectral energy distribution of CID lamps are listed on pages 366-367.

Light-Source Filters

These light sources vary not only in color temperature, but there are likely to be significant green-magenta shifts. It is recommended that anyone regularly working with the types of AC arc discharge sources delineated above should have a three-color color temperature meter. With such an instrument, and the system of filters created by Rosco Laboratories, Inc., it is possible to deal properly with all of the variations that are likely to be encountered with these lamps.

The possible range of lamp-to-lamp variations in color balance is primarily due to aging and manufacturing variations. In many situations, it will be highly desirable or essential to assure that the lamps in use will have the same color rendering characteristics.

Some claims have been made for single conversion filters for the HMI and CSI type lamps, but it is difficult to understand how a single filter could even come close to meeting the wide range of possible lamp color balances that are likely to be encountered within a given type. The range of available materials has been proven in practice to meet the requirements of color balancing lights so that minimum variations are present.

High-Pressure DC Short Arc Xenon Light Sources

This source is the best commercially available light source for use in higher-powered projection systems. The very small size and very high brightness of the arc source, and the stability of the arc location due to the DC operation, make it the source of choice around the world for motion-picture projection.

The efficacy of high-pressure xenon sources (lumens/watt) ranges from 35 to 50 LPW. Ballasting is very simple,

> **CAUTION**: These lamps have high internal pressure even when cold. They are supplied with a protective jacket over the bulb, and this should not be removed until the lamp is fully installed. It is required that a suitable face shield, body jacket and gauntlets be used any time that the protective jacket is removed. When removing a lamp the protective jacket should be installed before steps are taken to disconnect and remove the lamp.

requiring only a current-limiting rectifier that can produce DC that has less than 5% ripple. A high-voltage igniter is necessary to start these lamps, and they can be hot re-struck. These lamps permit the creation of an intense focused beam of pure, slightly cold daylight color balance light (about 6000° K), and have a Color Rendering Index of 95 to 98. They have found some limited application in motion-picture photographic lighting. The source is available in a wide variety of wattages up to 10KW.

Stroboscopic Lighting

Stroboscopic ("strobe") lighting for motion pictures has been available commercially for about 30 years. Typically these utilize xenon flashtubes which produce a good approximation of daylight (about 6000°K), and a relatively stable color temperature throughout life. Due to the fact that the flashtubes that are suitable for this application are either long slim sources or helical shapes, they can really only produce soft lighting. They can be color-corrected or adjusted using the same filter materials described for application to any of the normally utilized light sources and lighting instruments.

It is common practice to utilize continuous sources (such as tungsten) with strobes. Typical practice is to light 2 stops under the strobe with the tungsten lighting up to one stop over. The more tungsten lighting, the softer the image. The control equipment for these light sources permits an exposure duration of between $1/50,000$ and $1/100,000$ of a second. This permits stop motion with extraordinary sharpness of various phenomena, and delineates detail in real-time movement that is a blur in normal photography (even with very small shutter angles). The sharpness of results in slow-motion effects is unmatched by other techniques.

The strobes must be synchronized to the camera shutter. Usually the strobes are driven by the shutter pulse from the camera, and it is imperative that the units flash when the shutter is fully clear of the gate (otherwise a partially exposed frame will result). To check camera synchronization, the lens should be removed, and the cavity illuminated with the strobe with the camera turned on. The shutter should appear to be frozen in one position.

The control equipment for these strobes permits the addition of delay to the pulse in degree increments. The position of the shutter will either move forward or backward in relationship to the gate until it is in the proper position. For reflex cameras the strobe fires twice for each frame, once to illuminate the subject and a second time to illuminate the viewfinder.

CAUTION: People with photosensitive epilepsy should be informed that strobe lighting will be in use.

Commercial/Industrial Light Sources

This section will present information about the most commonly encountered types of commercial/industrial light sources which may be found in location situations.

For many exterior situations, there is little or nothing that can be done about the color of the existing light (e.g., roadway lighting or large-area exterior lighting). In many other situations it is completely practical and/or possible to apply filters to the light sources that are encountered in a location setting. This can result in minimizing the problems in the set-up, and achieving a more natural look (more nearly as the scene appears to the eye).

A further alternative is the use of camera filters to compensate for the color balance of the available light. In order to use conventional photographic lights for supplemental lighting, it is only necessary that they be filtered so that their color balance is the same as the dominant ambient lighting. This approach makes it possible to retain the "character" or "look" of the location lighting, and still allows the creative freedom to add such supplemental lighting as indicated for the desired dramatic or artistic effect.

Domestic Incandescent Lighting

Non-photographic types of incandescent lighting tend to have color temperatures that may range from 2400K up through 2900K or so at their rated voltages. The color temperature is directly related to the wattage of the lamp, with very-low-wattage types having the lowest color temperatures. Refer to page 319.

If these sources are providing sufficient light for exposure, and it is felt that no supplemental lighting is required, then a camera filter can be used to correct the lighting balance to an approximation of 3200K. Typically, this would represent application of one or more of the Wratten 82 series filters. The table on page 230 gives an approximation of the appropriate Wratten filter or filters required and the effect of that filter on the color temperature of the ambient lighting. (Alternatively, most laboratories could correct for the temperature deficiency in printing from color negative.) If used, supplemental lighting can be reduced in color temperature to match the ambient light; this would be done most easily by the addition of filters to the luminaires. It could also be accomplished by the use of a dimmer.

AC Discharge Lighting

The cinematographer on location assignment is more and more likely to encounter various types of discharge lamps. These may be in use for both interior lighting in stores and commercial buildings and for exterior lighting in sports stadiums, parking lots, shopping malls, and for street lighting.

Many of these types of light sources give excellent color rendering for the eye, and the manufacturers often give a correlated color temperature value to the source. This "Kelvin" temperature usually has no meaning for the purposes of color photography.

The following sections offer the means for dealing with these light sources to assure acceptable photographic results that should be well within the laboratory tolerances for correction of color negative film. (See "Color Balancing.")

Existing Fluorescent Lighting on Location

This is probably the most widely used type of interior lighting in commercial and industrial settings. It is not unusual to find commercial or industrial locations which are lighted to 125 or so footcandles using fluorescent lighting. Considering the speed and other characteristics of the newest film emulsions, this level is certainly sufficient to obtain reasonable exposure settings.

By making use of the ambient fluorescent light, the cinematographer can maintain the lighting quality and the character of the setting, that is to say, a more nearly "soft-lighted" appearance.

Most fluorescent illumination, because of its discontinuous spectrum, is not well-suited to color cinematography (see Figures 29 through 34). The correlated color temperature of a fluorescent lamp may provide a visual color match for a tungsten lamp of similar color temperature, but photographic color results will be quite dissimilar. Exposure may no longer be a problem under these conditions

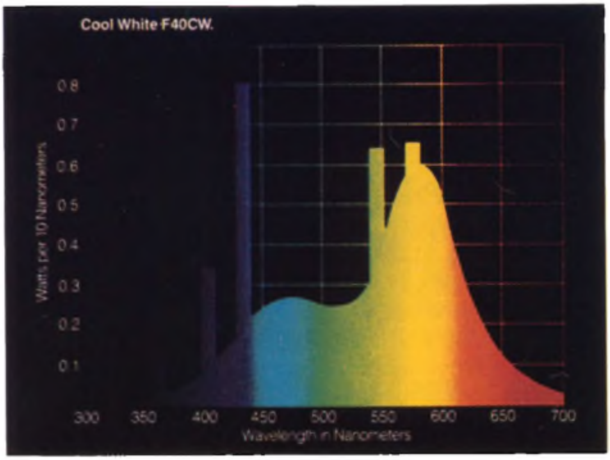


Figure 29. Cool White F40CW.

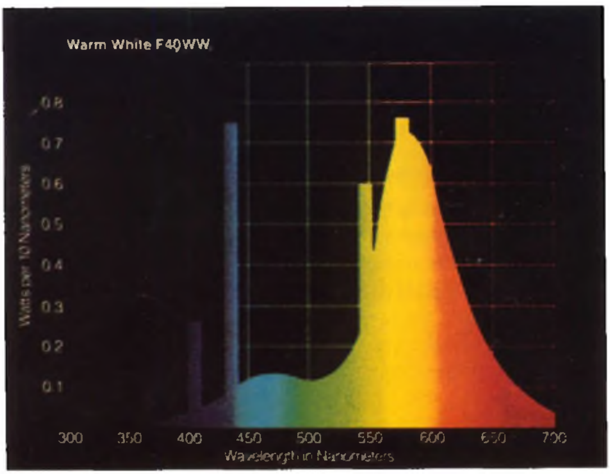


Figure 30. Warm White F40WW.

but color rendition remains a serious consideration with fluorescents found in commercial or industrial situations.

If color film is exposed without filter correction, the results will have a blue-green cast with weak reds, even with daylight type emulsions. The result is not at all what the viewer expects to see in a fluorescent-lighted setting.

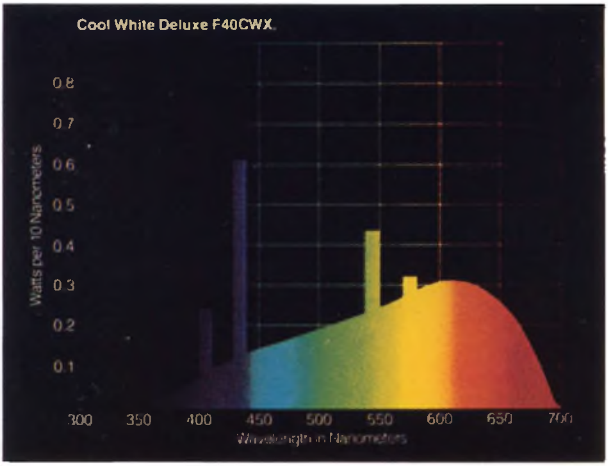


Figure 31. Cool White Deluxe F40CWX.

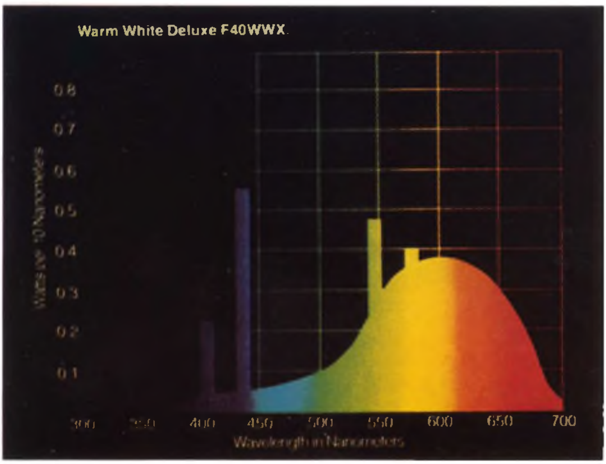


Figure 32. Warm White Deluxe F40WWX.

Mercury Vapor and Color Improved Mercury Lamps

The clear mercury vapor lamp will not produce acceptable color photographic results with any degree of filtering. The reason for this can be seen by examining the spec-

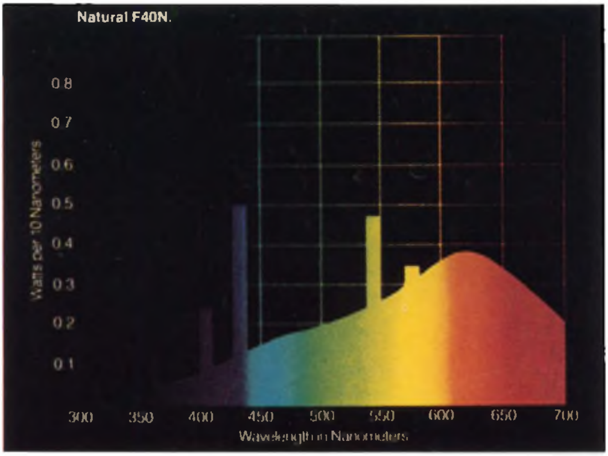


Figure 33. Natural F40N.

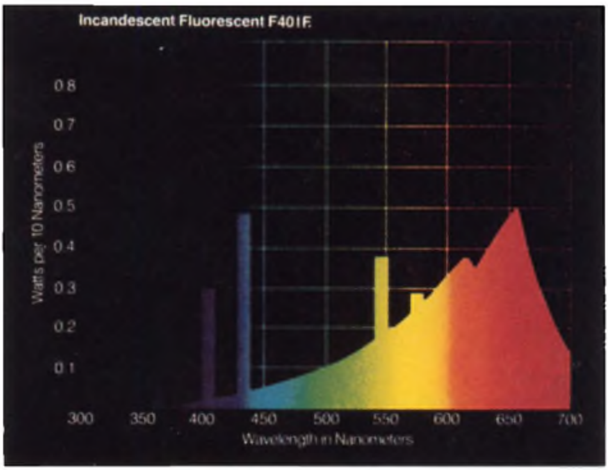


Figure 34. Incandescent Fluorescent F401F.

trum in Figure 35. Note that there is essentially no light output in the red portion of the spectrum and only line spectrum output in the blue and blue-green portions. Obviously, there is no way to compensate for the lack of red energy, so that this source must either be overpowered with

Fluorescent Lighting for Motion Pictures

by Freider Hochheim, President of KinoFlo, Inc.

Fluorescent lighting has traditionally had the reputation of being an inappropriate light source for motion picture production. The primary criticism has revolved around noisy ballasts, poor color rendering, green skin tones, 60Hz flicker and low light output. These criticisms are now a thing of the past. Technology has advanced to the point where high-quality fluorescent products are now being produced specifically for the motion-picture and television industry. The cinematographer can now consider using fluorescent lights not only in situations which are motivated by existing location fluorescent environments but rather in any situation requiring either daylight or 3200 Kelvin light.

The fluorescent lamp by its very nature has an indirect or ambient light quality which is desirable in situations calling for natural light quality. Instead of bouncing the light from an HMI or an incandescent fixture, the cinematographer can utilize a fluorescent light source which embodies the characteristics of a bounce board. The light is soft and has a spread and drop-off very similar to bounced light. Finding this quality of light in a long narrow light source which can be easily hidden in a set opens up new lighting possibilities and provides new solutions for old problems. The low heat and low power requirements give this technology added appeal amongst actors and electricians alike.

KinoFlo provides some of the most recent innovations. It is producing a line of location and studio lighting systems offering lightweight and portable, high-frequency flicker-free, color-correct fluorescent lighting instruments. KinoFlo offers a broad selection of color-correct lamps in sizes ranging from the micro at 100mm in length to the KF55 at 8 feet and in 5500 Kelvin and 3200 Kelvin color temperatures.

other lighting, or allowed to render its subjects with only blue/blue green energy.

A number of other types of mercury lamps have been made in which a phosphor coating has been put on the inside of the outer jacket of the lamps. In principle, this has worked very much like a fluorescent lamp and has resulted in an improved color rendering capability. A number of these types, such as the Color Improved Mercury, have sufficiently complete spectral energy distribution so that they are now finding application in certain types of commercial interior use.

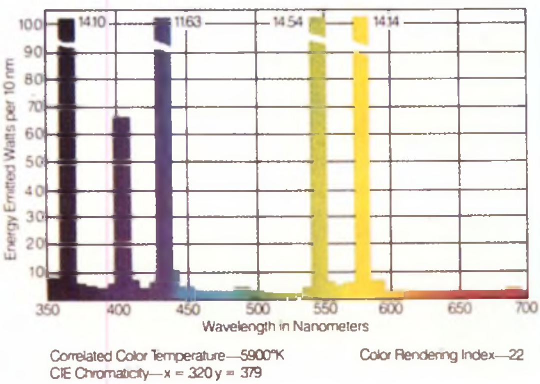


Figure 35. Spectral energy distribution of 400- W Clear mercury lamp.

Spectral energy distributions for some of these lamps are shown in Figures 36 through 38. It is evident from the examination of these distributions that there is a substantial improvement in the availability of energy at the intermediate wavelengths between the mercury lines. This results in improved color rendering.

Metal Halide Additive Lamps

The metal halide additive lamps known by a variety of trademarked names such as Metalarc, Multi-Vapor and HQI, for example, are essentially mercury vapor lamps which have had small additions of various metal halides made inside the arc tube. These lamps have generally high efficacies (approximately 85 lumens per watt typically).

These lamps are widely used in sports lighting as well as in shopping malls, and a wide variety of other commercial/industrial applications. Some typical spectral energy

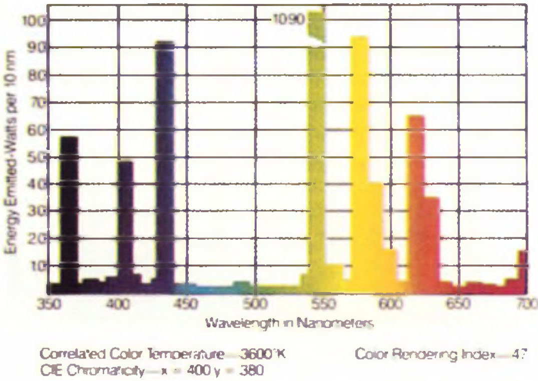


Figure 36. Spectral energy distribution of 400-W Warm Deluxe mercury lamp (H33GL-400-WDX).

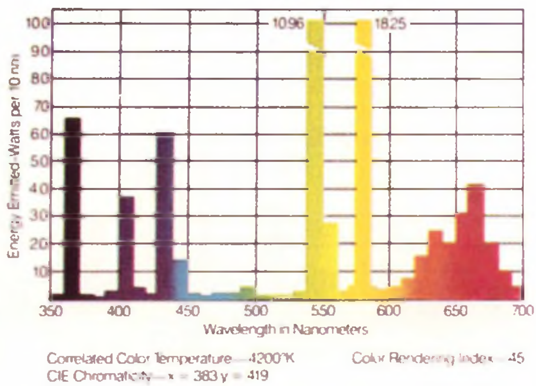


Figure 37. Spectral energy distribution of 400-W Color Improved mercury lamp (H33GL-400C).

distributions for these types are shown in figures 39 and 40.

Sodium Lamps

High-pressure sodium lamps have become an extremely important light source for roadway and large-area lighting such as parking lots. These lamps are known by various trademarked names such as Lucalox and Lumalux. These are high-efficacy lamps, up to 120 lumens per watt. They have a characteristically yellow-orange color. A typical spectral energy distribution is shown in Figure 41.

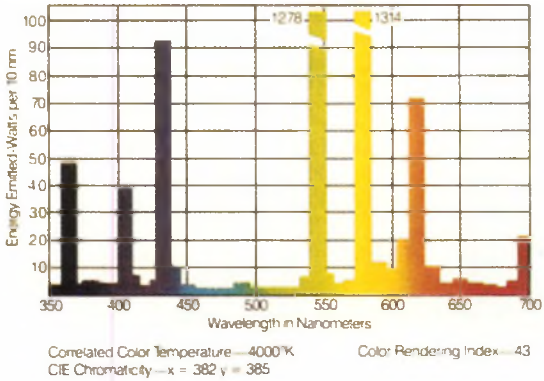


Figure 38. Spectral energy distribution of 400-W Brite-White Deluxe mercury lamp (H33-400DX).

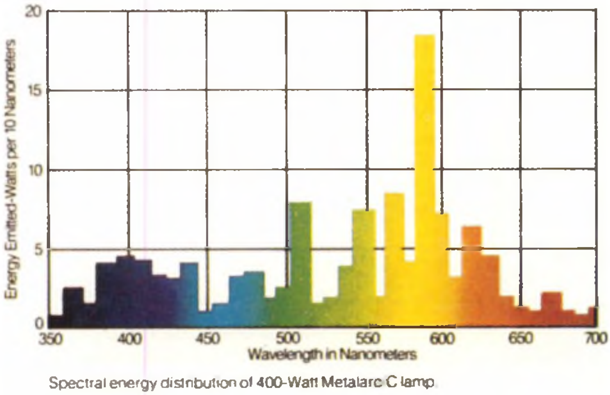


Figure 39. Spectral energy distribution of 400-W Metalarc clear lamp.

Low-pressure sodium lamps have been widely used in Europe for many years for the same applications. There are some installations in the US. This is the highest efficacy commercial lamp available (approximately 160 to 180 lumens per watt).

The spectral energy distribution for this lamp reveals that it is monochromatic; in effect, this is a yellow-only lamp. No degree of filtering will permit proper color rendition. These light sources are easily recognized (the source is quite large and relatively low brightness, particularly compared to the high-pressure sodium).

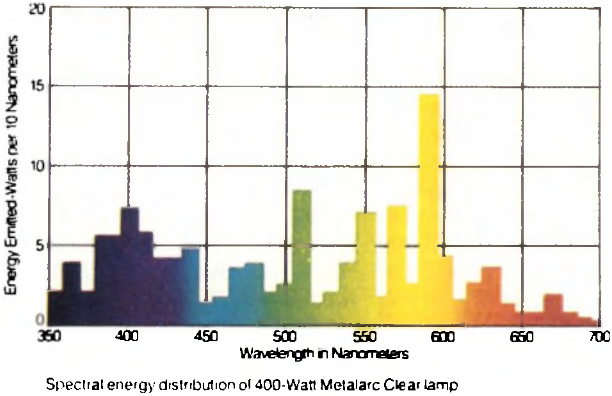


Figure 40. Spectral energy distribution of 1000-W Metalarc/C lamp (coated).

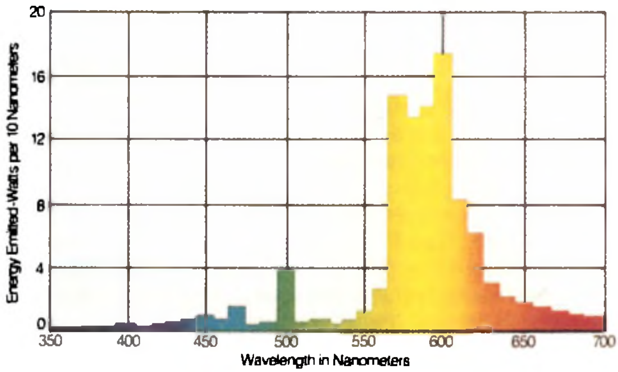


Figure 41. Spectral power distribution of 400-W sodium lamp, similar to types known as Lucelox or Lumalux.

Color Balancing for Photography

A series of approaches is outlined in the following sections to deal with lighting when any of the commercial/industrial AC arc discharge or fluorescent sources are encountered as the dominant ambient lighting environment. Exceptions are pure mercury and low-pressure sodium.

A. Leaving the Ambient Discharge Lighting "ON" — With Standard Photographic Lighting Equipment Used Supplementally

Where the ambient illumination is adequate for exposure, and assuming (1) reasonable uniformity in the types of lamps in the installation, and (2) that no supplemental lighting will be used, it would only be necessary to apply the appropriate filtering to the camera. When using color negative film and the required correction at the camera is small, it is possible that no camera filter be used, and the laboratory told to make the necessary correction.

If some supplemental lighting is required or necessary for dramatic or artistic reasons, the supplemental light should be filtered to match the dominant color balance of the ambient lighting. It is also possible to utilize the same type of lamps as the ambient lighting, on floor stands, for supplemental lighting (see pages 366-375 for camera and lighting filters).

B. Mixed or Unknown Types of Ambient Lighting as the Dominant Light Source

Many interiors are lighted by mixed types of fluorescent lamps, or the fluorescent illumination may be mixed with daylight or tungsten lighting. In shopping malls, it is possible to encounter several types of high-intensity discharge lamps. The use of a three-color type of color meter should make it possible to establish what the dominant color balance is. Some of the same procedures described above in (A) would then be applicable.

C. Filtering the Ambient Light Sources

Where the access to the ambient lighting fixtures is reasonable, and the quantity of them not too great, the individual lights or fixtures can be filtered to either a 3200K or a 5500K balance. It is then possible to utilize standard photographic luminaires for supplemental lighting.

D. Overpowering the Ambient Lighting

Directly illuminate the subject with or 5500K illumination. If this is done at a level such that this lighting becomes the dominant source for the exposure of the subject, then daylight-balanced film can be used without any camera filters. The background would, of course, be blue-green in color but this may be acceptable. This practice is commonly followed in newsgathering or documentary situations.

> **CAUTION:**
>
> 1.) There may be significant color variation encountered between the various types of lamps and even between lamps of the same type made by the same manufacturer. Some of the reasons for these variations may be age, burning position, temperature and manufacturing tolerances. A three-color type of color temperature meter is necessary for accomplishing the measurements required for some of the approaches described in the following section. (If the lamps can be identified, the tables noted below provide filter data for most situations; the 3C meter may then be used to verify the balance between lamps.)
>
> 2.) It is strongly recommended that film tests be run wherever there is great concern for color accuracy. These tests should be done under circumstances such that the anticipated operating conditions of the actual production are well duplicated.
>
> 3.) AC lamps are subject to the "flicker" phenomenon. That is to say, there is variation in the light output with time. For 24 fps exposure (crystal-controlled), where the power to the lamp is derived from a stable 60 Hertz source, there is very little likelihood of a flicker problem. Overcranking, very small shutter angles and some other combinations involving power supplied from unregulated generators may result in flicker. A more detailed treatment of the flicker problem can be found elsewhere in this manual.

Filter Selection

Filters for color balancing commercial/industrial lighting sources for color photography (tables 366-375) were derived and confirmed photographically by David L. Quaid, ASC, and copyrighted by him. They are accurate for the particular lamps tested; see the caution paragraph above about variation and testing, and page 238 about exposure meter variation. Deviation of typical exposure meters is indicated in T-stops next to certain filtered lights in the tables. When measuring incident filtered light from these lamps, adjust the ASA on the meter to compensate.

Neutral Density and Combinations (for windows)			
Neutral Density		Stops	
Rosco #3415 N.15	.15	1/2	
Lee #298 .15ND	.15	1/2	
Rosco #3402 N.3	.30	1	
Lee #209 .30ND	.30	1	
Rosco #3403 N.6	.60	2	
Lee #210 .60ND	.60	2	
Rosco #3404 N.9	.90	3	
Lee #211 .90ND	.90	3	
Lee #299 1.20ND	1.20	4	
		Effect on	
	Mired	5500°K	6000°K
Lee #207 Full CTO +.3ND	+159	2930°K	3070°K
Lee #208 Full CTO +.6ND	+159	2930°K	3070°K
Rosco #3405 Roscosun 85N.3	+131	3200°K	3360°K
Rosco #3406 Roscosun 85N.6	+131	3200°K	3360°K

Lighting Filters Green/Magenta Adjusting for Arc Discharge & Fluorescent (Used with Blue/Amber Color Temperature Filters)	
Green Filters (Decrease Red/Blue [magenta])	CC Equivalent
Rosco #3304 Tough Plusgreen	CC30 G
Lee #244 Plus Green	CC30 G
Rosco #3315 Tough 1/2 Plusgreen	CC15 G
Lee #245 Half Plus Green	CC15 G
Rosco #3316 Tough 1/4 Plusgreen	CC075 G
Lee #246 Quarter Plus Green	CC035 G
Rosco #3317 Tough 1/8 Plusgreen	CC04 G
Rosco #3306 Tough Plusgreen 50	CC30 G +85B
Lee #241 Fluorescent 5700° Kelvin	CC30 G +80A
Lee #242 Fluorescent 4300° Kelvin	CC30 G +80C
Lee #243 Fluorescent 3600° Kelvin	CC30 G +82B
Magenta Filters (Decrease Green)	
Rosco #3308 Tough Minusgreen	CC30 M
Lee #247 Minus Green	CC30 M
Rosco #3313 Tough 1/2 Minusgreen	CC15 M
Lee #248 Half Minus Green	CC15 M
Rosco #3314 Tough 1/4 Minusgreen	CC075 M
Lee #249 Quarter Minus Green	CC075 M
Rosco #3318 Tough 1/8 Minusgreen	CC04 M
Rosco #3310 Fluorfilter	(CC30M +85B)

Lighting Filters: Color Temperature Adjusting			
Increase color temperature (Blue)	**Effect on**		
	Mired Value	3200°K (312 Mired)	2900°K (345 Mired)
Lee #201 Full C.T. Blue	-137	5700°K	4810°K
Rosco #3202 Full Blue	-131	5500°K	4670°K
Lee #281 3/4 C.T. Blue	-113	5000°K	4314°K
Lee #202 Half C.T. Blue	- 78	4270°K	3750°K
Rosco #3204 Half Blue	- 68	4100°K	3610°K
Rosco #3206 Third Blue	- 49	3800°K	3380°K
Lee #203 Quarter C.T.Blue	- 35	3610°K	3230°K
Rosco #3208 Quarter Blue	- 30	3550°K	3180°K
Lee #218 Eighth C.T. Blue	- 18	3400°K	3060°K
Rosco #3216 Eighth Blue	- 12	3330°K	3000°K
Diffusing Blue			
Lee #224 Daylight Blue Frost	-137	5700°K	4810°K
Rosco #3017 Full Blue Frost	-131	5500°K	4670°K
Lee #221 Blue Frost	- 49	3800°K	3380°K
Rosco #3013 Tough Booster Frost	- 49	3800°K	3380°K
Rosco #3012 Tough Booster Silk	- 30	3550°K	3180°K
Lee #217 Blue Diffusion	- 18	3330°K	3000°K
Decrease Color Temperature (Amber)			
Rosco #33407 Roscosun CTO	+167	2865°K	3000°K
Rosco #3441 Full Straw (CTS)	+167	2865°K	3000°K
Lee #204 Full C.T. Orange	+159	2930°K	3070°K
Rosco#3401 Roscosun 85	+131	3200°K	3360°K
Lee #205 Half C.T. Orange	+109	3440°K	3629°K
Rosco #3408 Roscosun 1/2 CTO	+ 81	3800°K	4030°K
Rosco #3442 Half Straw (1/2 CTS)	+ 81	3800°K	4030°K
Lee #206 Quarter C.T. Orange	+ 64	4060°K	4330°K
Rosco #3409 Roscosun 1/4 CTO	+ 42	4480°K	4800°K
Rosco #3443 Quarter Straw (1/4 CTS)	+ 42	4480°K	4800°K

Lighting Filters: Color Temperature Adjusting			
Decrease Color Temperature (Amber)		**Effect on**	
	Mired Value	5500° K (182 Mired)	6000°K (167 Mired)
Lee #223 Eighth C.T. Orange	+ 26	4600°K	5180°K
Rosco #3410 Roscosun 1/8 CTO	+ 20	4950°K	5350°K
Rosco #3444 Eighth Straw (1/8 CTS)	+ 20	4950°K	5350°K
Rosco #3414 UV filter	+ 8	5260°K	5710°K
Lee UV	+ 2	5440°K	5930°K
Red-Amber			
Lee #236 HMI (to Tungsten)	+134	3170°K	3226°K
Lee #237 CID (to Tungsten)	+131	3200°K	3360°K
Rosco #3106 Tough MTY	+131	3200°K	3000°K
Rosco #3102 Tough MT2	+110	3425°K	3790°K
Lee #238 CSI (to Tungsten)	+ 49	4330°K	4640°K
Rosco #3115 Tough 1/2 MT2	+ 38	4545°K	5210°K
Rosco #3134 Tough MT54	+ 35	4610°K	5290°K

Color Balancing for Existing Fluorescent Lighting

Camera filters: Symbol "#": conversion or light balancing series; "CC" Color Compensating series (Pages 124 and 125). EI column is exposure compensation in T stops for filters.

Photo lamp filters: (Pages **366** and **367**) EI column is deviation of typical exposure meters due to color imbalance. When reading exposure in filtered light from these units, reduce the ASA/ISO meter setting (i.e. increase the light level) by the number of T stops indicated. Where correction is "minus" (-), decrease the light level (increase the ASA/ISO setting).

	Using existing fluorescent lighting unfiltered (☞ A page 241)								Filtering fluorescent lights to match photo lights (☞ C page 241)			
	Camera filters (Kodak or equivalent)				Photo lamp filters (Rosco Cinegel or equivalent)				Camera filter: None (Tungsten negative or reversal)		Camera filter: Tungsten Negative: #85 Daylight film: None	
Manufacturer Lamp type	**3200K film**	**EI**	**5500K film**	**EI**	**3200K**	**EI**	**5500K**	**EI**	**To match 3200K**	**EI**	**To match 5500K**	**EI**
Durotest Color Classer 75	#81EF +CC05M +#85	1⅓	#81B +CC10M	⅔	Full blue 50 +½Plusgreen +Quarter blue	⅓	Third blue +¼Plusgreen	0	Sun 85 +¼Minusgreen +Sun ⅛ CTO	-⅓	¼Minusgreen +Sun ⅛ CTO	0
Durotest Vitalight	CC10M +#81 +#85	1	CC10M +#81	⅓	Full blue 50 +¼Plusgreen +Sun ⅛ CTO	⅓	Quarter blue +½Plusgreen	⅓	Sun 85 +¼Minusgreen	0	½Minusgreen	-⅓
Durotest Optima 50	#85	⅔	#82A +CC05M	⅔	Full blue 50 +Sun ¼ CTO	⅓	¼Plusgreen	0	Sun ½ CTO	0	¼Minusgreen +Quarter blue	-⅓
Durotest Optima 32	#81 +CC05M	⅓	#80C +#82A	1⅓	Quarter blue +UV Filter	0	Sun ½ CTO +Sun ¼ CTO	0	¼Minusgreen +Sun ⅛ CTO	0	Half blue +Quarter blue	-⅓

General Electric Chroma 75	#81A +#85B	1	#81B +CC05M	2/3	Full blue 50 +Quarter blue +1/4Minusgreen	1/3	Third blue	0	Sun CTO +Eighth blue	- 1/3	Sun 1/8 CTO	- 1/3
General Electric Lite White	CC60M +#81C +#85	2 1/3	CC50M	1	Full Blue 50 +Half blue +2x(Plusgreen)	2/3	Third blue +Plusgreen +1/2Plusgreen +Eighth blue +1/4Plusgreen	2/3	Minusgreen +1/2Minusgreen +Sun 1/2 CTO +Sun 1/8 CTO +1/4Minusgreen	0	Minusgreen +1/2Minusgreen	- 1/3
General Electric SP-41	CC50M +#81B +#85	1 2/3	CC30M	2/3	Full blue 50 +Plusgreen +1/4Plusgreen +Quarter blue	2/3	Plusgreen +Third blue	1/3	Minusgreen +Sun 1/2 CTO +Sun 1/8 CTO	0	Minusgreen +Eighth blue	1/3
General Electric Chroma 50	CC05M +#81 +#85	1	CC10M +#82A	2/3	Full blue 50 +1/4Plusgreen +Sun 1/8 CTO	0	1/4Plusgreen	0	Sun 1/2 CTO +1/4 Minusgreen	- 1/3	1/4Minusgreen +Quarter blue	- 1/3

All Mfrs—Cool White, Cool White Deluxe, Warm White, Warm White Deluxe: See page 167

	Using existing fluorescent lighting unfiltered								Filtering fluorescent lights to match photo lights			
	Camera filters (Kodak or equivalent)				Photo lamp filters (Rosco Cinegel or equivalent)				Camera filter: None (Tungsten negative or reversal)		Camera filter: Tungsten Negative: #85 Daylight film: None	
Manufacturer Lamp type	3200K film	EI	5500K film	EI	3200K	EI	5500K	EI	To match 3200K	EI	To match 5500K	EI
General Electric White	CC50R +CC10M	1⅔	CC30M +#82B	1	Full blue 50 +Plusgreen +¼Plusgreen	⅓	Plusgreen +¼Plusgreen +Quarter blue	0	Minusgreen +½Minusgreen +Sun ¼ CTO +Sun ⅛ CTO	0	Minusgreen +Quarter blue	- ⅓
General Electric SP-35	CC50R +#82	1⅔	CC30M +#82C	1⅓	Full blue 50 +Plusgreen	⅓	Plusgreen	0	Minusgreen +¼Minusgreen +Sun ½ CTO	0	Minusgreen +Quarter blue +Eighth blue	⅓
General Electric SPX-35	CC40R +#81A	1	CC15M +CC30B	1⅓	Half blue +2× (½Plusgreen) +Third blue	⅓	Plusgreen +½Plusgreen	0	½Minusgreen +Sun ¼ CTO +¼Minusgreen +Sun ⅛ CTO	0	Half blue +½Minusgreen +¼Minusgreen	- ⅓
General Electric Regal white	CC30M +#85C	1	CC50B +CC05M +#81	1⅔	Half blue +Plusgreen +Quarter blue	⅓	Plusgreen +Sun ⅛ CTO	⅓	Minusgreen +Sun ¼ CTO	0	Half blue +Minusgreen +Eighth blue	⅓

General Electric SP-30 SPX-30	CC30M +#81EF	1	CC50B +CC05M	1⅔	Half blue +Plusgreen +¼Plusgreen +Quarter blue	⅓	Plusgreen +¼Plusgreen +Sun ¼ CTO	⅓	Minusgreen +Sun ⅛ CTO +UV Filter	-⅓	Half blue +2x (½Minusgreen) +Eighth blue	0
GTE Sylvania Lite White Deluxe	CC50M +#82A +#85B	2⅓	CC35M	⅔	Full blue 50 +Plusgreen +¼Plusgreen +Quarter blue +Eighth blue	⅓	Plusgreen +½Plusgreen +Quarter blue	⅓	Minusgreen +¼Minusgreen +Sun ½ CTO +Sun ⅛ CTO	0	Minusgreen +Eighth blue	-⅓
GTE Sylvania Octron-41K	CC30M +#81A +#85	1⅔	CC30M +#82	1	Full blue 50 +Plusgreen	⅓	Plusgreen +Quarter blue +UV filter	0	Minusgreen +Sun ½ CTO +Sun ¼ CTO	0	Minusgreen +Quarter blue	0
GTE Sylvania Design 50	CC05M +#81 +#85	1	CC10M +#82A	⅔	Full blue 50 +¼Plusgreen +Sun ⅛ CTO	0	¼Plusgreen	0	Sun ½ CTO +¼Minusgreen	-⅓	¼Minusgreen +Quarter blue	-⅓
GTE Sylvania Deluxe White	CC40M +#82A +#85	1⅓	CC30M +#82B	1⅓	Full blue 50 +Plusgreen +¼Plusgreen +Sun ⅛ CTO	⅔	Plusgreen +¼Plusgreen	0	Minusgreen +Sun ¼ CTO +Sun ⅛ CTO	0	Third blue +Minusgreen	⅓
GTE Sylvania Natural White	#85C	⅓	#82C	⅔	Half blue +Eighth blue	0	¼Minusgreen +UV Filter	0	Sun ¼ CTO +Sun ⅛ CTO	-⅓	Half blue	-⅓

All Mfrs—Cool White, Cool White Deluxe, Warm White, Warm White Deluxe: See page 167

Manufacturer Lamp type	Using existing fluorescent lighting unfiltered								Filtering fluorescent lights to match photo lights			
	Camera filters (Kodak or equivalent)				Photo lamp filters (Rosco Cinegel or equivalent)				Camera filter: None (Tungsten negative or reversal)		Camera filter: Tungsten Negative: #85 Daylight film: None	
	3200K film	EI	5500K film	EI	3200K	EI	5500K	EI	To match 3200K	EI	To match 5500K	EI
GTE Sylvania Warm Lite Deluxe	CC40M + #81D	1⅓	#80C + CC30M + #81	2	Half blue + Plusgreen + ¼Plusgreen + Quarter blue	0	Plusgreen + ½Plusgreen + Sun ⅛ CTO	⅓	Minusgreen + Sun ¼ CTO	0	Half blue + Minusgreen + Eighth blue	⅓
GTE Sylvania Octron 31K	CC30M + #85C	1	CC50B + CC05M + #81	1⅔	Half blue + Plusgreen + Quarter blue + Eighth blue	⅓	Plusgreen + ¼Plusgreen + Sun ⅛ CTO	0	Minusgreen + Sun ¼ CTO + 2x(UV Filter)	0	Half blue + ½Minusgreen + ¼Minusgreen + Eighth blue	0
GTE Sylvania 3K Royal White	CC35M + #81EF	1⅓	CC50B + CC10M	1⅔	Plusgreen + ¼Plusgreen + Half blue + Quarter blue	⅓	Plusgreen + ¼Plusgreen + Sun ⅛ CTO	0	Minusgreen + Sun ¼ CTO	0	Half blue + Minusgreen + Quarter blue	0
GTE Sylvania Incandescent Fluorescent	#82C #82A + CC05M	1⅓	#80A + #82C + CC05M	2⅔	Sun ⅛ CTO + Sun ¼ CTO	⅓	Sun CTO + Eighth blue	⅓	Third blue + Eighth blue	-⅓	Full blue 50 + ½Minusgreen + Quarter blue	-⅓

North American Philips Ultralume 50	CC50R +#81EF	2	CC30M +#81B	1	Full blue 50 +Plusgreen +Third blue	⅓	Plusgreen +Third blue	0	Fluorfilter +Sun ⅛ CTO	0	Minusgreen +Sun ⅛ CTO	0
North American Philips Ultralume 41	CC50R +#81B	1⅔	CC30M +#82	1	Full blue 50 +Plusgreen +Eighth blue	⅔	Plusgreen +¼Plusgreen +Quarter blue	0	Minusgreen +Sun ½ CTO +Sun ⅛ CTO	⅓	Minusgreen ¼Minusgreen	⅓
North American Philips Ultralume 30	CC30M +#81EF	1	CC50B +CC10M	1⅔	Half blue 2× (½Plusgreen) +Quarter blue	0	Plusgreen +¼Plusgreen +Sun ⅛ CTO	0	½Minusgreen +¼Minusgreen +Sun ¼ CTO	⅓	Half blue +Minusgreen +Eighth blue	⅓
North American Philips Colortone 50	CC05M +#81 +#85	1	CC10M +#82A	⅔	Full blue 50 +¼Plusgreen +Sun ⅛ CTO	0	¼Plusgreen	0	Sun ½ CTO +¼Minusgreen	- ⅓	¼Minusgreen +Quarter blue	- ⅓
Verilux Corp Verilux	#81EF +CC10M +#85	1⅓	CC10M +#81B	⅔	Full blue 50 +¼Plusgreen +Quarter blue	⅓	Third blue +¼Plusgreen	0	Sun 85 +½Minusgreen +UV Filter	0	¼Minusgreen +Sun ⅛ CTO	- ⅓

All Mfrs—Cool White, Cool White Deluxe, Warm White, Warm White Deluxe: See page 167

Color Balancing for Commercial/Industrial High Intensity AC Arc Discharge Lighting

Camera filters: Symbol "#", conversion or light balancing series; "CC": Color Compensating series (Pages 230 and 231). EI column is exposure compensation in T stops for filters.
Photo lamp filters: (Pages 366 and 367) EI column is deviation of typical exposure meters due to color imbalance. When reading exposure in filtered light from these units, reduce the ASA/ISO meter setting (i.e. increase the light level) by the number of T stops indicated.
Note: To avoid excessive filtration, the use of daylight-balanced film for Metal Halide and Mercury lighting is advised. If the lab can accommodate, and exposure is accurate, some or all *camera* filters may be left off.

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Mfr. Lamp	Camera Filters				Photo Lamp Filters			
	3200K Film	EI	5500K Film	EI	3200K Lamp	EI	5500K Lamp	EI
METAL HALIDE								
GTE MM400/ BU-HOR	CC50M +85B	1⅔	CC35M +#81D	1⅓	Full blue 50 +Plusgreen +½ Plusgreen +Third blue	⅓	Half blue +Plusgreen +¼ Plus green +Quarter blue	⅓
GTE M400/ C/U	CC40M +#81B +#85	1⅔	CC35M +#81A	⅔	Full blue 50 +Plusgreen +Quarter blue	0	Half blue +Plusgreen	0
GTE MS400/ 3K/BU ONLY	#81EF +CC10M	⅔	CC50C +CC25M	1⅓	Half blue +¼ Plusgreen +Eighth blue	⅓	½ Plusgreen +Sun ¼ CTO +Sun ⅛ CTO	0
GE MVR400/ U	CC50M +#85B	1⅔	CC35M +#81B	1⅓	Full blue 50 +Plusgreen +¼Plusgreen +Third blue +Eighth blue	⅔	Third blue +Plusgreen +¼Plusgreen +Quarter blue	⅓
GE MVR400/ C/U	CC50M +#85B	1⅔	CC30M	⅔	Full blue 50 +Plusgreen +¼Plusgreen +Third blue +Eighth blue	⅓	Half blue +Plusgreen	⅓

Mfr. Lamp	Camera Filters				Photo Lamp Filters			
	3200K Film	EI	5500K Film	EI	3200K Lamp	EI	5500K Lamp	EI
HIGH PRESSURE SODIUM								
GE LU250/DX	CC50B +CC30M	2⅓	#80A +CC50B +CC10M	3⅓	2× (Plusgreen)	0	Sun CTO +Plusgreen +¼Plusgreen +Eighth blue	⅓
GE LU250	#80C +CC50M	2	#80A +CC50B +#82A	3⅓	2× (Plusgreen) +Sun ⅛ CTO	⅓	Sun CTO +Plusgreen	⅔
GTE LU250	CC30M +CC40B	1⅔	#80B +CC50B	3	Plusgreen +½Plusgreen +¼Plusgreen	⅓	Sun CTO +Plusgreen	⅓
MERCURY								
GTE H37KC 250/N	CC50R +CC40M +#81A	2⅓	CC55M #81A	1⅔	Full blue 50 +Plusgreen +Third blue	⅓	2×(Plusgreen) +Half blue +Third blue	⅓
GTE H37 KC250/DX	CC85M +#85B	2	CC60M +#81D	1⅔	Full blue 50 +Half blue +3×(Plusgreen) +Third blue	1⅔	Full Blue 50 +2×(Plusgreen) +Sun⅛CTO	⅔
GE H250/ DX37	Not recom-mended		CC80M +#85	2⅓	Not recommended	1⅔	Full blue 50 +3×(Plusgreen) +Third blue	1

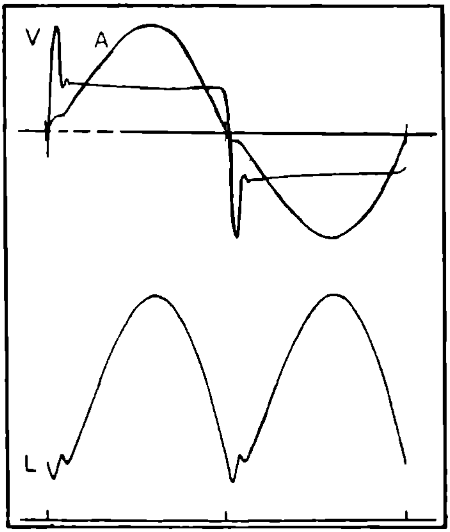


Figure 42. HMI applied lamp current and voltage with resultant light output versus time; results for standard reactance-type ballast are represented.

[Example: The first listed fluorescent light on page 368 (Durotest Color Classer 75) calls for filter adjustment of 1⅓ stops; using 3200K film at EI 320, read the exposure meter at EI 125 for the ambient fluorescent lighting. If filtered incandescent supplementary lights are used, the EI column calls for ⅓ stop, set the exposure meter to 100 to read them. If arcs or HMI supplementary lights are used, no further adjustment is required, so use the meter at 125, the same as for ambient lighting.] After color balancing as directed by the tables, a Minolta Color Meter II may be used to detect and correct for differences between individual lamps if desired.

AC Arc Lamp Flicker Problem

All of the AC photographic arc lamps described in the Lighting Section and in the Commercial/Industrial light sources section can exhibit the "flicker" phenomenon. This includes fluorescents, mercury vapor, metal halide additive types, and high-pressure sodium as well as the photographic types like HMI, CSI and CID.

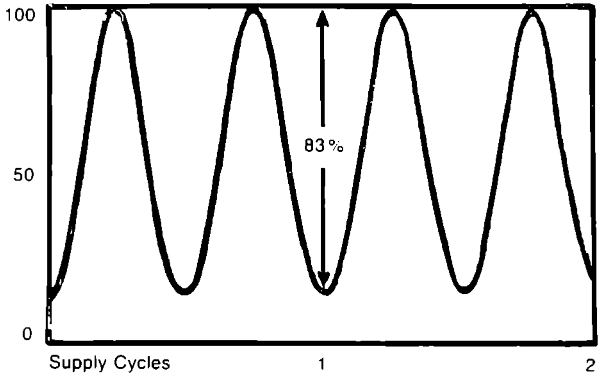


Figure 43. Waveform for an HMI lamp.

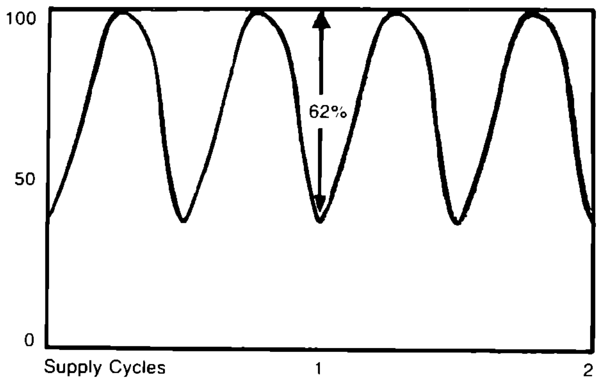


Figure 44. Waveform for a 1000-W CSI lamp.

All of the noted types of lamps require the use of a ballasting system to provide current limiting after the arc is struck. The most commonly encountered type of ballasting device is the inductor or "choke." *When used on simple inductive ballast systems, all of these lamps will exhibit a characteristic which is properly designated as time-modulation of the light output ("flicker").* This is due to the fact that the light output of these types of lamps follows the current wave form. The degree of modulation, or amount of "flicker" is different for each of the noted lamp types.

Reference to Figure 42 shows the effect as it is displayed for an HMI lamp. Note the voltage waveform which

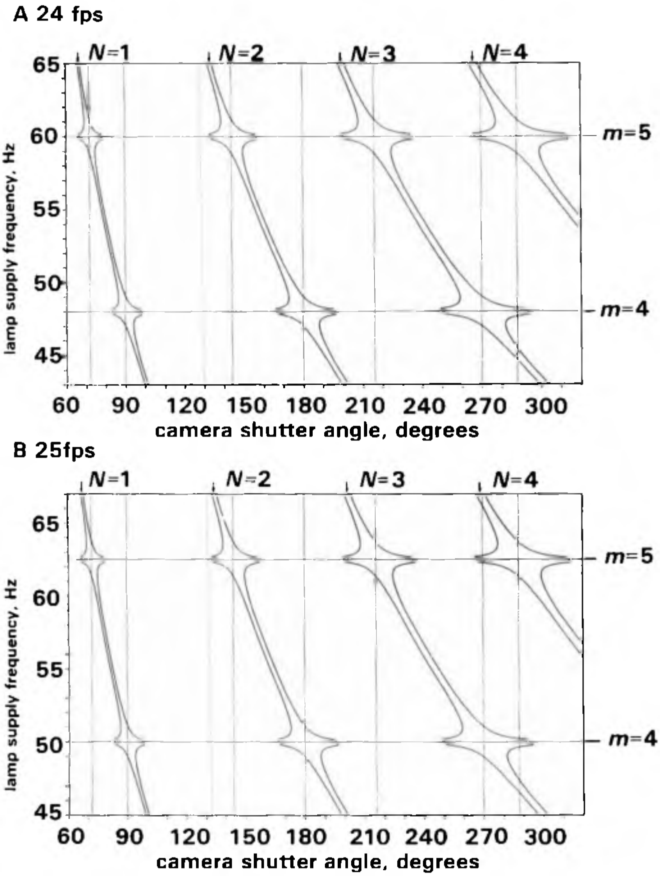


Figure 45A and B. Contours of safe lamp supply frequencies for one ripple ration value. m is the nearest whole number to the number of ripple cycles in the camera frame period. N is the nearest whole number to the number of ripple cycles in the exposure interval.

is characteristic of the effect of an inductance in a circuit, and further that the amperage is generally sinusoidal. The light output closely tracks the amperage waveform (not going negative). The result is that there are two light pulsations for each full cycle of the power line fundamental frequency (for 60-cycle systems, there are 120 pulses per second; for a 50-cycle system, there are 100 light pulses per second).

In the case of the HMI lamp shown in Figure 43, note that the modulation at its minimum represents only 17% or so of the peak light output. With the CSI lamp, this number is approximately 38% of peak (Figure 44), and for the newer CID types, it is reported that this quantity is only 55% of the peak light output. Obviously, the depth of the modulation will determine the amount of tolerance there may be in filming with this light relative to the necessary degree of control of those parameters which affect the steadiness of the exposure.

The time-related factors that are involved in assuring that a uniform exposure from frame to frame is guaranteed using these types of light sources (i.e., flicker-free) are the following:

1. Stability of the power frequency to the lamp ballast;
2. Camera framing rate;
3. Stability of camera speed;
4. Camera shutter angle;
5. Phase of shutter relative to light (particularly at high camera speed).

Simply stated, it is necessary to be sure that the same number of light pulsations are present during each exposure interval of the film. The amount of variation permitted is different for different values of the parameters noted above.

In the case where a very stable power line is available, as is true in most technically advanced countries, operating from the normal power net with a camera that is crystal-controlled, the shutter angle may be varied through a very wide range. There has certainly been adequate testing of this principle for shutter angles between 90 and 200 degrees.

It is important, however, to be aware that there are conditions where only a slight variation in one of the parameters of power line frequency or camera framing rate will result in flicker. Where possible, it is desirable to stay at the shutter angles shown in the "windows" that can be observed in Figures 45A and 45B.

These "windows" show where the range of operating tolerances is greatest. For example, in Figure 45A the intersection on the presentation at 60 cycles per second and 144 degrees shutter angle represents the middle of a "window." When operating at these conditions, a substantially large variation is possible, probably plus or minus 5%, on all the parameters which are subject to variation.

In a practical sense, operating with a 24 fps camera from a generator where there is uncertainty about its degree of regulation, it would be prudent to operate with the 144° shutter angle. In such an instance, moderate variations in the frequency of the generator output will not produce flicker. Plus or minus 2 cycles in the output power frequency would probably be acceptable when operating within the window location for a 144° shutter angle and 24 fps. A similar presentation is made for the 25 fps operation in Figure 45B.

Although the data shown is specifically for HMI, it must be reiterated that it is applicable for any AC arc discharge source. The window openings in Figure 45 are specifically determined for HMI.

They would tend to be very conservative for CSI, even more conservative for CID and possibly for some other commercial sources. However, particularly where one is encountering lamps operated from single phase systems, caution should be exercised. This chart can provide the cinematographer with those points of operation which will give him or her the maximum protection against the flicker phenomenon.

Electronic and some other types of ballasting systems which provide flicker-free ballasting are now available for a limited range of wattages of the HMI light sources. Some of these ballasts are constructed in such a way that they increase the operating frequency of the power to the lamp. The result of this is that there are many more pulsations per second so that small variations in the number of pulsations per shutter opening become unimportant. In addition, and of at least equal importance, the output waveform of essentially all of these devices is an approximation of a square wave rather than being sinusoidal. This further reduces the "off" time and with it the tendency to flicker.

The 200-watt HMI flicker-free systems have been in the field for the longest time of any of these types of ballasts. There is now such equipment for HMI at several other power levels.

Luminaires

In this section a brief description is offered of the optical systems and general performance characteristics of the basic types of luminaires utilized in cinematography.

Fresnel Lens Spotlights

Fresnel spotlights are made for standard incandescent and tungsten halogen incandescent sources, and also for the range of HMI, CID and CSI arc discharge lamps. The range of wattages, taking into account all types is from 200 watts or so to 12,000 watts.

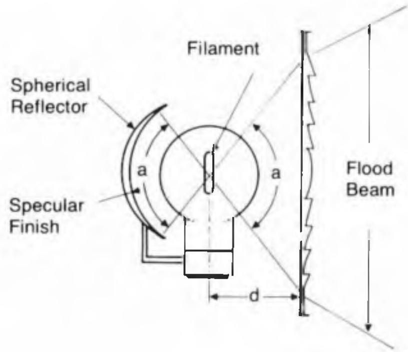


Figure 46. Optical system of Standard Fresnel Spotlight when in full flood position.

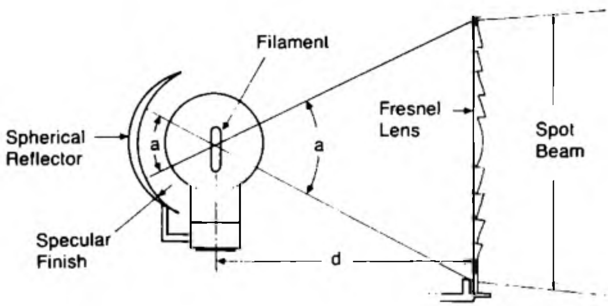


Figure 47. Optical system of Standard Fresnel Spotlight when in spot position.

These luminaires represent the most widely used motion-picture lighting units. They provide the means for changing the beam diameter and center intensity through a relatively broad range. Using standard incandescent lamps, the "spot" to "flood" ratio may be of the order of 6 to 1 or so, and with a tungsten halogen lamp, it may be

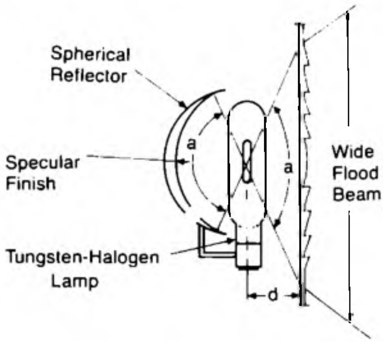


Figure 48. Optical system of Fresnel Spotlight when adapted for Tungsten-Halogen lamp.

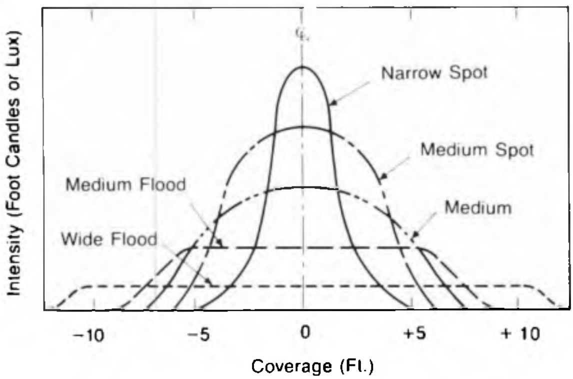


Figure 49. Characteristic intensity curve of Fresnel Spotlights.

possible to extend this ratio to 8 or even 9 to 1 under some circumstances.

The optical system of these luminaires is the same for all the variations that may be presented. The light source and a spherical reflector are located in a fixed relationship to one another. This combination of light source and back reflector is designed so that the spherical reflector reflects the energy being radiated toward the back of the housing through the filament and towards the lens. The effect intended is that the energy being radiated to the lens appears to come from a single source. The combination of the reflector and light source are moved in relation to the lens to accomplish the focusing.

Figures 46 and 47 show the optical system of the fresnel in the spot and flood positions. Note that the flood position is accomplished by moving the light source/reflector combination very close to the lens. When the tungsten halogen light sources are utilized in these systems, due to the fact that the envelope is much smaller, it is possible to move the light source/reflector combination even closer to the lens resulting in a wider flood beam distribution. This is shown in Figure 48.

This is a very attractive feature, since the highest efficiency is achieved in the flood position, and there need be no sacrifice in the spot performance. Typical efficiencies in the beam (the portion of the pattern that is within 50% of the center intensity) in "spot" focus for fresnels would be from 7% to 9% and in the "flood" position from 30% to 40%.

One of the most important features of the fresnel lens spotlight is its ability to barndoor sharply in the wide flood focus position. This property is less apparent as the focus is moved towards a spot (at spot focus it is not effective at all). The barndoor accessory used with this spotlight provides the cinematographer with the means for convenient light control. The sharp cutoff at the wide flood is, of course, due to the fact that the single-source effect produces a totally divergent light beam. The action of the barndoor then is to create a relatively distinct shadow line.

Occasionally it may be desirable to optimize the spot performance of these units, and for this situation "hot" lenses are available. These tend to produce a very narrow beam with very high intensity. It is important to remember that the flood focus is also narrowed when these lenses are used. Figure 49 shows characteristic intensity curves for fresnel spotlights.

Dedolight

The Dedolight, introduced within the last several years, is a lighting instrument whose concept is unique, and which offers a remarkable range of performance combined with small size, and low power requirements (see Figure 50).

The optical system is shown in Figure 51. Note that the moving element in the system is the light source with a collection mirror behind it, and meniscus lens opposite. To change the focus of the unit, these three elements, which are fixed with regard to each other, are moved as a unit relative to a clear fixed condenser lens.

Figure 50. The Dedolight.

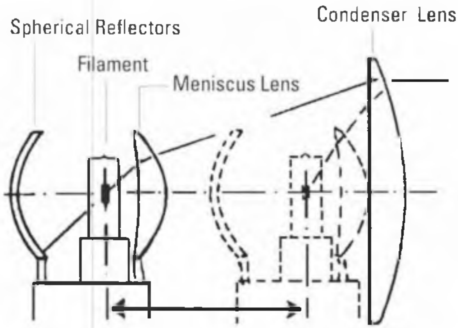


Figure 51. Dedolight Optical System.

The performance of the light is shown in Figure 52, where the 25:1 focusing range can be seen, and the unusually flat, even and soft-edged illumination fields are evident at all focus positions.

When fitted with an accessory projection attachment, the beam can be controlled further by the use of an iris or framing shutters. It projects Rosco "M"-size gobos and will project patterns with hard edges and without color fringing. Where a diffuse or soft-edged pattern projection is desired, the front lens of the projection accessory can be adjusted to accomplish this effect.

The Dedolight is made as either a 12-volt or a 24-volt 150-watt unit. The 100-watt unit can utilize a family of lamps including (at 12 volts) 20, 50 and 100 watts. The units can be battery operated or can be used from 120- or 240-volt AC supplies offered for use with these luminaires which permit selection of 3000° K, 3200°K or 3400°K operation.

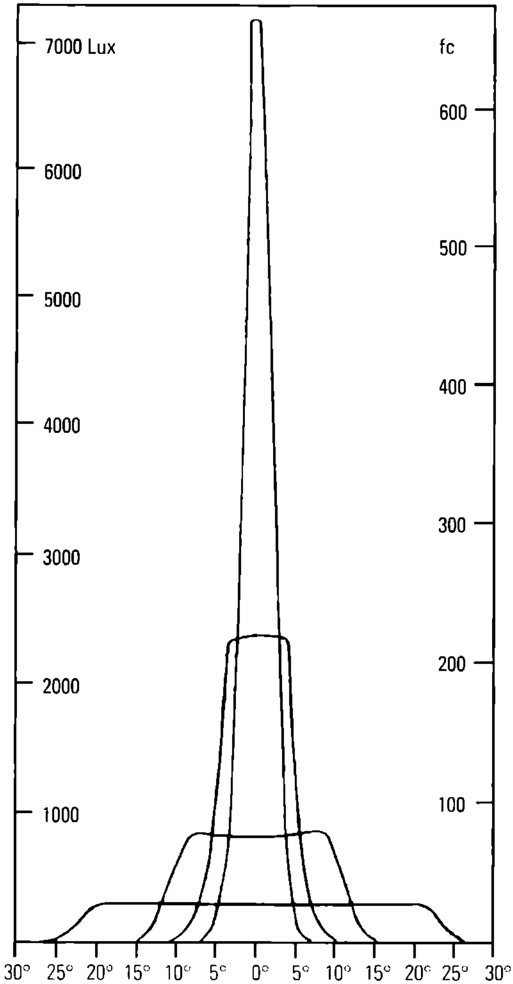


Figure 52. Dedolight performance with 100w source, 10 ft. distance, spot 3.4°, flood 40°.

Open Reflector Variable Beam Spotlights

These are typically the tungsten-halogen open reflector spotlights. There are also some low-wattage HMI-types available. These non-lens systems provide "focusing" ac-

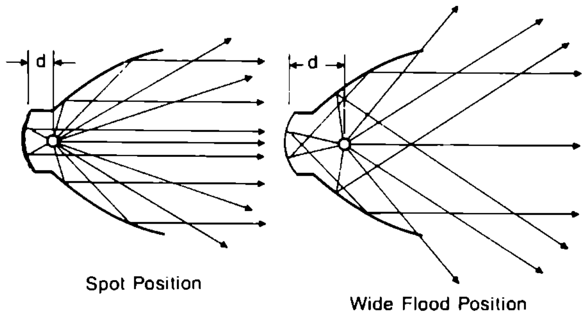


Figure 53. Optical system of non-lens spotlight (variable beam).

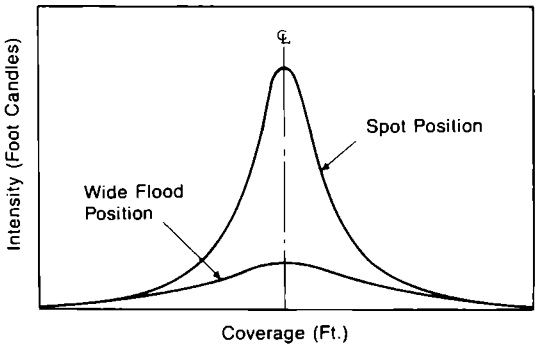


Figure 54. Characteristic intensity curves of non-lens spotlight (variable beam).

tion, and therefore a variable diameter beam, by moving the light source in relationship to the reflector (or vice versa). These types of units are available for sources ranging from 400 to 2,000 watts. Refer to Figures 53 and 54. One of the drawbacks of this system, when compared with the fresnel lens spotlights, is that there are always two light sources operative. The illumination field produced by these systems is the sum of the light output directly from the bulb and the energy reaching the field from the reflector. The use of the barndoor accessory with these lights does not produced a single shadow, due to this double-source characteristic. Typically a double shadow is cast from the edge of the barndoor. Figure 48 shows the optical systems of these open reflector spotlights in both the spot and wide flood positions.

The great attraction of these luminaires is that they are substantially more efficient than the fresnel lens spotlights. Typical efficiencies in the spot position give 20 to 25% of the source lumens in the beam (50% of the center intensity area) and in flood, efficiencies of 45 to 50% are not uncommon. Figure 49 shows typical intensity distributions for these units.

Typical spot to flood intensity ratios for these types of units is between 3:1 and 6:1.

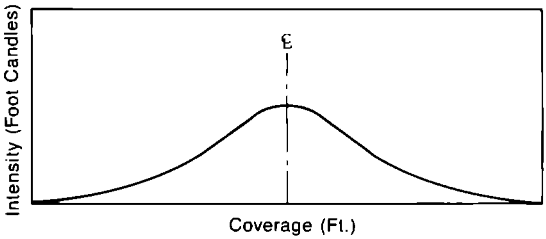


Figure 55. Characteristic intensity curve of tungsten-halogen floodlight (broad) (horizontal axis).

Tungsten-Halogen Floodlights

A variety of tungsten-halogen floodlighting fixtures have been developed, taking advantage of these compact sources. Two of the more typical forms are treated here. These fixtures are available in wattages from about 400 through 2,000 watts.

The so-called "broad" normally uses a linear source and represents a relatively high efficiency system. Barndoor control of the light is effective with the edge of the door that is parallel to the light source. Typical characteristic intensity curve for the broad is shown in Figure 55.

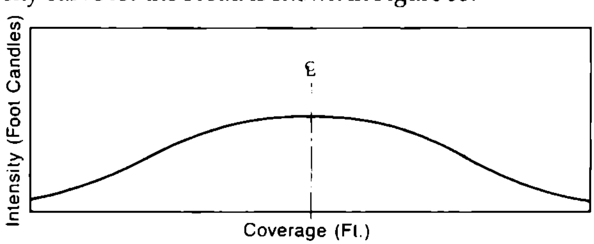


Figure 56. Characteristic intensity curve of "mini" floodlight (horizontal axis).

There are types of "mini" floodlights using the coiled-coil short filament tungsten-halogen lamps which provide very even, flat coverage with extremely sharp barndoor control in both directions. Due to the design of the reflector in this system, the light output from this fixed-focus flood light appears to have a single source. This accounts for the improved barndoor characteristics. The intensity characteristics of the "mini" floodlights on the horizontal axis is shown in Figure 56.

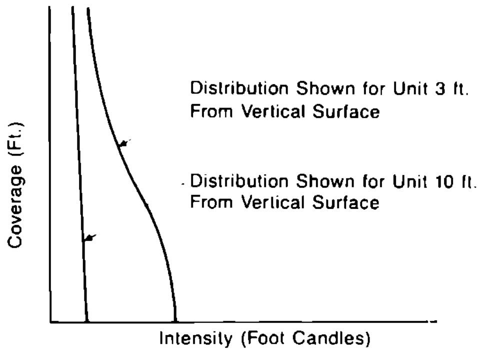


Figure 57. Characteristic intensity curve for cyclorama light.

Cyclorama Luminaires

These lighting fixtures were originally developed for lighting backings in television, but have broad application in similar types of situations in film. Because of the design of the reflector system, it is possible to utilize these fixtures very close to the backing that is being lit and accomplish a very uniform distribution for a considerable vertical distance. Typically these units are made for tungsten-halogen linear sources ranging from 500 to 1,500 watts.

Based on the variations in design, some of these may be used as close as 3 to 6 feet from the backing being illuminated. The spacing of the luminaires from one another along the length of the backing is in part determined by the distance of these fixtures from the backing itself. A typical intensity distribution is shown for a floor positioned unit lighting a vertical backing in Figure 57.

Soft Lights

The soft light, which attempts to produce essentially shadowless illumination, is now a fundamental tool in cin-

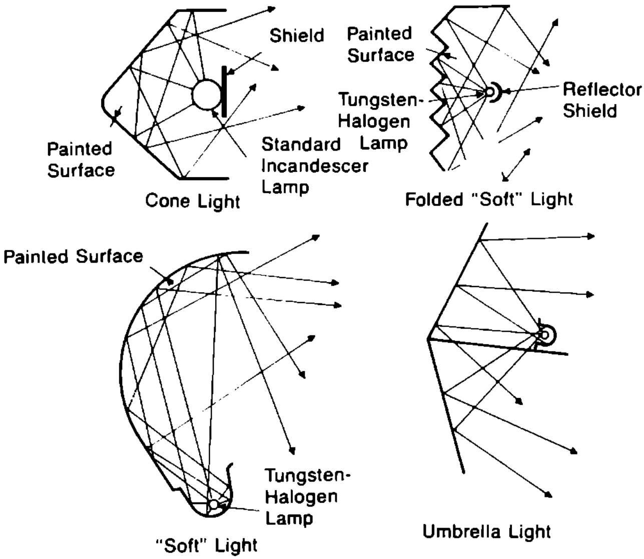


Figure 58. Optical system of various "soft" lights.

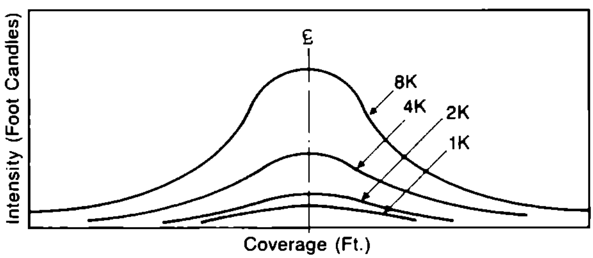


Figure 59. Characteristic intensity curves of "soft" lights.

ema lighting. Currently, these are made in wattages from 500 up to about 8,000, and typically utilize multiple 1000W linear tube tungsten halogen lamps.

The degree of softness is determined by the effective area of the source. All of these fixtures are indirect, in the sense that no direct radiation is permitted from the light sources into the beam of illumination. The "reflecting" surfaces vary in finish from matte white paint to a variety of semi-specular surfaces. The degree of specularity of the backing is not as important as the size of the reflecting surface which is uniformly illuminated and reflects the energy which makes up the illumination beam.

Formerly these were available only in the form of the Cone Light, but now a variety of other configurations have been developed largely due to the availability of the linear source tungsten halogen lamp. Figure 58 shows the configurations of some of the types of soft lights in current use. Typical intensity distributions are shown in Figure 59.

There are several types of light sources which are supplied by the manufacturers as essentially complete lighting systems.

Sealed-Beam Types (PAR Lamps)

The most popular of these are the PAR 64 and PAR 36 configurations. These lamps have a parabolic reflector which has a high reflectance aluminized coating, and a prismatic type of front lens. Typically they are supplied in VNSP (very narrow spot), NSP (narrow spot), MFL (medium flood) and WFL (wide flood) lens systems. They are extremely efficient optical systems.

Fixtures are available which assemble multiples of these types of lamp for daylight fill applications or for long-throw stadium and arena lighting requirements. Both 3200K type and the dichroic coated versions of these (approximately 5000K) are available.

Light-Control Accessories

The most typical lighting accessory supplied with the luminaires of various types described in the preceding sections would be the barndoors and scrim. Provision is made for mounting these accessories on nearly all of the luminaires described.

Barndoors

These have been briefly described in the section on fresnel lens spotlights. The purpose of this accessory is to prevent the illumination beam from the fixture from reaching certain portions of the set. It is intended that a relatively well-defined edge can be established defining the end of an illuminated area and the beginning of an unilluminated zone.

Barndoors are most effective when used on fresnel lens spotlights when the spotlight is in the wide flood position.

The effectiveness of the barndoor is reduced as the focus is moved toward spot and is totally without useful effect at the spot focus.

The effectiveness of the barndoor as an accessory on other types of luminaires varies sharply with the design of the specific item. In a number of the open reflector tungsten halogen systems (particularly floodlights) barndoor effectiveness is limited to the edge of the barndoor which is parallel to the source.

Overall, this is one of the most important and useful lighting accessories available to the cinematographer.

Scrim

The type of scrim referred to here is placed directly in the accessory mounting clips on a luminaire. This type of scrim is normally wire netting, sometimes stainless steel wire, which is used as a mechanical dimmer. There are normally accessory clips at the front of the luminaire to accept the appropriate size scrim.

The advantage of the scrim is that it permits a reduction in light intensity in several steps (single and double scrims) without changing the color temperature or the focus of the luminaire. Contrary to popular belief, it is not a diffuser.

The half-scrim is an extremely useful variation on the full scrim. It permits the placement of a scrim material in only half of the beam, and is widely used on fresnel spotlights. It overcomes the problem encountered when the fresnel is used at fairly high angles. The portion of the beam striking the floor or objects near the floor closest to the luminaire produces intensities that are too high to match the desired level at the distance associated with the center of the beam. The reason for this, of course, is the substantial variation in the distances that the illumination energy travels. The half-scrim applied on the portion of the beam impinging on the nearest objects can overcome this problem.

Gel Frames

Different forms of these holders are made and designed to fit into the accessory clips on the front of most luminaires. They permit the convenient use of various types of plastic filter materials to modify the characteristics of the beam. Color media may be put in these holders for effect color and a wide range of diffusion products are available which may also be mounted.

Grip Accessories for Light Control

Typically, grip equipment for lighting control represents devices not directly mounted to the light.

Diffusers

There are various diffusion materials sewn on wire frames of different types and size which permit the diffusion of both artificial and natural sources.

Typically these are known as scrims. They are generally translucent materials (various textiles) which truly act as diffusion. Special forms of these scrims may be called dots or fingers, which describe their size and/or geometry. When supplied in very large sizes which are supported from a single point, they are called butterflies, and where the frame becomes extremely large and is supported from two or more points it is called an overhead. Overheads are available to 20 X 20 feet in size.

Specialized devices and stands are available for the mounting of these various scrims, dots, fingers, etc. These stands and holding devices must deal with the fact that the loads supplied to them are often offset, and a high degree of stability is required. For this reason, it is usual to sandbag the base of these holders.

Gobos

Gobos come in the same form as the various scrims, dots, fingers, butterflies and overheads, but are opaque. In this form they are utilized to keep light from falling in a given area, and permit very fine adjustment of the lighting in a large area. The same assortment of holders and stands is available for mounting these devices.

A specialized variation of the gobo is the cucoloris, which is a cut-out pattern placed in the path of the spotlight in order to cast a shadow that might be comparable to the light coming through the leaves on a tree. Several versions of these devices are available.

Reflectors

Reflector boards are widely used for redirecting sunlight and modifying its characteristics so that it is suitable for use as set illumination. Reflectors come in a wide range of sizes and constructions, and a number of different surfacing materials are available for accomplishing the reflecting surfaces.

These boards have been surfaced with various reflecting media, including sign painter's leaf. However, the trend now is toward plastic laminates for this purpose. These are now available from Rosco in surface finishes ranging from an absolutely clear mirror through various degrees of diffusion of the mirror characteristics.

These variations permit the selection of surfaces which accomplish both reflection and diffusion. A graded series of these is available and are also, due to the laminated construction, very stable repeatable surfaces. They are not damaged by weather or by dust or dirt since they can be easily cleaned.

In addition to being able to reflect and diffuse at the same time, there are versions of these new laminate materials which also do color filtering. One version of a "soft" reflector has a slight blue tint which corrects the sunlight to a closer approximation to daylight. Gold reflectors are also available in these systems.

Special Visual Effects

Recent years have brought a high level of sophistication to the mechanics of special visual effects, allowing cinematographers' imaginations a greater degree of freedom. This chapter is intended to give the cinematographer an overview of the techniques available, including front and rear projection, the optical printer, motion control photography, and digital image manipulation.

Shooting Background Plates

Scenes projected on a translucent screen and re-photographed as a background for a live-action foreground have been traditionally called "plates" or "keys." Guidelines for the original photography of such scenes also apply when the scenes are to be composited by most of the methods discussed in this section.

General Requirements

A pin-registered motion-picture camera should be employed for filming all stationary background plates. Since the plate will later be re-photographed in combination with a live foreground scene, often employing the use of a solid set piece, the slightest amount of film movement due to poor registration will be readily detectable. It is not absolutely necessary, but desirable, that a pin-registered camera be employed for filming traveling plates. A full camera aperture is desirable, although an Academy aperture may be employed if it is the only size available. VistaVision and 65mm cameras are also often used. The larger negative areas lead to finer-grained, sharper composite images. Medium-speed emulsions are the usual choice of most background plate camera men for grain and sharpness. High-speed negative may be used under special circumstances.

Exposure should be on the full side; if in doubt, slightly overexpose rather than underexpose. A crisp, full-scale print with rich blacks and clean highlights is desirable. A muddy print made from a thin, underexposed negative is unsatisfactory and would be very difficult to match when the composite scene is later photographed. Backlighted scenes, except for effects such as sunlight shimmering on water, should be avoided. Background plates fall into two distinct categories: stationary and traveling.

Stationary Camera

A stationary plate is photographed with a rigidly fixed camera, tied down and firmly braced. Knowing exactly how and for what purpose the plate will be used is a great aid in setting up. An important factor in filming stationary plates is recording the proper perspective, with the correct vanishing point, to provide an apparent match with the foreground scene in the final composite picture. Unless the vanishing point is properly positioned, the linear convergence in the foreground scene will not match that recorded on the plate.

Camera elevation and tilt and horizon placement must be given serious consideration in order to meet these requirements. If in doubt, or if the plate is for library use, place the horizon dead center since it may be moved up or down when composited and allow the most leeway in fitting various composite situations. The ideal situation, of course is to film three plates: one with the sky ⅖ from the top, one with the horizon centered, and one with the sky occupying ⅗ of the frame. This will allow for any eventuality and give the director added scope if he decides to shoot up or down. Usually, however, the horizon is placed about ⅖ of the distance from the top of the frame. It is advisable to have slightly more foreground, whether water, pavement, or scenery. If sufficient foreground is not provided on the filmed image, it may be necessary to blow up a portion of the picture to provide it, resulting in increased grain and poorer image quality.

Plates shot to script are usually ordered with sufficient data for the cameraman to do the job properly. Stock plates, filmed for library use, are a little more difficult since they must be photographed in a manner that will allow using them in a more general way to fill various situations.

Background images should be sized so that the fullest possible area of the filmed frame can be utilized. This provides the finest photographic quality, least grain and sharpest picture, and result in a top quality combination of plate and foreground. It is inadvisable to employ a lens shorter than 35mm (for 35mm photography) unless only a part of the image is later utilized. Some background scenes shot with an extremely wide-angle lens may present very difficult matching problems when composited. Slightly longer lenses, on the order of 40mm and 50mm, are best. (Lenses of comparable angle are recommended for VistaVision or 65mm photography.)

An excellent method for securing an accurate match for a plate shot to script is to use stand-ins positioned exactly the same as the players will later be positioned in front of the background. A few feet of film should be shot with the stand-ins in position and they then should be moved out and the plate photographed. This will give the compositing cameraman a good idea of how the final shot should look and is particularly valuable if the plate cameraman is on an extended location trip and might not be available should questions arise. While the plate is being shot, be certain that no one walks closer to the camera than the positions occupied by the stand-ins. If someone were to walk between the stand-in position and the camera, the person would appear too large, upsetting the required diminishing perspective. To be safe, keep everyone ten feet or more behind the positions occupied by the stand-ins.

Background views seen through a door or window are less critical to shoot, since the view is a distant one and does not require an perfectly integrated relationship with the foreground. The camera angle must be correct, however, and present the proper vanishing point. A scene supposedly occurring in an office on the 20th floor should have a window plate possessing a view taken from that apparent elevation, and presenting the proper viewpoint. While a considerable amount of "cheating" can be tolerated (such as shooting from the 10th floor of a building), the view presented should be one that would appear normal to a person on the live set looking out the window. The plate camera could not, for instance, be angled up or down; it must be shot dead level so that a "square on" view with vertical lines is recorded. A special background slate should be used to film all pertinent data: production number, scene number, camera height, camera angle, sun angle, focal length of lens, et cetera. This data will be a help later in duplicating the setup when the composite scene is filmed. The background plate cameraperson should bear in mind that he is not expected to record beautiful compositions in themselves. He is simply furnishing the background to back up the combined scene.

Moving Camera

Traveling background plates for rear process projection are used in combination with supposedly moving vehicles, airplanes, trains or boats. They may be filmed with either single or multiple cameras. In order to provide the various plates necessary for shooting various combinations of group shots, close-ups, over-the-shoulder scenes, etc., several angles must be filmed from the moving camera platform. It is advisable to use a single camera whenever possible to allow "cheating" the sunlight so that a time interval between runs may be chosen which will record each plate with the best light condition. Camera car speed may also be varied, if desired, for the various angles, if plates are shot individually.

Single camera plates will usually suffice, since the change in camera angle when the process scene is photgraphed is usually sufficient to cover any mismatch that exists. Remember that the audience is intent on watching the foreground action and the background plate will not distract unless something very jarring appears. Normally, a considerable amount of "cheating" is permissible (indeed, often required) in order to record the best possible set of plates, in the proper light, at the correct rate of speed. Sometimes a single side of the street is filmed to serve for both side angles — by shooting left rear going one way and right rear going in the opposite direction. Or, a single plate may be turned over in projection (if no telltale signs appear) to serve both sides of the street. Turning the plate over is usually reserved for country roads, since its use on traffic-laden streets may be more obvious (parked cars on either side of the street will point the same direction).

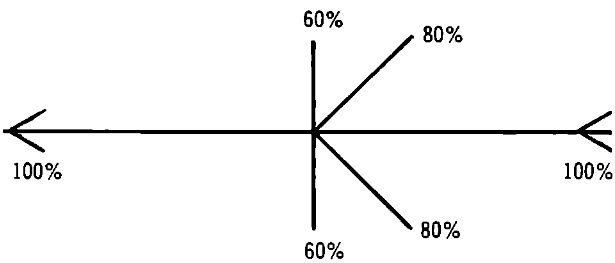
Of great importance in filming moving plates is that the camera be at the correct height. For autos the height should be at the shoulders (not the eye level) of a person seated in the car who will later be seen in the rear projected composite shot. This will vary, for example, with low-slung sports cars and buses. It would not do to look outside a sports car window and see the roofs of cars following (which would result if the plate camera were too high).

On the other hand, a low-angle shot shooting up into trees and buildings is equally bad because it is not feasible to angle a camera in a car to photograph seated people and see this perspective through the window. The plate camera should be tilted slightly downward — just a trifle below horizontal. The vanishing point of a straight-on shot would be just above dead center of the screen. Remember it is always better to have a little more pavement than sky. A set-up may require tilting down on a mock-up car, so additional image in the lower corners of the frame is desirable. Traveling plates should be photographed with 35mm or 40mm lenses on side and three-quarter angle shots. A 35mm, or some times a 50mm if only a small area of the plate will be utilized, is used on straight-back shots.

Speed vs. Angle

The camera angle on a moving shot affects the apparent speed of the projected image. Plates shot from straight side angles appear to move much faster than those filmed from either straight forward or straight backward angles — even if the speed of the vehicle from which the shots were made was the same. It is often necessary, therefore, to cheat the camera vehicle speed (not the camera speed) so that all angles will appear at the same relative speed when rear-projected. This effect is less apparent in open country than in city streets with closely packed traffic and nearby buildings. It is advisable to use normal 24 frames per second camera speed whenever possible so that pedestrians appear to be moving normally. It may be necessary on wild chase shots to undercrank since this is the only way to record ultra-fast vehicle speeds with safety.

The following diagram will be useful for estimating camera car speeds for various camera angles. This is for city traffic. Various angle plates may be filmed in open country at the same camera car speed for all angles if nothing close to the camera appears in the plate.



For example, if the camera car travels at 50 miles per hour for the straight shots, it should travel at 40 miles for the three-quarter angles and at 30 miles for the side shots. Be certain to set the camera at the same height and with the same slight downward tilt for all angles.

Plate Print Preparation for Back Or Front Projection Or Aerial Image Compositing

Color matching is affected by the lenses, arc mirror, quartz protector plate, cooling water cell, and by the screen itself. Preproduction testing is suggested. Plate prints should incorporate color ratio correction for projection conditions. Print contrast may be lowered by flashing and/or using low-contrast print (TV) film; both will also affect color saturation. Masking has also been suggested (*American Cinematographer* Magazine, Nov. 1984, p. 109, J. Danforth). Prints should be on B & H perforated stock.

Front-Projection Process

by Petro Vlahos

The front projection process of composite photography was made possible by the development of a highly directional reflective material by 3-M (Scotchlite #7610).

Scotchlite is a glass beaded reflex reflector that returns most of the reflected light back to its source. The gain of Scotchlite is so high that a fraction of a footcandle of background image intensity is sufficient to balance a 200-footcandle foreground illumination.

Although the projected image falls upon foreground subjects, its intensity is so low that it is not visible on the subject. When the camera is exactly aligned on the optical axis of the projector, it will not see the shadow cast by the foreground subject. The very low level of illumination required by the Scotchlite screen makes possible background screens as large as 30,000 sq. ft. when using an arc projector.

The practical use of front projection requires careful alignment of the camera and projector lenses to (optically) superimpose their front nodal points. When the nodal points are misaligned, or when the subject is too close for a given lens focal length and f-stop, a dark halo is developed. The appendix at the end of this section defines a safe minimum object distance as a function of screen distance, lens focal length and f-stop. By observing the limitations of the front-projection process, excellent results have been obtained.

Geometric Relationships

The shadows cast by an actor, or any foreground object, are largely obscured by the object as the projector is brought close to the camera. The shadows are completely hidden from the camera when the camera and projector lenses occupy the same position. Since this is not physically possible, the axes of both lenses are made to coincide optically by the use of a semi-transparent mirror. The arrangement of the camera, projector, mirror and screen are shown in Fig. 1.

The function of the semi-mirror is to bend the axis of the projector in a right angle so that the light which reaches the screen appears to originate from within the camera lens. Since the camera cannot see around or behind a foreground object, it will not see the shadow cast by that object if the shadow is confined strictly to the area behind the object. Placing the projector axis coincident with the camera axis accomplishes this objective within certain limitations that

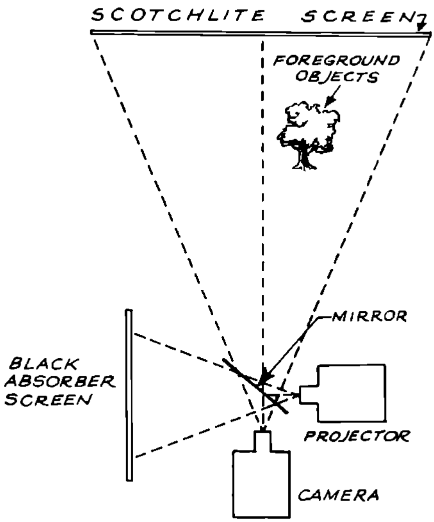


Figure 1. Arrangement of camera, projector, mirror and screen.

will be described. Although the projector is located to the right of the camera in Fig. 1, it may be located on either side or may project into the mirror from above or below. It is also permissible, from a functional point of view, to interchange the camera and projector locations.

The mirror, at 45° to the projector and camera axis, reflects the projected image onto the screen; but the mirror, being semi-transparent, allows about half of the projected light to go directly through the mirror onto the nearest wall and be wasted. Such wastage is unavoidable since the mirror must be semi-transparent to permit light from the foreground scene, as well as from the background itself, to reach the camera lens.

The 45° mirror is also a partial mirror as seen by the camera, and provides to the camera a view of the side wall of the stage as well as a second image resulting from the projector waste light. To eliminate these secondary images a small, dull black screen is placed opposite the projector, as shown in Fig. 1.

Introvision (Hollywood) replaces portions of the black screen with a piece of Scotchlite screen. Supplementary lenses permit focusing the projected image onto the supplementary segments. When matched to black flats on the main set, it is possible to have actors appear to emerge from doorways and from behind objects in the projected background.

Another development by Courier Films Limited, the Zoptic Process, employs a zoom lens on the camera and the projector and interlocks the zoom controls. By simultaneous zooming of the foreground and background lenses in the same direction, objects in the field appear to move toward or away from the camera. This technique was used extensively in the 1978 production of *Superman*. The transmission/reflection ratio of the mirror is not critical; however, for best utilization of foreground and projection illumination, transmission should always equal or exceed reflection. Their relationship is shown in Fig. 2. The projector light that finally enters the camera experiences a reflection at the mirror to get to the screen, and then a transmission through the mirror to get to the camera. Utilization is therefore a function of the product of the reflection and transmission percentages. Even if one assumes no losses, the maximum efficiency cannot exceed 25% and it occurs at a 50/50 ratio. In front projection, one should expect two stops of light loss.

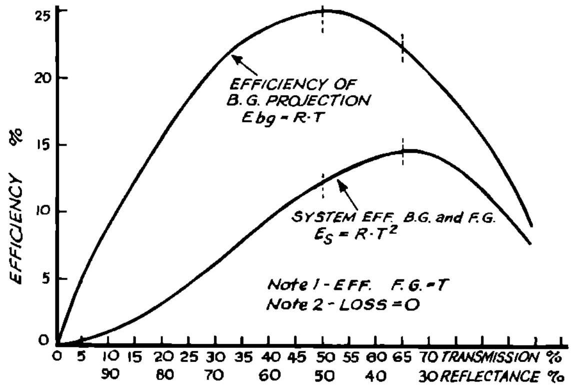


Figure 2. Front projection mirror; transmission/reflection ratio and efficiency.

Since film exposure of foreground objects requires a given amount of light at the camera, any transmission loss through the mirror must be made up by increasing the illumination of the foreground. Thus transmission should be as high as possible. The efficiency of utilization of the foreground (FG) illumination is a linear function of transmission and increases as the transmission increases. An increase of transmission from 50% to a value of 60% results in a 12% increase in the utilization of the foreground illumination. It can be seen from the figure that this change from 50 to 60% in the transmission results in a drop of only 4% (25 down to 24) in the utilization efficiency of the background (BG) illumination.

The scene being projected onto the screen is also being projected onto the foreground objects and actors. Whether or not the scene being projected on foreground objects will be visible in the photography depends upon the intensity of the projected light relative to the intensity of the foreground illumination. A specific high-gain intensity relationship is thus far solely a property of the Scotchlite screen.

The Scotchlite Screen

The special properties of the front-projection screen make front projection practicable. One screen made by the 3M Company, commonly known as Scotchlite, Type 7610, is a reflex reflector — that is, it has the property of reflecting light back to its source. A reflex reflector can be made by using corner mirrors or glass beads. The 3M screen uses glass beads. The limited angular distribution of reflection is illustrated in Fig. 3. Because of the controlled angle of the reflected light, the screen has a very high gain. If one observes the screen from a vantage point not more than about ¼° from the axis of the projector, it will appear to be nearly 1,000 times brighter than would a matte white surface receiving the same illumination. Because of this high gain of Scotchlite, very little illumination is required from the projector; therefore front projection can provide backgrounds of almost any desired size. A 130-A arc lamp projector can easily illuminate a 30,000 sq. ft. screen of Scotchlite to balance a 200-fc-key foreground scene. Thus, screens up to 120 X 250 feet can be used.

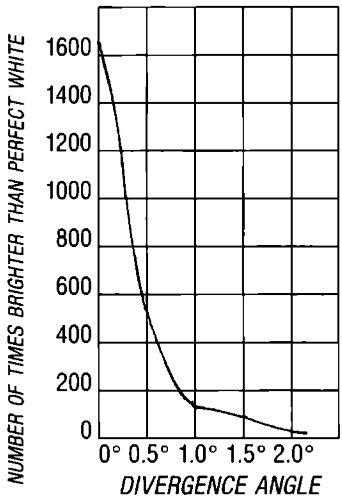


Figure 3. Relative angular distribution of reflection of 3M Scotchlite reflective sheeting Type 7610.

The ability to use large background screens is one of the principal advantages of front projection. By comparison, rear projection was limited to a screen size of 20 to 30 ft., even when illuminated by three high-powered projectors. Even considering the losses of the semi-mirror, one need only use about one footcandle of illumination on the screen to balance a foreground key light of 200 fc. This is a net ratio of about 200:1 and is more than adequate to result in invisibility of the image projected on foreground objects — even a white shirt. If one considers a white shirt to be nearly 100% reflective, and the reflectivity of black velvet to be approximately 2%, this represents a ratio of only 50:1. Thus a white shirt is so dull compared to Scotchlite (200:1) that it appears to be blacker than black velvet when the Scotchlite is illuminated to the brightness of the foreground scene.

The Scotchlite material is available in two-foot-wide rolls. The screen can be constructed by simply papering the material onto a wall-like surface or wooden backing or hanging it in horizontal strips. It is only necessary to cover all of the screen area. Butt edges are not required, and pieces may be overlapped. It is advisable, however, to prepare a screen from the same production batch since a second batch may differ slightly in brightness gain.

Tesselating The Screen

Irregularities in reflection of the Scotchlite material may be minimized by cutting or tearing the Scotchlite into small pieces, scrambling the pieces, and reassembling them into a mosaic. This, however, is wasteful of material and is labor intensive. Apogee, Inc. has designed a die which cuts Scotchlite into symmetrical hexagons with curved edges; with the aid of a template the tiles are mounted on a prepared Dacron and Mylar sheet with a 3% overlap. The completed screen is checked by photographing it using a ring light and high-contrast film in order to exaggerate any imperfections that might exist. (Apogee, Inc. holds a patent #4,548,470 covering this method of screen fabrication and supplies either the complete screen assemblies or separate tiles for the user's application.) It is not necessary that Scotchlite be absolutely flat or square to the camera since its gain is quite uniform over a rather wide angle of incidence, as shown in Fig. 4.

Alignment of Nodal Points

The practical usage of front projection requires careful alignment of the camera and projector lenses. All multi-element lenses, whether for camera or projector usage, have two or more nodal points. In the front-projection process we are interested only in the front nodal point. For the pro-

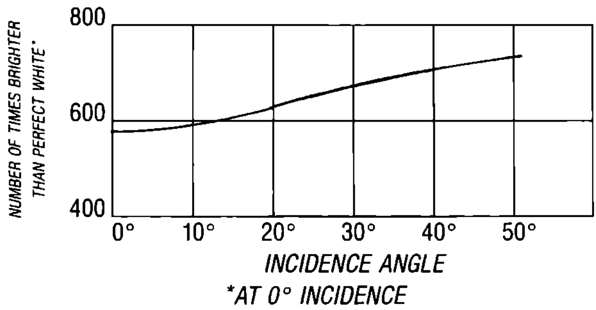


Figure 4. Gain of Scotchlite screen as a function of the angle of incidence, for a constant divergence angle of ½° between incident beam and measuring axis.

jector lens, the front nodal point is that position within the lens from which the light appears to emanate. For the camera lens, the front nodal point is that point within the lens toward which all incoming light appears to converge. Since the camera lens has a finite field angle, and since it is possible to have foreground objects anywhere within the field of view of the camera, there is only one position of the camera lens that will eliminate shadows for all objects within its field of view.

This position is obtained when the front nodal point of the camera lens is effectively coincident in all axes with the front nodal point of the projector lens. If these nodal points are not effectively coincident, a black shadow line will appear at the edge of foreground objects.

Where there is only one foreground object in the scene, and that object is located symmetrically on the camera axis (as in a closeup of one person), it is possible and sometimes desirable to place the camera nodal point ahead of the projector nodal point. The desirability of this procedure will be explained later, in the discussion of shadow gradients.

The camera and projector each have three degrees of freedom in translational motion. A sliding movement of the camera or projector to the left or right is a translation along the x-axis. Similarly, a change of elevation is translation along the y-axis; movement toward or away from the screen is translation along the z-axis. Adjustment of the position of the camera or projector along these three axes is required to obtain effective coincidence of their lens nodal points. An adjustable base for the projector or camera facilitates this adjustment.

It is the virtual, or reflected, nodal point of the projector that is to be co-located with the nodal point of the camera lens. Thus any adjustment of the mirror's placement or angle shifts the position of the projector nodal point with respect to that of the camera. Since the nodal point of a lens is a single point somewhere within the lens, it is not accessible for making a direct mechanical alignment. Therefore it is necessary to make the alignment optically by using test targets located in the camera field. The degree of permissible error in the alignment of the lens nodal points is a function of several variables.

The principal variable is the separation of foreground objects from the screen. When the foreground objects are quite close to the screen, one may misalign the camera by as much as an inch in any direction without inducing a visible shadow line in photography. As foreground objects approach the camera, the alignment becomes more critical, until only 1/32 in. of alignment error can cause a visible shadow line. Thus, when alignment targets are used, they should be placed close to the camera to simplify the alignment procedure and to assure alignment accuracy.

The type of alignment target used can impose some problems. The use of white cards requires separate illumination, and balancing the brightness can be a bit of a chore. Small sections of the Scotchlite screen may be used, but since the brightness varies inversely with the square of the distance, they are over-bright when brought close to the camera. A good procedure is to stop down the projector and camera lenses to f/22, if possible, and tip the Scotchlite targets well past 45°. At a very steep angle, their brightness can be made to match that of the screen. Under these conditions, a misalignment of as little as 1/32 in. can be readily observed.

The source of light that produces a shadow line originates from the projector lens, which in turn receives its light from the lamphouse and its optics. The alignment of the lamphouse and its optics should result in symmetrical illumination of the exit pupil of the projector lens. When the exit pupil is not symmetrically illuminated, the center of the emerging light bundle is not at the lens center. And while this off-center illumination in no way affects the background scene, it does result in shifting the shadows to one side or the other, just as though one had shifted the projector. Any change of the projector lens iris then acts not only to change light level, but produces the equivalent of a shift in x or y of the whole projector. An iris change on a projector with a poorly centered lamp can result in up to ½ in. of apparent misalignment.

A computer-generated table has been prepared to show the alignment error that induces a 0.0002 in. shadow line on the camera negative under a variety of conditions. This dimension (0.0002 in.) represents the threshold of visibility of a line projected on a large screen. The primary utility of this data, found in the appendix on page 413, is to show the relative influence of the object-to-screen separation, and to indicate the magnitude of alignment accuracy required. The actual alignment error that can be accepted is reduced by the halo effect, which will be discussed a little later.

Alignment of Anamorphic Lens

The use of anamorphic lenses introduces special problems in front projection. Such lenses have two front nodal points, one associated with the vertical tilt motion and the other with panning motion. Both nodal points exist in the camera and projector lens, since these lenses have, in effect, two different focal lengths. If these nodal points in the camera and projector lenses are not equally spaced, there is no way to simultaneously superimpose both sets of nodal points.

The problem can be minimized by splitting the distance between front nodal points for each lens and co-locating this median position. Simultaneously, one should keep foreground objects relatively close to the screen, whereby rather large misalignment of nodal points can be tolerated without introducing a shadow line.

Pan, Tilt and Zoom

It is possible in front projection to pan and tilt the camera during photography, provided that the x, y, z relationships of the nodal points are maintained. To do this, it becomes necessary to use a nodal-point camera mount that permits the front nodal point of the camera lens to be located at the center of rotation for both pan and tilt motions. This requirement of maintaining a co-location of projector and camera lens nodal points also applies to a zoom lens.

Because the front nodal point of a zoom lens may shift by several inches during a change of focal length, it is necessary to shift the camera body an equal distance, in order to maintain a fixed spatial relationship between the two axes of rotation and the nodal point. An alternative, of course, is to limit the zoom range, and to place all foreground objects close to the screen, thus taking advantage of the resultant increased tolerance of nodal-point positioning, as mentioned earlier.

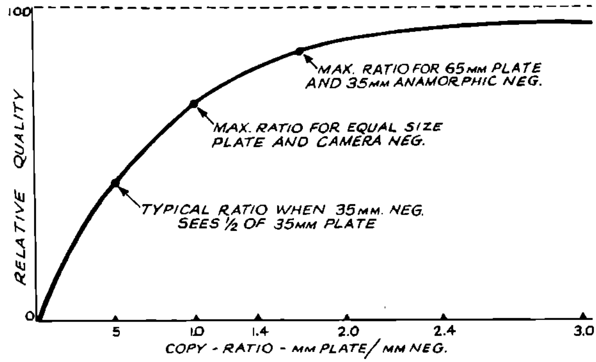


Figure 5. Relative loss of image quality as a function of copy ratio.

Problems of Grain in Front Projection

There are rather severe limitations on the use of zooming in a front projection scene and these limitations are caused by image grain. It must be remembered that the scene being projected was once photographed by a camera on negative film. In front projection, this scene is being copied onto the film in the camera and this film is a negative. Thus the background part of the scene is a dupe that has been made on camera negative rather than a fine grain duping stock. The graininess is therefore increased.

If, for example, both the camera and projector films are 35mm, and if the entire projected scene just fits the full aperture on the camera ground glass, then there is a one-to-one relationship between the image on the projected film and this same image as it is being exposed in the camera. In this case we have a 1:1 copy ratio. If one now zooms to twice the initial focal length, only ½ of the width and ½ of the height (or ¼ of the area) of the projected print is being copied. This is in reality a 16mm area. Owing to the loss of resolution and increase in grain, it will look like a 16mm background.

If, on the other hand, the entire background image is projected onto a small screen that represents, for example, a window, then one can zoom in until the window fills the camera viewfinder. At this point the copy ratio has again dropped to 1.0. Figure 5 illustrates the relative loss of image quality as a function of the copy ratio. Note the advantage of using a 65mm BG.

The Halo Effect

From the earlier discussion on the alignment of nodal points, we may have implied that once exact alignment is achieved there will be no visible shadow line; this is not necessarily the case. Perfect alignment of nodal points assures the absence of a shadow line only when both the projector and camera lens apertures are as small as pinholes. Normal lenses do not approximate a pinhole. Actual entrance pupil diameters are in the order of one inch, as is the case for a 100mm lens at f/4.0. Since lenses have aperture dimensions significantly larger than a pinhole, their depth of focus is limited as a function of aperture.

When a foreground object is in focus and the background is not in focus, a black halo forms around the foreground object on the camera negative. This halo is not a black line, such as is experienced by misalignment, but is best described as a brightness gradient that falls to 50% intensity at the edge of the foreground object. The halo is most often seen on closeups.

As objects recede from the camera and approach the screen, the halo shrinks to a faint line and, at some distance it seems to disappear. This edge-gradient halo is most conspicuous when the background scene is a clear sky or a blank wall. It is less noticeable on backgrounds such as dark foliage.

The halo phenomenon is explained by reference to Fig. 6. If the camera is focused on a foreground object, this object will be in sharp focus at the film plane. If one assumes, for the moment, that the projector aperture is a pinhole, then the shadow cast by the foreground object will appear quite sharp on the screen. In the camera, the projected background image and the shadow will both be in sharp focus at some plane ahead of the film, but not on the film. From the diagram it can be seen that the light rays, continuing

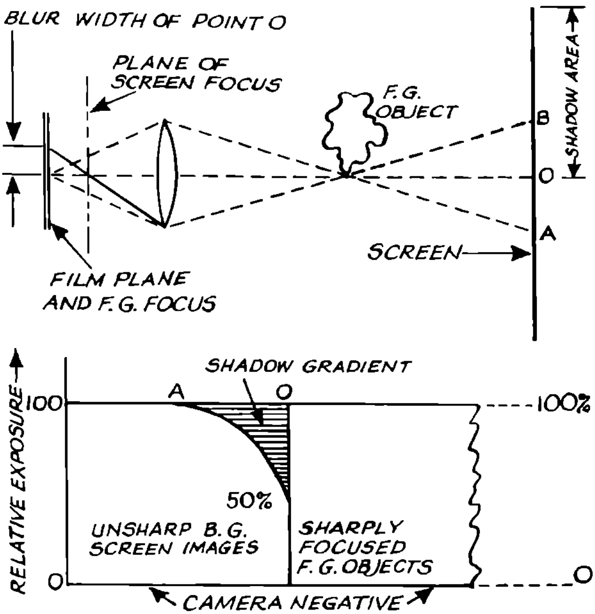


Figure 6. The halo phenomenon.

past this plane of focus, diverge as they reach the film plane and become a blur on the film. Point A on the screen can be seen by all of the camera lens; but point O, the edge of the sharp shadow, can be seen by only half the lens. Thus A is at full intensity at the film plane, but as point O is reached, the light has fallen to half intensity on the film (because half the lens has been occluded). This gradient is shown in the lower part of the figure and exists for all objects.

The edge gradient described above is produced by the camera lens aperture alone, because the projector was assumed to be a pinhole. In practice the projector aperture is not a pinhole, but has some finite diameter. This real diameter of the exit pupil of the projector lens causes the shadow on the screen to have a soft edge and this edge spreads out for some real distance on the screen. However, the gradient already produced by the camera lens aperture does not see this second gradient (produced by the projector lens) as long as the size of the projector lens aperture is equal to or smaller than that of the camera aperture.

This conclusion was verified by computing the size and shape of the edge gradient for two extreme conditions; one condition was a knife-edged screen shadow, while the other condition was a uniformly increasing shadow extending from A to B. These two conditions cover all possible projector lens apertures up to and equaling that of the camera aperture. The gradient on the camera negative was identical in size and in shape for both cases. The edge gradient halo is therefore a function of whichever lens aperture is larger.

In practice it can be concluded that one should always stop down the projector until its exit pupil diameter is less than the diameter of the entrance pupil of the camera. If both lenses have a focal length of two inches (50mm) and the camera is at f/4.0, then the projector can be at f/4.0 or 5.6 or any smaller aperture. But if the projector lens has a four-inch focal length (100mm), it must be stopped down to f/8.0 to match the entrance pupil diameter of a two-inch camera lens at f/4.0.

Minimum Foreground-Object Distances

A table has been prepared that specifies the closest distance that foreground objects may approach the camera for a 0.0002 in. half-gradient halo as a function of screen distance, camera focal length and lens aperture setting. This table appears on page 413.

After the camera and projector nodal points are aligned in all three axes (x, y, z) by the method described, one must then be concerned with the halo effect. Appendix 1 may be used as a practical guide to determine safe object distances that will not result in a visible halo. The Appendix is organized by lens focal length. After selecting the table corresponding to the camera lens, find the camera-to-screen distance located in the left-hand column. The row of numbers opposite the screen distance represents the closest distance objects may safely approach the camera without developing a visible halo. This distance is listed for several lens stops. These lens stops are for the camera, or for the projector lens if its aperture is the larger. (Note: f/2.8 is a larger relative aperture than f/4.0.)

The near distance limits listed in the tables of Appendix 1 will result in a halo around the object of 0.0004 in. on the film. Since the halo is a gradient, the first half of the gradient between A and O (Fig. 6) is of low visibility. Therefore, only the steeper half of the gradient is considered as capable of producing a visible shadow. The tables, therefore, define an object distance for which the steeper half of the gradient will produce a 0.0002 in. shadow line on the negative; there is always some question as to how much halo can be present before it is visible. The 0.0002 in. value has been used by Technicolor, for example, as a limit for color registration. It represents ⅛ in. on a 50-ft. screen. The exact width at which a shadow line is visible or invisible depends upon how close one sits to the screen, the quality and sharpness of the projection lens, contrasts in the picture, and of course one's own visual acuity.

Perhaps the most significant variable affecting the visibility of halo is picture contrast. The most critical scene is white against white, since these objects match in color and are at high luminance. The darker and more mottled the background, the less visible the halo. The Appendix is for the worst case, white against white. Most scenes do not present these critical brightness conditions. It is therefore practical in many cases, where the background is dark or mottled, to accept the nearer closeup limit indicated for the next smaller stop. With a dark foliage background, even closer subject-camera distances can be tolerated.

Z-Axis Displacement for Closeups

When it is essential to make a rather extreme closeup of a single object or person, it can be done without a halo by observing a special rule. If the single foreground object extends outward in all directions from the center of the camera-lens axis, it then becomes possible to move the camera forward by several inches, placing it well within the shadow cone of the projector. This action would normally produce a severe shadow on the inside edge of all off-center objects. But the single object (or person) that extends outward in all directions from the camera center has no inside edges, and thus no shadow line or halo will be visible.

Brightness and Color Matching

Segments of the front-projection screen material can be placed in positions forward of the main screen for certain special effects, such as doorways. It should be remembered that the inverse square law also applies to Scotchlite. If one places a piece of the material at half the screen dis-

Appendix I
Minimum Object Distance (in ft.) for 0.0002-in. Haif-Gradient Halo.

Screen distance	Lens aperture and object distance f/ 2.8	f/ 4.0	f/ 5.6	f/ 8.0	f/ 11	f/ 16
25mm lens						
10	8	7	6	6	5	4
20	13	11	10	8	6	5
40	19	16	12	10	8	6
60	23	18	14	11	8	6
80	25	19	15	11	8	6
100	27	20	15	11	8	6
120	28	21	16	11	9	6
32mm lens						
10	9	8	8	7	6	5
20	15	14	12	10	9	7
40	24	20	17	14	11	8
60	30	25	20	15	12	9
80	34	27	22	17	13	9
100	37	29	23	17	13	9
120	40	31	24	18	13	10
40mm lens						
10	9	9	8	8	7	6
20	16	15	14	12	11	9
40	28	25	22	18	15	12
60	36	31	26	21	17	13
80	43	36	29	23	18	14
100	48	39	32	25	19	14
120	52	42	33	26	20	14
50mm lens						
10	9	9	9	8	8	7
20	18	17	16	14	13	11
40	31	29	26	22	19	16
60	42	38	33	28	23	18
80	52	45	38	31	25	19
100	59	50	42	34	27	20
120	66	55	45	36	28	21
75mm lens						
10	10	10	9	9	9	9
20	19	18	18	17	16	15
40	36	34	32	30	27	24
60	51	48	44	39	35	29
80	64	59	54	47	41	33
100	77	70	62	53	45	36
120	88	79	69	59	49	39
100mm lens						
10	10	10	10	10	9	9
20	19	19	19	18	18	17
40	37	36	35	33	32	29
60	54	52	50	46	43	38
80	70	67	63	57	52	45
100	85	80	74	67	60	50
120	99	93	85	75	66	55
150mm lens						
10	10	10	10	10	10	10
20	20	20	19	19	19	18
40	39	38	38	37	36	34
60	57	56	55	53	51	48
80	75	74	71	68	65	59
100	93	90	87	82	77	70
120	110	106	101	95	88	79

tance, for example, it will be 4X (2 stops) brighter than the main screen. Thus all such applications should strive to keep supplementary screen material close to the main screen.

As in rear projection, the eye is not an adequate instrument to determine color or lighting balance between foreground and background. Where the background is simply passing scenery, eye-balance may be sufficient. When the foreground is a continuation of the background, photographic tests should be made to ensure a good color and brightness match. Lens coatings, the ultraviolet cutoff of optical glass and the spectral sensitivity of color negative material are all influential in determining color balance of film. The color response of the human eye is significantly different from that of color film. The eye, therefore, is not an accurate predictor of the film's color rendition in this application.

Steps to Avoid Shadows and Halos

1. Align camera and projector lens front nodal points by placing targets of Scotchlite at the f/16 distance of Appendix 1. Place targets at left, center, and right of camera field. Tip targets until their brightness matches that of main screen. Stop down camera and projector. Position camera and projector for no shadow on any target. Camera is correctly located on nodal head when the camera is panned to place right target at left edge of camera field and no shadow appears.

2. Set camera lens to desired f-stop. Set projector lens to a smaller f-stop. Recheck for shadows at edge of targets. A non-uniform field of light into the projector lens will cause a shadow line as projector stop is changed.

3. Observe minimum object distance of Appendix l to avoid halo. Projector exit pupil should not be larger than camera entrance pupil. (Pupils are equal when the depth of field is the same for both lenses. Use lens tables.)

4. If using a zoom lens, line up shot at maximum focal length to be used in the shot, and then check for shadows at minimum focal length. If shadows appear, reduce zoom range or use proper nodal head that couples to zoom control.

5. If projected image is larger than camera field of view, background plate negative should be larger than camera negative, otherwise background will be grainy.

6. When using anamorphic camera lens, keep objects close to screen and co-locate a median point between the two front nodal points of the camera lens with nodal point median of the projector.

7. If camera is moved forward of normal nodal point location to make an extreme closeup, the object must be on camera center and have no inside edges (i.e., no space between arms and body).

8. Supplementary screen set forward of main screen should be kept very close to main screen to avoid a brightness change.

9. When background is a continuation of foreground, photographic tests are needed to assure a good color and brightness match.

Additional information on front projection and on Scotchlite front projection screens 7610 and 7615 high contrast sheeting is available from Safety and Security Systems Division/3M, 225-4N-14, St. Paul, Minnesota, 55144-1000, (612) 733-4433, (800) 328-7098.

Compositing

William Hansard
ASC Associate Member
President, Hansard Enterprises

Rear-Screen Projection

Rear-screen projection process essentially consists of filming live foreground action against a specially photographed background "plate" which is being rear-projected onto a translucent screen. The following items are required:

1. Special background projector with camera-type registration and 220 volt, 3-phase, AC sync motor.

2. Motion-picture camera with crystal-controlled motor with a camera/projector electronically phaseable shutter sync box.

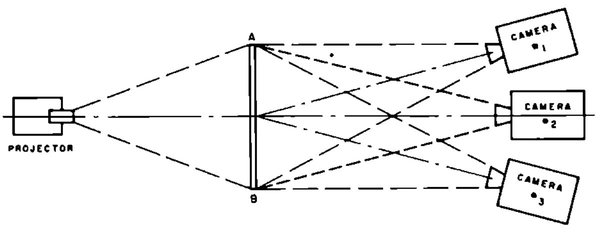
3. Specially prepared print on print stock with B & H perforations, made from plate negative filmed to production specification or from stock library plate material.

4. Translucent projection screen.

Process shots usually are filmed on a motion-picture stage or in a warehouse. Portable process projectors and screens can be rolled onto any set and employed to back up the action by furnishing the "view" seen through a window or door of a house, plane, train, automobile, etc.

Camera and projector are electrically locked so that their shutters open and close simultaneously. The projector does not have a "flicker blade" as in theater projectors, to interrupt the screened image and shorten the dark interval between frames.

Process projectors have camera-type shutters and movements so that the individual frames are in perfect sync with the camera's filming action. This results in a visual "flickering" picture but a photographically perfect image since each frame of film is projected for the entire interval the camera shutter is open and therefore provides maximum light exposure frame for frame. If the projected image is a stationary plate it must perfectly registered, because any unsteadiness would be readily discernible when filmed in combination with a fixed foreground set.



Camera and projector must be lined up so that the screen image is photographed with equal brilliance across its full width. Camera #2 will photograph screen "A-B" with even brilliance. Camera 1 will record the "B" side of the screen darker. Camera #3 will record the "A" side of the screen darker.

Traveling plates need not be critically registered since their movement will usually cover any inherent unsteadiness. A step printer (with camera-type registration) should be employed to print stationary plates. A continuous printer may be used for traveling plates. A center line is drawn on the stage floor so that camera and projector may be set up in line with each other. Generally speaking, camera and projector should be lined up, although the screen may be swung at a slight angle, if desired, to the foreground set. If the camera is not squarely on the projector center line, an unevenly illuminated screen image, with one side darker, will result. However, you do have the liberty of getting off center line approximately five degrees on each side with a Hi-Trans screen and 45 degrees with a Lumiflex screen.

There is absolutely no substitute for experience in photographing process scenes. They cannot be done "by the book" — too many technical and artistic factors are involved. It is up to the director of photography, along with the process coordinator, to base decisions on previous experience, inherent skill and basic knowledge of the many variables in each setup.

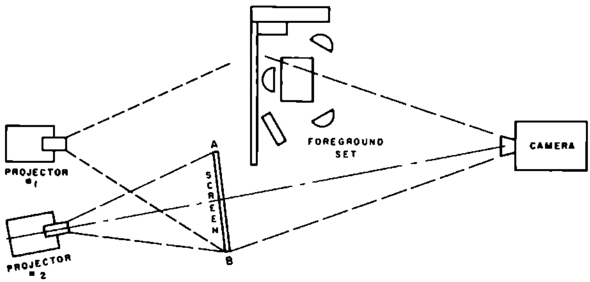
One basic problem is balancing the light on the screen with the foreground illumination. The angle, shadow effects and light quality of the illumination on the live set must match the projected plate to form an acceptable overall picture. Care must to taken to keep all light illuminating the foreground set off the background screen or it will wash out the projected picture.

Screen brightness will vary with the plate in use. Measuring is a matter of balancing by eye, preferably with a monotone viewing filter and an out-of-phase sync box for direct viewing through the camera (to achieve perfect balance while the camera is running without film). The screen is illuminated only half the time, while the foreground set is constantly illuminated. The screen image is projected with a carbon arc light, which requires a daylight film index for black & white films, and the foreground is lit by tungsten lamps. "YellowFlame" carbons are used for projecting color plates so that their color temperature matches the tungsten-illuminated foreground set.

The camera should be positioned at an elevation relative to that employed by the camera used to filmed the original plate. The floor of the set should be regarded as the camera floor — do not use the stage floor if the set is built higher on a false floor. Preserving the relationship between foreground and background is of paramount importance — elements must appear to have been photographed together. Best results are achieved only when camera angles and lighting are matched to preserve perspective, space relationship, convergence of lines and photographic tonal values.

On stage, short focus lenses should be avoided. The closer the camera is to the process screen, the more brilliant the center of the screen, causing what is known as a hotspot.

Longer focal length lenses on both camera and projector will produce the best results. A 5-inch projection lens and a 2-inch camera lens is a popular combination. A 40mm lens should be the shortest employed on the camera if the full screen is being filmed. A wide-angle lens may be used on a large set where the process screen is only partially used, or when a relatively small projected image is used for a view through a window or door. Care should be taken to keep the camera and projector lined up when filming a partial screen image on one side of a live set. The foreground set and the players should be positioned as close to the screen as possible, so that the projected picture is photographed as sharp as the available depth of field permits.



Camera and projector must be lined up when the camera is panned from a screen image on one side of a live set to the action on the opposite side. Projector #2 is correctly positioned. Projector #1 would result in a darker image on the "B" side of the screen.

Another advantage in working with the action close to the screen is that it requires a smaller projected picture. The result is greater image compression, lending colors richness and brilliance. On moving background shots, such as a rocking boat, rocking the camera slightly aids the illusion of motion. Such rocking must not be apparent, but give the appearance of integrated motion of foreground and background action.

Print density will depend on the subject matter. It is advisable to have two prints for 35mm and three prints for VistaVision. One copy should be of good, rich normal density with normal color, and the second copy should be ⅔ of a stop lighter in density.

Overall screen brightness can be controlled by varying the amperage on the projector arc, adjusting the projection lens diaphragm and by employing neutral-density

Handsard Background Projection Chart

Camera Lens		Picture size	Full Aperture Throw			Slide Projector		Camera & Proj. Total Distance		
2"	3"		5" Lens	6" Lens	7" Lens	4" x 5"	3" x 4"	35mm	V.V.	70mm
13½'	20'	4' x 6'	31'	37½'	45½'	20'	25'	65'	70'	91'
20½'	30½'	6' x 9'	47'	56'	65½'	30'	37½'	87'	90'	120'
27'	41'	9' x12'	62½'	75'	87½'	40'	50'	110'	140'	160'
41'	61'	12' x 18'	93½'	112½'	131'	60'	75'	165'	179'	184'
54½'	81½'	18' x 24'	125'	150'	175'	80'	100'	195'	229'	223'
82'	122'	24' x 36'								
For 3M front projection system, use above 2 columns for appropriate screen width throw.			The above five columns are from the nose of the projector to the screen. Add approx. 10 feet for projector working space. Note: The slide projector chart is for a 16" lens. 18", 20" and 24" also available.					The above three columns are total throw required for camera and projector.		

16mm Projector Distance: (2" lens 40" picture — 18') (2"lens 50" picture — 22')
35mm Slide Projector Distance: (5" lens 40" picture — 13') (5"lens 50" picture — 16')
VistaVision Distance: (9' x 12' — 80') (12' x 18' — 119') (18' x 24' — 159') (24' x 36' — 238')
70mm Projector Distance: (6' x 9' — 51') (9' x 12' — 69') (12'x18' — 103') (18'x24' — 138') (24'x36' — 206')

filters. Very little can be done to alter the tonal contrast inherent in an individual print.

A simple rule of thumb for calculating projection distances and focal length of projection lens for a particular screen size: the projector lens focal length multiplied by the screen width plus 10% equals the projection distance — give or take a few feet. Thus a 5-inch lens will fill a 20-ft. screen from approximately 110 feet away.

Static background scenes can be handled with greater economy by using a 4" X 5" stereopticon slide projector. Time is saved between takes since the film does not have to be rewound. Also, color slides may be used for black & white film photography; in fact they are often preferable because they present a less grainy image and better black & white separation. Rear projection slide projectors are usually equipped with arc lamps, although sometimes tungsten bulbs are employed for small screens. Specially prepared 3 ¼" X 4" or 4" X 5" slides are used. The emulsion is removed from the base and transferred onto Pyrex glass to eliminate burning or bleaching of the transparency; this also results in sharper focus and facilitates cooling of the transparency and glass mounts.

One final note: the professional result of any process scene is only as good as the background plates provided.

Photographing Miniatures

by Dennis Muren, ASC

The recent increase in the use of miniatures in motion pictures means that live-action cinematographers may now be called upon to photograph miniatures, an area usually handled by specialists. Today's pinpoint-sharp lenses, very fine-grain color negatives, and crystal-clear 70mm release prints can reveal flaws, and the solutions require the utmost attention to detail by every member of the effects team. The cinematographer should talk to the director, the live-action director of photography, and the effects crew. He or she should look at as much footage from the job as possible, especially immediately preceding and following the miniature shot. Based on this material, he should then visualize how the shot would have been photographed had it been built full-sized and apply that information to the following:

1. The notion that miniatures look big when photographed with wide-angle lenses from a low viewpoint is somewhat true. But when cut into a sequence filmed from above or with long lenses the shot may look out of place.

2. A small f-stop is usually necessary to hold the depth of field needed to keep the model in focus.

3. The entire model and set must appear to be in focus, as it probably would have been if the scene had been built full-size.

4. When shooting a fully miniature shot, a D-1 filter on the camera can give an artificial atmosphere which enhances the sense of reality.

5. Match the preceding and following live-action photography as closely as possible. Lighting units should be placed at the scaled distance from the model to duplicate natural light fall-off. Small units help the scale.

6. Artificial smoke can be used to slightly cloud the atmosphere in a miniature and give a realistic aerial haze. In instances where more control is needed, bridal veil material can be tightly stretched within a set and separately lit.

7. Panning, tilting, trucking, even jolts and shakes can add greatly to a shot if they are appropriate with that moment.

8. High-speed film stocks allow for extra stopping down. Perforation size and location can be checked on each roll to help insure rock-steady images, if necessary.

9. For high-speed shooting any rental cameras should be loaded and tested by the assistant who will use them. Registration steady tests should be made at the chosen speeds, if necessary.

Model Size

Water, fire, and exploding models should be as large as the budget and safety allows, even half-size if possible and shot high-speed. Intense wind can help break up out of scale water droplets and in some cases, fire. Exploding models should be pre-broken, reassembled, and exploded within slow-moving, low-powered, and colorful pyrotechnics preferably with two or more blasts. Other types of models can be built just big enough to be adequately detailed and still carry depth of field.

Miniature explosions and fire can be dangerous because the camera may need to be in close proximity to the miniature. Plan accordingly.

Shooting Speeds

If there is no motion on the miniature, it can be photographed at any speed. Water, fire, explosions, and falling effects are usually done with large models and camera speeds up to 360 fps. The exact speed depends upon the scale of the model and the effect desired. The accompanying chart is a starting point, but for the best results, tests should be made (page 423).

High-speed shots can often be expensive and unpredictable events because of the uncertainty of required camera speeds, pyrotechnics, winds, mechanical equipment, human error, and the need to sequence events in much faster succession than they will be viewed. If an explosion is photographed at four times normal speed (96 fps), then all other controllable actions within the shot must happen four times faster. Achieving an adequate level of good-looking lighting can be very difficult if shooting high-speed at a small f-stop. If using HMIs, make sure that there will be no flicker at the filming speeds. Scenes which are supposed to take place outdoors should be shoot outdoors if weather permits.

With stop-motion, shooting is accomplished at one frame at a time with the object being slightly moved by hand between each frame. One-fourth-second exposures or more per frame allow for great depth of field in low light levels. Stop-motion photography is used to give a freedom of movement and expression to an object or figure.

Motion-control photography is used when an object or figure is moved by computer-controlled motors at very slow speeds. Long exposure times per frame allow for very small f-stops. The computer can repeat the movements of the motors, which allows for multiple exposures. Any facet of a shot can be isolated and wedged for intensity, color, filtration, and atmosphere. The image can be built up through multiple exposures made from the chosen wedge frames, while the computer repeats the same motions each time.

Go-motion shooting is used when shooting animal or creature models. The major body parts are attached to rods which are moved by computer-controlled motors.

Miniatures: Camera speed, model speed, exposure factors vs. miniature scale

Scale: inches per foot	3	2	1½	1	¾	⅜	¼	⅛
fraction of full size	¼	⅙	⅛	1/12	1/16	1/32	1/48	1/96
Frames per second	48	59	68	84	96	136	166	235
Exposure factor	2x	2.5x	2.8x	3.5x	4x	5.7x	6.9x	9.8x
Exposure increase, lens T stops	1	1⅓	1½	1¾	2	2½	2¾	3⅓
Portrayed Speed miles per hour	Model Speed-Feet per second							
60	44	36	31.1	25.4	22	15.6	12.7	9
40	29.3	24	20.7	16.9	14.7	10.4	8.5	6
30	22	18	15.6	12.7	11	7.8	6.4	4.5
20	14.7	12	10.4	8.5	7.3	5.2	4.2	3
10	7.3	6	5.2	4.2	3.7	2.6	2.1	1.5
5	3.7	3	2.6	2.1	1.8	1.3	1.1	.7

Detail movements are animated by hand each frame. Single frame shooting allows for small f-stops at long exposure times. Coverage at various angles and camera speeds is especially useful to help cushion the risks on high-speed shots.

Calculating Camera Speed

Explanation of table (Page 424)

The scale of the model may be stated as "inches per foot" or as a fraction of full size. In photographing a miniature, portraying any motion when the speed of that motion depends on gravity, the frame rate of the camera is governed by the scale. This includes falling objects or water, wave action, fire or smoke, explosions in which objects are thrown into the air, etc. On the other hand, any object (for instance, an automobile) moving at a controllable speed can be related to the selected camera speed in the first instance (gravity), the camera frame rate is increased as the inverse square root of the scale fraction (the square root of the relation of full size to miniature). For instance, for a miniature ¹⁄₁₆ full size (¾"=1'), the inverse of the fraction is 16. The square root of 16 is 4 and the frame rate should be 4X normal = 96 fps.

In the same set, an automobile portrayed as traveling 60 miles per hour should move ¹⁄₁₆th that speed because of the scale, but increased 4 times because of the frame rate.

$$\frac{\text{(Scale fraction)} \times \text{(portrayed speed)} \times \text{(frame rate)}}{\text{(normal frame rate)}}$$

$$\tfrac{1}{16} \times 60 \times \tfrac{96}{24} = 15 \text{ mph (or 22 ft/sec)}$$

Motion-Control Cinematography

by Richard Edlund, ASC

Motion-control has become an inseparable part of film grammar. Inexpensive solid-state digital electronics, a technology born of the space race in the late '60s, made it possible to accurately record and play back motion with sufficient reliability to achieve the robotic camera systems necessary to produce the space sequences in *Star Wars*, the success of which brought on a renaissance of motion-picture visual effects. Since that time a majority of the top ten box office grossers have relied on motion control for crucial scenes. Prior to the advent of digital technology, the control of motion had been attempted with various degrees of success by using analog electronics, selsyn motors and gears, even by hand-cranking mechanisms using a metronome for synchronization!

To define it, motion control is an electronically controlled mechanical system that allows the physical motions of a camera and/or other objects to be recorded, enabling successive passes to be photographed "on the fly" with the corresponding motion blur characteristics of normal motion-picture cameras, so that composites can be created in an optical printer or digitally. The composites may comprise separately photographed actors, miniatures, backgrounds, and a myriad of other creative possibilities. Thus, traveling matte systems of varying kinds can be used, foregrounds and backgrounds of differing scales can be used with a moving camera, and when synchronized with video playback systems, actors can perform within impossible sets and locations, interacting with creatures and miniatures shot previously or subsequently. In practice, the production company will generally contract with a visual effects company to carry out specific shots and sequences that will require this equipment and these techniques.

Several companies have developed field recording units, hybrid systems which have various facilities, such as speed and distance of travel, tracking, panning, tilting, booming, follow-focus, remote operation, pre-programmability, ease of set-up, quietness of operation for sound, and adaptability to various formats such as 65mm, VistaVision, or 35mm. Such a company will assign a visual effects supervisor to work with the director, director of photography and other appropriate crew members to achieve the proper set-up time for any given plate. Of course there is responsibility implied to achieve a given plate within reasonable and predictable set-up time, and for this reason careful preproduction planning is necessary between the effects company and the U.P.M. When shooting actors within the principal production schedule, usually blue-screen photography is required and in these cases even the wardrobe should be discussed with the visual effects supervisor.

Motion-Control Equipment: Field

In the field (defined here as outside the walls of an effects studio, with the camera operating at sound speed) there are different requirements. The director will usually want a moving camera if he/she can have it, but this has been (and still is) difficult to achieve in effect shots. If this is to be done, the following equipment is required:

1. A steady camera, usually of a larger format than the production is originating with, with a special motor that is slavable to the motion-control electronics, and that will provide frame/shutter position accuracy in successive passes. Though not imperative, the camera should be silent, so dialogue can be recorded, and it should have a calibrated videotap viewfinder.

2. A reliable follow-focus system that is repeatable. Double-pass shots must exactly repeat with high resolution.

3. A pan-tilt head which by any of a variety of techniques can provide scaleable lens entrance-pupal positions for subsequent repeat passes on less than full-scale propers or miniatures. This pan-tilt head should have a remote operating console with hand-wheels and video monitor. Usually such a head will have DC servo motors to provide real-time normal to high-speed pan/tilt range.

4. A dolly with track, having a powerful tracking motor, motorized boom, and positional encoders for both axes which allow for either dolly grip control as in normal shots or remote operation or pre-programmed moves. The above equipment should be as standard as possible in appearance and operational characteristics, and operate on standard production dolly track.

5. A motion-control electronics console, operated by a suitably wizened technician who can efficiently log and store motion files, shot-by-shot, invisibly to the rest of the production.

6. A videotap flicker-free console, which will store shots on tape or laserdisc, as the shots are made, and play back instantly for directorial scrutiny. This system should be able to provide on-the-spot video composites for comparisons of A to B scene action, and the ability to playback A while recording B, etc. The video requirements will vary with the shot requirements.

7. A bookkeeping detail which will log actors' positions and distances, camera and track positions within the set, and other mathematical and geographical information.

Again, this should happen systematically and invisibly to the rest of the production. This is crucial to the creation of the rest of the jigsaw puzzle of elements that make up any given shot.

Motion Control Equipment: Studio

A versatile motion-control system for photographing miniatures consists of a steady pin-registered camera, built into a pan-tilt-roll head wherein the entrance pupil of the lens can be situated at the vertex of all axes, hung from a boom arm, all mounted on a track of at least 50 feet in length. Various model movers, rotators, or pylons are usually mounted on another track of 20 feet or so set perpendicular to the camera track. Again, there are many variations on this basic theme incorporating various levels of engineering prowess within the industry and the precision and reliability of such systems provide the operators with different levels of creative freedom.

An electronic system runs the motors (usually stepping motors unless considerable speed or power is needed, in which case DC closed-loop servo motors are used), then stores the motion files laid down by the operator and enables the operator to interact with the system. There are many bells and whistles which include move-smoothing programs, graphics tablets, and specialized software ad infinitum.

Studio motion-control equipment often has provisions to control the camera shutter angle over a wide range in order to control the apparent motion blur. The exposure range is from about ¼ second to extremely long. Most systems have several ways to program moves and any or all of the following methods may be used.

Joysticks (usually potentiometers or rotary optical shaft encoders) are used to manually move the motors that operate the various parts of the system. The joystick might control the speed or position of one or more motors at a time and all these motions are recorded for future playback. This is similar to remote controlling a model airplane or car and making an exact record of what happened.

The joystick might be used to move the system to a series of fixed positions while a record is made of these key positions. The system could later generate a mathematically smooth path through these points. This is similar to an animator drawing key frames and then creating all the in-betweens automatically.

If the system has a computer keyboard, then a move could be created using only start and end positions with ease-ins and ease-outs much like an animator's exposure sheet. Much more complex methods of move generation are available using computer graphics. The move files can be edited and modified in as many ways as there are motion-control systems. Some computer-control systems have graphics which allow the operator to preview the shot before the camera is used.

A number of commercial electronic motion-control systems are available, as well as mechanical systems. Some of the major visual effects studios build their own motion-control systems. Although the use of motion control in modern effects work is commonplace, the process can be expensive and time-consuming, but when properly approached, high-quality visual effects can be produced at budget and on time.

Motion Control Extends Cinematic Capabilities

Motion-control systems are used in many ways for visual effects. The following list is certainly not exhaustive:

1. The ability to program model shots so that the motion of objects in an effects scene is believable, and to preview these moves and modify them as needed for approval.
2. The ability to repeat these scenes for front-light/back-light or front-light/front-light matte passes if needed.
3. The ability to repeat these scenes for enhancement effects such as engine passes, running lights, smoke-room effects, filtration, etc.
4. Precision fly-by and extremely close approaches to objects can be accomplished smoothly and in perfect (programmable) focus.
5. Stop-motion animation can be included in scenes that have field-recorded moving camera.
6. Go-motion animation is made possible by using extremely complex mechanical systems with upwards of 50 motion-control channels to create impossible creatures in motion. This system was pioneered in *Dragonslayer*.
7. Mo-motion — a system wherein field recorded scenes with pan, tilt, track, boom are combined with par-

tially motorized rod puppets (controlled mostly by puppeteers). This technique was developed for *Alien*[3]. It also included a laserdisc video processing system capable of converting any filming rate, from 1 fps to 48 fps, back to 24 fps on the spot so scenes could be video-composited during the shooting day to enable interaction of a ⅓-scale Alien puppet with live actors in field-recorded scenes.

8. Optical printers can be equipped with motion control so that optical pans, tilts, zooms, fades, diffusion, wipes and dissolves can be repeated for successive passes.

9. Animation cameras can become much more versatile, since all axes can be programmed; objects, miniatures, etc. can even be shot against miniature blue screens; and front-light/backlight repeat passes can be accomplished.

Motion-Control Technique

When working on *Star Wars*, we started with an empty building and had to amass, modify and build our motion-control equipment before we could produce any images.

We had built up visual "violins" and had to learn to play them. Fortunately, the picture hit and a large audience showed up for our motion-control recitals. Since then, many innovations have come about in the equipment (which are not seen directly by the film-going public) and many good motion-control cinematographers have developed.

There are two main techniques for programming motion files: One is to use start and end positions for each axis of motion (there could be any number up to perhaps 16) and have the computer generate the moves. The other allows the cameraperson to generate the move by joystick. It is my opinion that the computer-generated method is superior for graphics and animation purposes, and the human interface is best for most miniature and model photography. If shots are created using a computer, the moves will have mathematically perfect curves, slow-ins, slow-outs, etc., and no heartbeat or verve — especially in action sequences — therefore becoming subliminally predictable and less interesting to the audience. Human operators do not produce this mathematical perfection; instead they tailor the camera move to what is interesting in their viewfinder. This human sense of curiosity is present in the work of a great operator, and this transfers to the audience.

Traveling Matte Composite Photography

by Petro Vlahos and Bill Taylor, ASC

In this type of composite photography, the compositing is done on an optical printer. Both the foreground and background scenes are printed onto a dupe negative. A silhouette (male) matte is employed to prevent the background scene from exposing the area occupied by the FG action. A cover (female) matte is used to protect the background scene from veiling when the FG action is printed onto the dupe negative (see figures 1-5).

There are two basic techniques for generating the matte: dual film, and single film. The dual film technique employs a dual film camera and beam splitter. A color negative records the action, and a black & white film records a matte (silhouette) of the action. The backing behind the actor requires special illumination which will expose the B & W matte film, but will not expose the separate color negative. Various illuminators have been used including Ultraviolet, Infrared, and Sodium.

The sodium system is by far the most-used dual film matte system. As originally used in England, it required a backing illuminated by monochromatic sodium light. Didymium glass filters were required on all set lamps to subtract the sodium wavelength from the foreground lighting. These filters caused a light loss of about two stops.

An improved sodium system initially introduced in 1959 employed a special beamsplitter and narrow band filter in the camera. It does not require filters on the set lamps and does not significantly affect exposure. This improved sodium system was used extensively at Disney Studios and is still used occasionally, as in the feature *Dick Tracy.*

The sodium system (or any dual film system) has the basic disadvantage of requiring separation between the backing and the actor. The actor must be kept well away from the backing so as not to be contaminated by sodium illumination. For this reason the actor (and his feet and his shadow) cannot get into and among the elements of the background scene. Set pieces may be photographed with the actor and matted into the background scene along with him, but it is very difficult to perfectly match (say) a foreground floor to a floor in the background without a test.

Development of dual film systems has not kept pace with improvements in the blue screen system, and beginning in the *Star Wars* era, the blue screen system became overwhelmingly the method of choice.

Blue Screen Process

The Color Difference Traveling Matte System is the most flexible of all compositing techniques. It can be used with any pin-registered camera, and with normal unfiltered set lighting lamps. The only special requirement is that one must paint the backing an appropriate blue. The blue-screen traveling matte technique prior to 1959 had as its trademark a blue halo following all moving objects (and frequently non-moving objects). The Color Difference system eliminates the blue halo and provides nearly all the advantages offered by other compositing systems but without their disadvantages or limitations.

The Color Difference Traveling Matte System properly mattes rapid motion, smoke, glassware, water, fine detail, and so forth. It also permits an actor in the FG to move in, among and behind objects in the background scene. Further, the actor's shadow can be caused to fall realistically upon the objects in the BG scene even when that scene is in reality a miniature. No other compositing technique offers this range of flexibility.

The theory of the Color Difference system is based on colorimetry, and is stated as follows: (1) Excepting the colors blue and magenta, all colors have a blue content that is equal to, or less than, their green content. (2) All the remaining colors except yellow and green have equal blue and green content.

When the blue and green content of a scene is equal, the blue and green B & W separations will be identical. Thus, there is no need to make a blue separation to reproduce such colors as reds, flesh tones, all shades of pink, white, gray, and all saturations of cyan. Since the blue and green separations (for these specific colors) are identical, one would simply use the green separation twice; once as the green printing separation, and once as the blue printing separation.

When this select group of colors appears in the foreground of a blue-screen shot, the green separation has one unique difference as compared to the blue separation. Whereas the blue screen area is essentially clear on the blue

Fig. 1. Action as filmed in front of plain (blue) backing.

Fig. 2. Female matte of action in Fig. 1; also called "matte master."

Fig. 3 Male matte of action on Fig. 1. (In practice, a print from film shown in Fig. 2.)

Fig. 4. Background scene to be combined with foreground action in Fig. 1.

Fig. 5. The final composite print; Fig. 1 plus Fig. 4, via Figs. 2 and 3.

separation, this area is quite dense (black) on the green separation. Because of this density, the blue screen reproduces as a black screen when the green separation is substituted for the blue separation. Very little cover (female) matte is needed because of the high density on the green separation in the blue backing area.

A cover matte density of 0.6 to 0.9 is generally sufficient when using an excellent blue screen such as the rear-illuminated Stewart T-matte blue. The problem with the blue separation is that it is essentially clear in the blue backing area and requires a very dense cover matte which rarely fits.

The green separation is an almost ideal replacement for the blue separation because of its high density (blackness) in the blue-screen area and because it has the correct density for all of the foreground colors except for yellow and green.

The green separation would be a perfect blue replacement if a way could be found to add a little extra density where green and yellow objects occur. The addition of this needed extra density for green and yellow is the function of the Color Difference matte. The Color Difference matte is otherwise a clear film except for a few spots of density where a yellow or green object existed.

The Color Difference matte is made by printing with blue light through a bi-pack consisting of the original negative and the green separation positive. The only areas that are simultaneously clear on both films are those areas that were green or yellow in the original scene.

When the Color Difference matte is laid over the green separation, and their combined densities are compared to the blue separation, they will be identical in all areas except the blue-screen area, which will be black instead of clear. Thus, the Color Difference matte together with the green separation area makes a perfect replacement for the blue separation. This "synthetic" blue separation is perfect because it has all the correct densities for foreground colors while remaining essentially black in the blue backing area.

The only limitation of the system as described is that it cannot reproduce colors in which blue content exceeds green content, e.g., blue and magenta. Desaturated blues (like blue jeans) reproduce acceptably.

When it is necessary to reproduce a saturated blue in the foreground, a green backing may be substituted for the blue one. While this is a common practice in video matting, it's harder to get a good result in film because the blue record (the grainiest of the three layers) must then be used twice. Good pure-green illuminators are not widely available.

Because all three separations (with blue being replaced with the synthetic blue) are essentially black in the blue-screen region there is no need to use high-contrast, high-density cover mattes. The mattes should be made on film stocks having essentially the same gamma as the B & W separations. The male matte should be transparent to the degree the subject was transparent and should be no denser than is necessary to just prevent print-through. Such semi-transparent mattes permit the reproduction of semi-transparent objects.

When it is practical to eliminate yellow and green from the foreground objects, it is possible to simply substitute the green separation for the blue separation and achieve the full flexibility of the Color Difference system.

When it is permissible to allow a reduction of saturation of yellow objects and a shift of green objects a little toward cyan, the blue separation can be made by a mixed blue/green exposure. The blue backing area will be quite dark. Actually, it is only one stop (about 0.3 density) below that of the green separation. The use of a slightly denser cover matte (increased about 0.3) is all that is needed to prevent veiling of the background. This mixed blue/green technique is a simplification and produces acceptable results when it is not necessary to reproduce saturated yellow or green.

Screen Types and Lighting: Back-lit screens

A perfect blue backing would expose only the blue-sensitive layer of the color negative. Crosstalk in the negative layers, imperfect illuminators, and spill light on the set all compromise this ideal. Nevertheless, thanks to the joint efforts of the visual effects community and film manufacturers, the best current combinations of screen illumination and negative type yield backings of unprecedented quality.

Either of two types of blue backings can be used in the blue-screen matte process. If the background scene is one into which the actor (or subject) will not enter, then a simple vertical blue surface is all that is needed for matting. An excellent blue backing for this purpose is the rear-illuminated Stewart T-matte blue screen.

The best illuminators available today are banks of narrow band fluorescent tubes driven by high-frequency (flickerless) electronic ballasts. These tubes can be filmed at any camera speed without frame-to-frame variation in illumination. The phosphors in these tubes are formulated to produce a sharply-cut blue light that will not expose the green sensitive layer of the 5248 and 5296 color negative to any harmful degree, and will not expose the red-sensitive layer at all. These nearly-perfect blue illuminators allow the use of the thinnest possible cover matte for best results in reproducing smoke, transparencies, blowing hair, reflections, et cetera.

Manufacturers of these special purpose tubes and fixtures include the originator, Jonathan Erland, at Composite Components Co. in Los Angeles, who can also supply fabric and paint. Lightweight fixtures and high frequency ballasts are available for rent from Kinoflo in Sun Valley, California. Ballasts made by these companies can be dimmed; a great convenience in adjusting screen brightness. The only drawback of these setups is cost.

Fair results (at much less expense) can be achieved with commercial daylight-blue fluorescent tubes wrapped with deep blue Rosco or other manufacturers' filter sheets. The combination of the Stewart screen and the filters eliminate most of the green light from the tubes. Although commercial blue-print tubes have also been used, this is not recommended because of their very high UV output.

Regular 60-cycle ballasts can be used with any of these tubes at the cost of weight and power efficiency. The drawback is that 24 fps filming must be crystal-controlled to avoid flicker, and any high-speed work must be at crystal-controlled multiples of 30 fps. These tubes are somewhat forgiving of off-speed filming because of the slight "lag" of the phosphors.

In the past, Stewart translucent screens have been lit by large banks of Par reflector floods. Since incandescent lamps are a very inefficient source of blue light, the fluorescent system has made this method obsolete.

Front-lit Screens

The principal advantage of the rear-illuminated screen is the instant uniform illumination obtained at the flip of a switch. Unfortunately, few studios have permanent facilities for large back-lit screens. A front-illuminated blue-painted surface is also acceptable for traveling matte photography. It has the advantage of availability. Any smooth surface that can be painted, including flats, a canvas backing, and so forth, can be used as the blue backing.

An increasingly popular illuminator for front-lit screens are arrays of the special-purpose blue fluorescents described above. The broad, soft-light nature of fluorescents makes it relatively easy to illuminate screens of 100 feet or more in width. More care must be taken to eliminate spill illumination on front-lit screens. With care, front-lit screens can produce a result every bit as good as back-lit scenes.

Blue screens can also be front-lit with blue-filtered HMI or Carbon Arc Lamps. Getting even illumination with these sources is a time-consuming challenge, and filters must be carefully watched for fading. Photographic results are good to fair. Least desirable by a large margin (for film purposes) is a blue surface front-illuminated with white light. White light, however, is essential when the actor and his shadow must appear to enter into the background scene.

Blue Floor Shooting

If the actor is to get into and walk about in the background scene, then the floor must also be painted blue. The same type of (white) light and lighting fixtures that light the actor (subject) are also used to light the blue floor and backing. A shadow cast on a blue-painted wall or floor by the subject can be transferred (when desired) into the background scene together with the subject.

Floor shooting is the most difficult kind of traveling matte shot to light. It is also the most rewarding because it permits the actor to walk or sit upon objects in the background as well as to enter or exit doorways, even when the background scene is a miniature. When the actor's shadow is made to fall upon the ground or other surfaces in the background scene, the composite scene is readily accepted as real.

Matte contrast must be high in a floor shot to achieve separation from the contaminated blue of the floor. The problem is often compounded by glare from back lighting. Cover mattes must be heavy, and will take on a "cut-out" appearance unless measures are taken to soften the edge.

Necessarily, reproduction of fine edge detail will suffer. An acceptable compromise between edge softness and detail is sometimes impossible. When it is possible to reproduce the actors' shadows, the shadows are often unacceptably grainy. Industrial Light & Magic's tiny "brownies" in *Willow* are the most successful white-light blue-floor composites to date, partly because the costume color was controlled to stay on the warm side of the spectrum. Even so, their shadows had to be entirely hand-animated. The finest-quality blue-floor shots are yet to come, from electronic compositing (see below).

Front-lit Blue Screen Materials

Composite Components and the Dazian Company supply a useful screen material in blue or green; the fabric is slightly stretchy and has a fuzzy surface that helps to kill reflections of foreground lights. It is not the preferred choice for a white-lit floor. An acceptable blue paint is the 5720 Ultimatte Blue from Rosco Laboratories.

A new backing material is the Stewart-Ultimatte Blue Screen designed for front illumination. It is a plastic sheet material that can be rolled or stretched on a frame. It is tough enough to walk on and is washable. This material is slightly photographically superior to any of the paints for matting. It is available in sizes up to 40' x 90'. Since this material is quite expensive, it is best used for floors where its scuff-resistance is most valuable. The material may be used with walls and backings painted with high quality blue paint.

Front-Projected Blue Backings

Blue backings of almost unlimited size may be front-projected onto Scotchlite material using a beamsplitter and a special blue illuminator. A refined system of this type is the Apogee Blue Max projector, now owned and operated by Sony Studios. An ingenious extension of this system, known as Reverse Front Projection, can create a blue backing that will not reflect in even the shiniest foreground objects. Space helmets and completely silvered props were matted using this system in *2010* and other films. These systems are described elsewhere in this book.

Light Level for the Stewart T-matte Blue Translucent Screen

A paper gray scale and a Wratten 47 blue filter may be used to set the light level on the translucent Stewart T-matte screen. When the paper gray scale is in the position of the actor and illuminated for normal exposure *at the desired f-stop,* the blue backing illumination should be adjusted when the gray scale and screen are viewed simultaneously through the 47 blue filter. The illumination is proper and sufficiently uniform when it falls within the range defined by white and the first step below white on the gray scale.

Note that the blue screen negative density should be the same at all f-stops. A spot meter may be calibrated for use with the appropriate blue filter to read f-stops directly.

Lighting a Front-Illuminated Backing

Backings illuminated separately from the subject, such as those lit by blue fluorescent lamps, may be balanced by the same procedure as the translucent screens above.

If one is using a relatively efficient blue surface lit with white light, such as the Stewart-Ultimatte Front-Lit blue screen mentioned earlier, the proper incident light level on the backing is the same as that illuminating the subject. Thus, whatever value is used to light the actor's face is also the correct value for the backing.

Lighting Procedure for Holding the Shadow

1. Turn on the key light so as to cast the desired shadow.

2. Adjust the fill light in the shadow to achieve the desired shadow density.

3. Measure the brightness on the floor just outside the shadow (use a spot brightness meter and blue filter).

4. Light all the rest of the blue floor to this measured brightness. while adding as little light as possible to the shadow area.

5. Light the blue walls to achieve the same brightness as the floor.

6. Reduce fill in the shadow, if necessary, to retain shadow density. Shadow density is controlled by adjusting the fill light, not by adjusting the keylight.

Outside the shadow, the entire blue set should appear to have equal and uniform intensity as seen from the camera position.

Since the human eye has a fast automatic iris for small light changes, it is not a good measuring device. It is necessary to use a spot brightness meter and blue filter to check for uniform brightness. A Polaroid camera with black & white film and a blue filter is also useful for making a quick check of lighting uniformity. Because of the relatively flat angle between the camera and floor, the floor will not appear to be as blue as the back wall. A diffused, polarized white light component is reflected by the floor because of the flat angle. For holding good shadows it is essential to use a polarizing filter over the camera lens. The HN38 is recommended. Rotate the filter until the floor glare is canceled.

Lighting to Eliminate the Shadow

1. Light the entire blue set uniformly with large area diffused light sources.

2. Check uniformity as noted in the preceding paragraph.

3. Place the actor in position. If he casts a shadow, add additional low-level lighting to return the light level in the shadow to its original level.

4. Add a modest key light to create desired modeling, and ignore the shadow it casts. The added key light will cause a shadow to be visible to the eye, but because the key light did not reduce the blue intensity of the floor (in the shadow it has created), the shadow can be made to drop-out in the matting process.

Lighting to Match the Background

There is more to lighting a convincing composite than simply matching the direction and color of the lights on the background. It is not immediately obvious, but for practical purposes, a person on a blue stage is (from a lighting standpoint) standing on and/or in front of black velvet. Since the matting process drops out the blue backing and the blue kick from the edges of the FG object, the object may as well have been in a black stage. This blackness causes no problem if the background scene is a night scene that is essentially dark.

However, if the background is to be a light day scene, then if the person had really been in that day environment, that environment would have provided back and edge light well as reflected light to light up the hair and to provide the normal edge brightness along arms, sides of the face, etc. The cinematographer must back- and side-light the subject to provide about the same amount and direction of lighting the environment would have provided. If this is not done, edges of arms and legs and faces go dark and the scene looks like a cutout.

Inappropriate lighting will compromise a shot the instant it comes on the screen, while faulty compositing technique may be noticeable only to experts.

Other Lighting Considerations

Blue illumination and blue reflections from the screen on the subject must be minimized for top-quality results. It should be noted that *illumination* and *reflection* are separate issues!

Blue illumination from the screen can be made negligible by moving the actors away from the screen (at least 15', 25' is better) and by masking off all the screen area that is not actually needed behind the actors. (The rest of the frame can be filled in with window mattes in compositing.)

Reflections can be controlled by reducing the screen size or disguised with dulling spray, but sometimes cannot be eliminated. In the worst case, reflections make "holes" in the matte which must be filled in with hand work in compositing. Of course when the actor must stand in the middle of a blue-painted set, some blue contamination is unavoidable.

Using the UltiMatte Video Previewer

UltiMatte is a video matting device that can provide a preview of the final composite scene on a color monitor prior to and during photography. The UltiMatte eliminates much of the guesswork and uncertainty in photographing complex scenes in which the actor must be realistically integrated among people and objects in the background scene. Prior to UltiMatte, complex blue-screen shooting was slow, difficult, and often unsuccessful.

A small color video camera is used to observe the scene to be photographed. A videocassette player is used to provide a background scene. if the background scene is unavailable, UltiMatte generates a test scene. The UltiMatte accepts and mattes both scenes to show the composite on a color monitor. The UltiMatte generates electronic male and female mattes which are the equivalent of the mattes generated by the Color Difference Blue Screen Process. What one sees on the monitor correlates quite well with the subsequent film composite.

The UltiMatte Previewer does the following:

1. It observes the blue backing and indicates visually any areas that are under-illuminated. This reduces lighting to a fraction of the normal time.

2. It displays the male matte and determines whether

or not the subject can be matted. It shows exactly where a dulling spray or a change of angle of a set piece is needed.

3. It displays the fully matted picture and indicates what lighting adjustments may be needed to successfully hold or eliminate a shadow.

4. It permits exact positioning of set pieces to match positions of objects in the background scene.

5. It permits all the problems on the set to be detected and corrected before shooting. This is a prerequisite to getting a good matting job from the lab. After the quality of the foreground image is ascertained through the UltiMatte previewer, a motion picture camera replaces the video camera and the process continues in the conventional manner.

Laboratory Procedures for Compositing

The Color Difference Blue Screen Traveling Matte System permits a high level of realism. To maintain this realism in such items as smoke, glassware, fine detail, and so forth, special care must be exercised in selecting the density and gamma of the separations and mattes. All separations (and certain mattes) are to be made on a black & white panchromatic film stock at a nominal gamma of 1.0. (with all printing factors, such as the "Callier Q Effect," taken into account). The Eastman 5235 film is suitable. Each positive separation of a gray scale, when superimposed over the color negative, should result in a constant density-sum for all steps on the scale. Furthermore all the steps on the gray scale must lie on the straight line portion of the D-Log E curve for each layer of the color negative and for all three separation positives.

Upon examining the red separation positive (Red+) it will be seen that the film is quite dark in the blue-screen region. The Red needs very little additional density to fully protect the dupe negative. Depending upon the red contamination in the blue backing, a cover matte adding as little as 0.3 to 0.6 density may be adequate to prevent red veiling.

The green separation will be less dense in the blue backing region and will require additional density to protect the dupe negative from veiling. The fact that as much as 0.9 additional density may be needed indicates a substantial green leakage. If the added density is obtained on a separate piece of film having density of 0.9, this low-density female cover matte may be under-sized, resulting in a greenish edge that may be visible against the background.

If the additional density is added as additional exposure before developing the green printing separation, normal edge growth is achieved and no green fringe occurs. The female matte should have a gamma of 1.0. It may be made directly or printed from a male matte.

The green cover matte is generally too dense to use for printing the red separation. If the same cover matte is used for this purpose, transparent objects and the blurred edge of moving objects will have a cyan tint. The density difference between a white object and the blue backing (with cover matte) should be the same for both separations.

The gamma of the color difference matte must be arrived at by experiment to match the contrast of the separation positives. A gamma of 1.0 is a good starting place. The color difference matte can exist as a separate film, or be combined with one of the other films.

The male matte should be just dense enough in the subject area to avoid print-through, while being relatively clear in the blue backing region to permit printing in the BG scene. Depending on the nature of the two scenes and the lack of purity in the blue backing, it may be necessary to increase the gamma of the male matte to as high as 1.5 to 2.0 to obtain enough density to avoid print-through.

The gamma of the male matte should not be increased more than is necessary to prevent print-through because excessive gamma causes noise in shadow areas, a loss of fine detail, and a loss of transparency range.

The following table lists alternative methods that may be used to produce the various mattes and printing records. Choices are determined in part by the colors in the FG scene.

Current Film Stocks are:

Color Negative:	Eastman EXR 5248 & 5296
B&W Separations:	Eastman Panachromatic Separation Film 5235
Matte Films:	Eastman Panachromatic Separation Film 5235 & S0202 developed to high gamma or Eastman High Contrast Panachromatic Film 5369 developed to a low gamma.
Color Dupe Negative:	Eastman Color Intermediate 5244

Product	Printing Light	Film Source	Raw Stock & Gamma	Comment
1. Red Sep. Pos.	R	Color Neg.	B&W 1.0	Normal B&W separations on straight line portion of H&D curve.
2. Gr. Sep. Pos.	G	Color Neg.	B&W 1.0	
3. Bl: Sep. Pos.	B	Color Neg.	B&W 1.0	
4. Color Diff. Matte	Blue	Color Neg. & Gr. Pos. Bipack		
5. Male Matte	Blue ½ exp.Wht. ½ exp.Wht.	Color Neg. Red Sep. Pos. Gr. Sep. Pos.	B&W 1.5	Except for shadows, blue backing area to remain. Suitable for all colors of wardrobe. (exposures are clearsequential).
6. Male Matte	Blue White	Color Neg. Red Sep. Pos.	B&W 1.5	Not adequate for cyan colors (sequential exposure).
7. Male Matte	Blue White	Color Neg. Gr. Sep. Pos.	B&W 1.5	Not adequate for magenta colors (sequential exposure).
8. Male Matte	White	A female matte	B&W 1.5	Female must have full grey-scale density-range.
9. Female Matte	White	A male matte	B&W 1.5	
10. Female Matte	½ exp. Red ½ exp.Gr.	Color Neg. & Blue Pos. Bipack Color Neg. & Blue Pos. Bipack	B&W 1.5	Suitable for all colors. Must retain full grey scale if used to generate male matte. Two low-density mattes are required when printing Red & Green FG subject.
11. Female Matte	Red	Color Neg. & Blue Pos. Bipack	B&W 1.5	Not adequate for cyan colors.
12. Female Matte	Green	Color Neg. & Blue Pos. Bipack	B&W 1.5	Not adequate for magenta colors.

The "Comment" column indicates which mattes are acceptable for various colors.

Electronic and Digital Compositing

Because Ultimatte video composites are much more forgiving of contaminated backings, it was a natural progression to adapt Ultimatte matting logic to create film composites by both analog and digital means.

The Sony high-definition cameras, together with the 30 Mhz. high-definition Ultimatte-6, have produced some scenes for theatrical motion pictures in Japan and Italy. More recently, Sony Hi-Definition Facilities, Inc. in Culver City, California has offered a film-to-film service using the same high definition video equipment. Feature films using this compositing process are in production.

Already the line between optical effects companies, computer graphics companies and video post houses has begun to blur as digital film composites become widely available from these sources.

Most visual effects companies, such as ILM and Boss Film have developed proprietary systems. Computer Graphics creators such as the pioneering Digital Film Company and Pacific Data Images provide digital composites along with their other services. Composite Image Systems in Hollywood offers their "D.O.T" process, another 1000+ line, film-to-film system. There are certainly many more to follow.

At this writing, a most advanced digital film-to-film system is being demonstrated as a pilot project of the Eastman Kodak Company. Their Cineon system can create digital dupe negatives indistinguishable from the original on the screen. Ultimatte Compositing technology is employed in their work stations at Kodak's Cinesite, which offers a 4000 line ultra high-resolution film-to-film scanning, printing, and compositing service. Effects teams for several feature films, including *Super Mario Brothers*, have used Cinesite services.

Ultimatte Digital Compositing, which now includes screen correction, represents a major advance in image compositing. Ultimatte Cinefusion compositing software is available for several computer platforms.

Digital compositing greatly expands the scope and application of blue-screen photography. White-lit screens are much less of a problem. Ultimatte Screen correction, at the touch of a button, provides instant lighting uniformity on walls and floor having non-uniform illumination and varying shades of blue.

Particularly exciting is the prospect of shooting front-lit blue screen composites outdoors in natural light; it's relatively easy to get good results in the electronic realm, but nearly impossible with present purely photo-mechanical methods.

With all that said, even in this digital age, we should not forget that first-class composites can still be made on inexpensive, widely available optical printers. In Jonathan Erland's phrase, optical printing is "parallel processing at the speed of light!"

Black & White Self-Matting Process

The Stewart T-matte translucent blue backing provides a blue of sufficient purity to make possible a self-matting process. The subject is illuminated with yellow light and is photographed on Eastman 5248 color negative, or a color reversal film. When the negative is used, a color print is made. (The yellow filter should pass no blue light in the 400 to 500 nanometer range.)

The color positive is printed to a B & W dupe negative using yellow light. The blue field on the print is its own cover matte, and no exposure occurs in the blue field area. Next, the color positive is used as a male matte through which the B & W background scene is printed on the same dupe negative with blue light. The color print prevents exposure in the subject area by blue light.

In this system, no other separations or mattes are required. The process holds smoke, glassware and hair detail. It is not an important system in an era when almost all films are made in color.

The Future for Traveling Matte Composite Photography

by Jonathan Erland, FSMPTE
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The 1977 release of *Star Wars* precipitated a new era of visual-effects wizardry that continues to the present. In fact, with the advent of digital film scanning, electronic image manipulation and computer-generated imagery

(CGI) added to the still-growing wealth of evolving photochemical and in-camera compositing technique, the art and craft of cinematography finds itself in possession of unprecedented power over the moving image. Implicit in this newly acquired capability is a requirement for an increased awareness and sensitivity to the new and evolving technology on the part of all the craftspeople involved in cinematography. Composite cinematography should be preceded by careful analysis of both the method and the material most appropriate to achieve the desired result.

Film Stock

Improvements in film stocks are now occurring with such rapidity as to preclude the prior practice of providing comparative data in this manual. Instead, guidelines for use in selecting and testing appropriate stocks for composite photography will be discussed.

The importance of color difference matting in composite photography has now been sufficiently well established that all manufacturers have made efforts to achieve the requisite chromatic discretion in their product. Recent years have seen the advent of a major breakthrough in film stock construction. This is attributed to the development of tabular-shaped silver halide crystals, commonly called "T" grain, in which the crystal is as little as one-tenth as thick as it is wide. The goal of the new crystal design is to provide a relatively larger target for a given mass of crystal. This has two effects: one, the speed versus grain ratio is increased, producing a finer grain image for a given speed; two, the various layers that make up the total emulsion are relatively thinner, providing for less light scattering within the emulsion and producing a clearer, sharper image (greater accutance).

The new grain structure is a substantial improvement, and still better performance is promised for the future. However, cinematographers intending to produce composite photography must be aware that such enhanced performance is accompanied by increased susceptibility to instability; the very high-speed film stocks are sensitive to physical stress. Certain types of camera movements disrupt the silver-halide crystals within the emulsion, causing uneven exposure of one or more color records. In tungsten stocks, this is usually the blue (and fastest) record. In normal conventional production, the effect is usually so subtle as to be inconsequential. However, in the far more critical realm of composite photography, such effects can be very serious. Thus it is ever more important to test both the film stock and the camera prior to embarking on any composite cinematography.

Split-screen composites are particularly susceptible to high-speed emulsion stress syndrome, as the two (or more) elements will be acquired from different takes. Since the effect is erratic, the result is to reveal the split. In blue screen composites, the effect can cause the mattes (usually derived from the blue record) to beat (fluctuate) from subtle size changes.

Therefore, film stocks and cameras under consideration for the production should be subjected to a simple test. Expose the candidate film stock in the camera of choice so that a uniformly illuminated 18 percent grey card fills the frame. Include a slate in the field to record pertinent data. Make two successive takes. In take one, allow the camera to run normally for several seconds. In take two, allow the camera to come to speed and then intermittently interfere with the feed pulley of the magazine by pinching the pulley with the fingers. This action has the effect of sending a shock wave through the film as it passes through the camera, exacerbating any tendency on the part of either the film stock or the camera to emulsion stress syndrome. On projection, the print may exhibit density and colorimetry changes corresponding to the interference applied to the magazine. If the print does exhibit such changes, it is probably the result of emulsion stress.

What is occurring is a transient disorientation of the silver-halide crystals due to their uniquely thin and flat structure. The consequence is a piezoelectric effect in which electrons are momentarily dislocated. This temporary phenomenon affects the relative speed of the emulsion, which translates into the characteristic fluctuations in image density. The degree of fluctuation observed will indicate the magnitude of risk. If fluctuations are observed in the initial and unstressed take, the stock should be absolutely avoided. If needed, a careful analysis can be made by having black & white color separation positives made from the negative on a high-contrast stock such as Eastman 5269. This test will more readily reveal the degree of density fluctuation in the separate color records of the stock. Alternatively, the negative may be run on a telecine, permitting any fluctuations to be observed on a waveform monitor.

Remember that the stress syndrome is a function of both the stock and the camera, so that a change of either may rectify the problem. In some cases the necessary camera modification is quite simple. For example, the modification for the Mitchell Standard is the substitution of a large diameter (.700") first idler roller for the stock (.366") roller.

The camera must also be rigorously tested for steadiness of the movement and should preferably have provision for the inclusion of a film clip in the viewfinder system to facilitate the lineup of the other elements of the composite photography.

Colorimetry tests should now be conducted which will determine the suitability for the color difference traveling-matte technique. For these tests, the frame should consist of a blue field of the type anticipated in production (a discussion of various types of backing follows). Also included in the frame should be an 18 percent grey card, as well as a black void. The black void is created by lining a box, tin can or other vessel with black velvet and displaying it to the camera in such a way that no light falls on the interior, the object being to provide an area on the negative in which no exposure has occurred.

This particular test is useful in revealing any tendency of the lens to "veil" blue light across non-blue areas of the image, and also to indicate the presence of excessive ultraviolet radiation scattering in the lens and camera body. While the ultraviolet can be blocked with a filter (such as a Wratten 2E), nothing much can be done about a lens that is veiling blue, and in such a case an alternative lens should be selected. If possible, the frame should also contain a pure blue reference. For the test only, both the blue backing field and the gray card should be illuminated equally when read by a spotmeter. A wedge should be shot extending two stops above and three stops below nominal at half-stop increments.

The developed negative should be read on a color densitometer, preferably in consultation with the technician responsible for the compositing process. For simplicity, the densitometer can be nulled to zero on a clear, unexposed portion of the negative. This permits subsequent readings to produce values for each record above D min. For a photochemical composite process, the candidate film stock should exhibit a high degree of color discretion. (For an electronic composite process different criteria apply, and these will be discussed separately). Sample readings from an actual desirable film stock are: Red .02, Green .16, and Blue 1.20. This yields a Blue/Green difference of 1.04 density units. Sample readings from a less-than-desirable film stock are: Red .04, Green .44, and Blue 1.24., yielding a Blue/Green difference of .80 density units.

As is observed in Petro Vlahos' tutorial on blue screen, the degree of green density in the blue-screen area will determine the density of the cover matte, which in turn determines the quality of the final composite. Thus the low green reading of the first example is very desirable compared to the considerably higher reading of the second example.

If the wedge reveals that a desired balance between a low green density and a sufficient blue density results in an underexposed gray card, then an adjustment to the luminance of the blue backing is called for. In practice, this frequently results in a blue backing luminance about one stop lower than the foreground illumination. Some optical camera operators prefer a slightly overexposed foreground scene, which can increase still further the spread between foreground and blue backing. On the other hand, other operators prefer a higher backing luminance. Moreover, the luminance of the background plate will influence the selection of backing luminance values, with high-luminance plates (i.e., bald sky) requiring higher luminance backings and night scenes calling for lower backing levels. The lesson here is to consult with the operator at the earliest possible opportunity.

While the catalogue of techniques for enhancing the results of blue screen process is too extensive to explore in this tutorial, there are two relatively simple tactics that can make a significant difference. The first procedure is to rerate the film stock to half its normal rated speed, thus overexposing it by one stop, and then compensate for this overexposure by instructing the lab to pull process one stop, thus reducing the development. This maneuver results in a normally exposed negative but with a noticeable reduction in graininess and improved resolution. The second procedure is to select a fine-grain daylight-balanced stock for the blue screen photography. This requires either lighting with HMI or filtering tungsten light appropriately. The main reason this is effective is that the blue screen process makes use of the blue record of the negative to derive mattes; and while this is a fast, relatively coarse-grain record in a tungsten-balanced stock, it is a very fine-grained record in a daylight-balanced stock. The tradeoff for both of these maneuvers is the relatively extravagant use of light.

Video and Electronic Scanning

The criteria for backing exposures for telecine transfer and electronic scanning intended for computer image manipulation can differ quite significantly from photochemical requirements. In general, a negative properly exposed for film compositing will have a blue luminance level at, or above, the upper limit for optimum video matting. A sophisticated video matting system such as the Ultimatte is capable of producing a matte from as little as 40 I.R.E. video units, which would occur at about four stops lower backing luminance than for a film blue screen composite. Video "clipping" occurs at about 100 I.R.E. video units. Thus, with a high-luminance blue backing, the blue level will reach clip and cannot increase further, while the inevitable green density may continue to rise, reducing the degree of separation between green and blue. Moreover, excessive luminance of the backing threatens the image detail at the matte edge, which will detract from the quality of the composite. A target, then, is a point within the capability of both the optical and video processes, and this occurs at the 1.20 density units above D min. in the blue record. Below this point, film compositing becomes difficult, while above it, video matting suffers.

Ultimatte "Screen Correction"

Video matting from film via the Ultimatte can also avail itself of the screen-correction feature. To use this attribute, a take should be prepared of the blue-screen scene exactly as it will be shot for the production, with a locked-off camera but without any of the live action. If the scene requires camera moves, a motion-control system should be provided for the camera, and the calibration take run with the motion-control program for each shot. No further changes should be made to such motion-control programs unless another calibration take is also made.

In the postproduction compositing process, the calibration take will be used to "map" the blue-screen area and correct for any deficiencies. Thereafter, actual production takes will use this information as a reference and correct the deficiencies for all subsequent takes. The main advantage of this procedure is to lessen the burden on the stage crew in providing effective matting backings, thus speeding setups and reducing costs. Permitting this technology to become a panacea, however, entails risk; if the Ultimatte is unavailable or the calibration take is unusable for any reason, it will then be difficult to fall back on more conventional techniques. The result will be very costly and time-consuming to overcome. It's a good idea to make screen-correction calibration takes while also making every reasonable effort to provide a functional blue screen in the original photography, relying on the screen correction only as an insurance policy.

Electronic Scanned Film for Feature-Quality Composites

As this edition of the manual goes to press, a variety of digital electronic film scanning systems are making their appearance in the feature film industry. The Eastman Kodak facility, Cinesite, is one. Others include: Computer Film Co. (London and Los Angeles); Component Video, (Los Angeles); Pacific Title, (Los Angeles); Pacific Data Images, (Los Angeles); Video Image, (Los Angeles) and Sony High-Definition Facilities, (Los Angeles). Various other facilities are providing work stations for digital image manipulation. As with photochemical and video matting technique, these new systems have their own optimal performance parameters.

While it is theoretically true that digital electronic matting can be performed on any color coordinates, the safer practice is to select one of the three primary colors. The main determinant in selecting the backing color will be the color content of the foreground scene. However, other issues to be considered are: the matting performance of the particular film stock, the software program on which the composite will be performed and the circumstances in which the matte will be acquired. In the latter case, a variety of new options will become available to the cinematographer. Green backings, for example, can be provided for effective daylight exterior traveling mattes more readily than can blue.

Ultimatte composites including the "screen correction" feature are also available on workstations that have licensed the process. Feature-film productions intending to use this method of compositing should observe the guidelines for preparing for video matting via Ultimatte, and the lower backing luminance values generally apply.

It is always wise to shoot a wedge test, if the opportunity exists. Such tests should include foreground detail similar to the actual shoot. Thus costume materials and colors, as well as props, should be included where possible. Stand-ins for principal players with similar hair and other characteristics are helpful. The foreground should be properly exposed so that an 18% gray card will yield proper LAD #'s. (Laboratory Aim Density values are read from the developed negative and should be approximately: Red 80, Green 1.20 and Blue 1.60). Artistically desired "deviations" from this "normal" exposure and development can more effectively be accomplished in the subsequent image processing than in original photography, where they can compromise the scanning process.

A series of short takes is then made in which the luminance of the backing screen is progressively adjusted from "par" with the foreground to two and a half stops below par, in half-stop increments. This test is then scanned and test composites made on the workstation of choice. In practice, it may be more practical to adjust the foreground light than the backing illumination, compensating for exposure via ND filters.

The cinematographer should make it a practice to include the gray card and gray scale at the head of each take. It is convenient to display these to the camera along with the slate unless the slate is illuminated with a separate slate light. Additionally, the running camera should be briefly "capped" so as to provide a short length of film devoid of exposure, so that a D-min. reference is produced to assist in calibration at the scanner.

Front-Lit Backing Materials

As with film stocks, backing materials currently undergo revision too rapidly to permit full discussion here. The newly emerging electronic matting processes will make use of paints, fabrics and plastics only now being developed. Inquiry directed to the following providers of such materials will yield current information: 7-K Color (Los Angeles); Composite Components Company (Los Angeles); Daizians (New York and Los Angeles); Gothic Color (New York); Paramount Paint (Los Angeles); Rosco (worldwide); Stewart Filmscreen (Los Angeles).

Transmission Blue Screen

In transmission blue screen, the source lights, power supplies and color of the screen itself have all seen changes. Incandescent lights, impractical because of their low blue content, have been replaced by fluorescent lamps, in particular by lamps containing the single phosphor strontium pyrophosphate: Europium. Such lamps have a narrow band output peaking at 420 nanometers. They may be obtained from the major lamp manufacturers and are identified by the prefix SDB (Super Diazo Blue). These lamps (indeed all fluorescent lamps) emit a certain amount of ultraviolet light; therefore, it is wise to use a Wratten 2E at the camera or a comparable UV filter at the lamp.

It should be mentioned that there is some evidence to suggest that the blue end of the spectrum, particularly the area around 440 nanometers, causes accelerated aging of the retina. This should not be confused with cataracts and problems that relate to short-wave ultraviolet. There is no cause for concern for people who are casually exposed to blue light, such as actors or stage crew, who may only spend a few days a year working around blue screens. However, people who spend many weeks a year working with significant amounts of blue light should take some precaution to limit their exposure. Excellent filtered glasses, known as "Blue Blockers," are now available that will completely block not only the UV but most blue light.

Stewart Filmscreen can produce transmission green-screen material; a polychromatic screen can be made from Rosco black-screen rear-projection material and illuminated with the appropriate filtered light to achieve any desired backing color.

The strobing associated with 60-cycle AC-driven fluorescent lamps may be essentially overcome by the use of special high-frequency solid-state power supplies.

Reverse Blue Screen

This process was developed in response to a requirement to be able to matte objects incorporating highly reflective surfaces, such as glossy paint (even blue paint) or specular metallic materials, as well as details such as mesh, thin wires, and the like. Such characteristics have proved to be difficult, and in some cases, impossible to matte by conventional blue screen or frontlit/backlit processes. The process requires a sophisticated motion-control system capable of multiple passes in registration, and consequently cannot be used for live-action filming.

Reverse blue screen derives its name from the basic concept that, instead of trying to photograph an opaque object against an illuminated screen, it is desirable to photograph an illuminating source against a black or otherwise contrasting background. In this way, limitations inherent in the blue screen process, notably the tendency of the screen to reflect off the surface of the foreground subject, can be avoided.

The subject to be photographed, for example a model on a motion-control stage, is coated with a transparent medium, such as lacquer or acrylic, containing one or more phosphors which are invisible under white light. The subject is photographed, illuminated by normal stage lighting sources. A second pass is then filmed, on the same film load, but consecutive to it. This time the stage lights are extinguished, and the subject is irradiated with ultraviolet radiation of a wave length of about 360 nanometers (black light). This process is applied to stop-motion by simply filming alternate white light and black light frames instead of complete sequences. The ultraviolet radiation is converted by the phosphors on the surface of the subject from 360 nanometers to either 450 (blue); 550 (green); or 650 nanometers (red) and re-emitted as visible light. If a color stock (such as EK 5248) is being used, this will usually be red so it will record on the finest-grain emulsion layer.

The subject is now functioning as an illuminating source rather than as a reflector of light falling upon it. It is this source which is photographed. Further refined by the use of a color separating filter at the camera lens, the image is formed primarily by the selected phosphor coating on the surface of the model, with relatively little vestigial imaging from the model itself. (In the case of red, a Wratten 23A; blue, a blue dichroic plus a Wratten 2E; and green, a green dichroic alone.) In this way, variations on the model brought about by paint color, texture changes, etc. are minimized, as the object is to produce a monochromatic image with as uniform a density as possible. It is sometimes helpful to reduce the contrast range in the subject to avoid the juxtaposition of brilliant white and jet black areas (i.e., space-shuttle models). but this should usually be done as a matter of course in preparing subjects for composite photography, since the ensuing optical processes will build up contrast in the final composite image.

In addition to the desired elimination of restrictions on subject characteristics, this method of obtaining mattes provides the following advantages: First, there are fewer steps and fewer pieces of film required in the optical composition sequence. Second, even under some extreme conditions, such as a subject receding into the distance and becoming quite small, the matte image retains its integrity and refuses to disintegrate, as happens when the same shot is attempted via conventional blue screen. Third, camera freedom increases, in that a backing screen is not required to be kept in the camera view; consequently, the camera can make a 360-degree turn around a subject.

The procedure in the optical department is straightforward, fast and economical. The original negative matte image is printed to a high contrast stock via the appropriate filter. The exposure of best contrast between the clear subject area and the opaque background area, usually a density of approximately 2.6 to 2.7, is printed. The selected density tends to "pinch" the subject image slightly, thus affording a tight fit. The reverse is then printed from this matte, completing the set. The first matte, or "burn-in," is then simply bi-packed with a positive of the original negative, printed and followed by a bi-pack of the background scene with the "hold-out" matte.

A more complex version of this process provides for the addition of a contrasting phosphor backing (usually blue) and model mount which is recorded via the appropriate filter onto the previously recorded phosphor image. Or, with appropriate filtration (Wratten #31) both phosphors may be recorded simultaneously. The result is the creation of an image capable of providing both male and female mattes in one generation. One situation in which this is helpful is the case of a model with extreme texture or holes that cannot be adequately penetrated by the black light. If used alone, such an incomplete image would result in holes in the matte. However, when each side of the set of mattes is made from its own respective phosphor, the result is that dark areas of the burn-in matte remain dark and do not permit the print-through of the background scene.

Such mattes can have the added property of containing slightly but importantly different information from each other. Subtracting one matte image from the other therefore yields a third which represents the difference between its two predecessors. This is known as a "matte-difference-matte" and may be used to create additional effects (such as the re-entry glow on a spacecraft). Further, it naturally follows that this concept can be extended to include the green record, obtaining a total of three original mattes plus any number of permutational derivatives. Apogee, Inc., holds a Patent (#4,417,791) on Reverse Blue Screen and supplies the process under license.

Front Projection Blue

This process provides a method for producing blue screen of exceptional purity, with great economy and, if needed, on a truly large scale.

Demands made for very large-scale blue screen composites prompted Apogee to build a dedicated, high-power blue flux front projector. This device, known as "Blue-Max," incorporates the best features of both blue screen and front-projection compositing. From blue screen, we acquire the ability to composite a final image in which the foreground and the background are of the same generation one to the other. From front projection, we acquire the absence of blue spill and the almost unlimited screen size plus the modest expense of operating a 5000-watt lamp rather than a large transmission screen. Moreover, we can perform multi-plane effects which permit the actors to appear both in front of and behind portions of the blue field, or we can use flags to obscure apparatus such as lights and rigging. At the same time, we have dispensed with the front-projection restrictions of poor re-photography of the projected plate. By using a narrow band interference coated beam splitter designed to split only the desired matting line, we can eliminate the necessity of lighting the foreground scene one stop hotter to compensate for the one-stop loss of a conventional beam splitter.

The "Blue-Max" consists of the following basic elements:

1. The light source, a 5000-watt Mercury-Xenon short-arc lamp.

2. A light collection and delivery system based on a modified Abbe illumination system in which the arc is re-imaged by an optical integrator and from there modified by lenses to conform to the characteristics of the camera lens in use.

3. A series of filters designed to isolate with great accuracy the selected matting color: Red, Yellow (for Sodium Vapor two-strip process), Green or Blue.

4. An attenuation system which can modify the output of the projector during a shot in order to maintain a specified screen brightness level.

5. A selection of beam splitters of various reflection and transmission ratios, including some having the property of splitting only the matting line in use, so as to reduce unnecessary foreground light losses.

6. A light trap incorporated with the projector so as to allow for relatively unlimited camera movement.

The set-up for a "Blue-Max" shot is very similar to that for conventional front projection. It is perhaps even more essential to keep ambient light contamination off the screen. The light level at the screen is measured on a ground glass mounted in the film gate by use of a fiberoptic probe connected to a light meter. In front-projection blue, it is not necessary to carry focus to the screen as in conventional front projection.

Reverse Front Projection

In both front projection and transmission blue-screen compositing, extreme close-ups have presented various problems. In close-up photography via transmission blue, blue spill is the principal villain encountered. In front projection, if a subject approaches very close to the camera/projector apparatus, the projected light will record on the subject in spite of the vast difference in gain between the subject and the Scotchlite screen. Furthermore, certain rules have long existed in front projection technique regarding the spatial relationships between the camera, the subject and the screen. (See Front Projection section.) These rules are directed at preventing the fringing of the subject that results from having a soft shadow rendered at the screen, the consequence of a relatively short subject-to-camera distance versus a relatively long subject-to-screen distance. Additional problems are introduced if the subject includes highly reflective surfaces, e.g., silver lamé clothing or space helmets; and all these problems are exacerbated if the subject is backlit.

In "Blue-Max" compositing, these difficulties can be resolved by the adoption of "Reverse Front Projection." In its simplest terms, Reverse Front Projection can be described as a radical rearrangement of the basic front-projection setup. In conventional front projection, in which a camera and a projector are disposed at 90 degrees to each other with a beam splitter arranged between them at 45

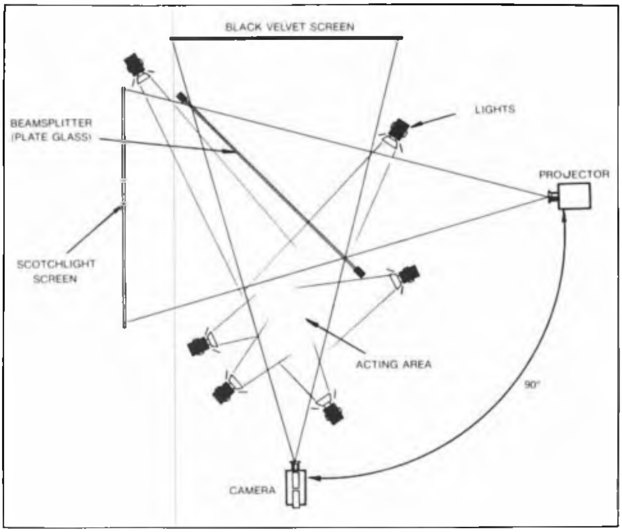


Figure 1. Diagram of reverse front projection.

degrees to both, a subject to be photographed is positioned in front of the camera/projector apparatus, and a front-projection screen on which the projector will form an image is deployed beyond the subject. The camera is thus able to record and combine both the returning projected image and the foreground subject.

In Reverse Front Projection, the camera and projector are still at 90 degrees to each other, but separated by a considerable distance, and the foreground subject is placed between a very large beam splitter (which may be plain glass, or preferably a pellicle) and the camera. The front-projection screen faces the projector instead of the camera, while the camera faces the light trap normally confronted by the projector. (See Figure 1.) The effect of this arrangement is to take the diverging projected cone of light from the projector and deliver it as a converging cone of light, having turned it 90 degrees. We then position the camera so that the nodal point of its lens coincides with the focal point at which the projected cone of light converges.

By this process, we acquire all the advantages of front-projected blue, in terms of the purity of color as well as the absence of blue spill, without having to project the blue onto the subject. We have also eliminated the fringing resulting from poor alignment of projector and camera nodal points, as there is no shadow at all cast upon the screen by the foreground subject. Furthermore, we have eliminated the haloing resulting from the backscat-tered light that occurs when the subject is backlit. This is due to a "diode effect" produced by the arrangement of elements in Reverse Front Projection. In normal front projection, a ray of light striking the back surface of a foreground subject is reflected back to the Scotchlite screen and then returns again along the same axis, plus or minus some 2%. Therefore some of the light restrikes the subject, while some passes the subject, making its way back to the camera to produce the objectionable halo.

By contrast, the "diode effect beamsplitter" handles the situation in the following manner: a ray of light striking the rear of the foreground subject is reflected back towards the beam splitter; approximately 92% of it is passed through the beam splitter to the black velvet screen, where it is absorbed. The remaining 8% is reflected back to the Scotchlite screen, and from thence returns to the beam splitter, where again 92% is passed through and 8% is reflected towards the foreground subject. Thus, only 8% of 8%, or .64%, is made available to the camera to record as halo. To be sure, only 8% of the projected blue light is being made available to the camera also, but that is not a serious problem to the Blue-Max with its massive output. It should also be borne in mind that in conventional front projection, only a theoretical 25% of the projected light survives the journey to the camera, so we are, in fact, sacrificing approximately one and a half stops.

We sacrifice some degree of camera flexibility in using Reverse Front Projection, as the camera cannot move from the nodal point defined by the projector unless provision is made to move both the camera and projector in synchrony. In some cases, it may be easier to move the subject in relation to the camera. Zooming is certainly possible, as are all nodal-point moves for the camera, and these should cover most requirements for close-ups. Apogee has applied for patent protection on Reverse Front Projection as well as the "Blue-Max," and both are available to the industry under license.

Current backing materials include the following paints and fabrics. Paints: Paramount Ultra-Marine Blue #8580 (a tough surface paint that resists scuffing, but is more applicable to television than to film, as it lacks sufficient color saturation); 7-K Infinity Blue (for years the industry standard); Apogee Process Blue, Rosco Ultra Blue and Gothic Ultra Blue. Fabrics: "FRP 100" (flame retardant) and "Tempo," (not flame-retardant though it has superior color saturation and a felt-like texture with a thin foam-rubber backing), both available from Daizians in New York and Los Angeles, and a new material from Rosco. Besides these there is a vinyl plastic sheet material from Stewarts called Ultimatte Front Lit Blue. This material, besides providing a very clean blue, is also very durable -- sturdy enough to drive vehicles on.

Digital Effects Cinematography

by Dennis Muren, ASC

The arrival of theatrical-quality digital image manipulation brings to the cinematographer new responsibilities. It is important that we do our best to understand and eventually master the capabilities of this new tool. On the set, we will soon be asked, "Can we keep shooting and fix it digitally?" or "Can't we just paint out the wires?" As of now, there are no industry-wide standards defining image quality, and there are only a handful of computer artists who know our expectations. Our participation is vital. Perhaps within this decade entire films will begin passing through a digital printer, where the choices of color timings will be only one of a dozen possible alterations. The cinematographer will need to be at these sessions to follow through on his vision. He may have chosen to light and expose the negative in specific ways, knowing that with digital manipulation he will later alter the image to best create a specific mood or effect.

Many of these techniques are available for TV at video post houses. But we have no control over how a home viewer chooses to adjust his TV. In feature films, it is the cinematographer who can have the final say, because he works with the color timer and often approves the release prints.

For a few years, digital manipulation will be restricted to special instances where the expense is justified. The work will be done at a film effects house or a high-end video house. One way to begin feeling comfortable with this technology is to tour a number of suppliers' facilities. Ask to see their sample reel on film, not tape. Then trust your own eye in evaluating the work. Since equipment costs change as technology advances, pricing should not be assumed. Feel free to consult experts whom you trust. There is still no substitute for experience on a set. On a show with difficult effects work, an experienced expert should be there whenever possible. Later, you may want to check the final manipulated film that has been cut into the workprint, and project it if possible. It should be up to the video house to ensure that a shot will intercut, but they may in fact have very little film experience.

Here is a brief summary of the three steps needed to transfer film into a computer and back onto film. Each step is controlled by a computer:

1. Input: The original negative or interpositive is scanned by a sensor, which produces the electronic equivalent of a photograph. Each frame is subdivided into millions of discrete dots, and each dot's position, color and brightness is stored on digital tape or disks.

2. Manipulating: The digital tape or disks are read into a computer where the image is reassembled on a monitor for viewing. It can then be manipulated with computer-painting and image-processing programs, either by an artist a frame at a time or preprogrammed and recorded unattended, and then stored onto digital tape or disks.

3. Output: The digital tape or disks are read into a computer where the image is put back onto film, either through photographing a high-quality TV image or by lasers scanning onto film and reconstructing each dot's position, color and brightness. The film is then processed and printed for viewing.

It is during step two that we have an opportunity to alter the image. We work with a computer artist who runs the computer, much like in a postproduction video suite. For now, monitors are not exact representations of what will show on film. But their usefulness lies in making judgments of images relative to one another or within the frame. As we have learned to interpret how a set will look on film by using our eye, we will need to learn to interpret how a monitor's image will look on film. Today, the processing of the images happens much more slowly than in a post suite. So before a job is completed, a wedge of one frame can be requested and checked for final approval before running the job. Here are a few specific manipulation techniques now available:

Image Processing: This will become both a creative tool and a worry for cinematographers. Color, contrast, saturation, sharpness, and even the apparent shape of objects can be altered. Single color can be changed, areas can be isolated, and the changes will only affect that area. These tools may eventually be in the printing laboratory, which will make a completely new negative to be used for release printing.

Painting: Wires or supports can be painted out and not appear on the film. This can make stunt work safer. Unwanted objects can be painted out. If a difficult effects shot has an artifact, it might be easier to paint the defect out than try to correct it at an earlier step.

Compositing: For blue-screen work, in some cases the quality of the blue background need not be prefect if the composite is to be made digitally. This means we can set up faster. The screen can be positioned in difficult places or at extreme angles. Green or red screen may work better, depending upon the colors in the subject. Mattes can be made from differences in color and brightness at the same time. Since the process is self-contained within the computer, there are no problems with film shrinkage, unsteadiness, exposure fluctuation, or photochemical development as there are with optical printing. The composite is viewed on a monitor and adjusted at every step. When properly photographed, compositing can now be perfectly executed.

High-Resolution Electronic Intermediate System for Film

by Don Miskowich

Eastman Kodak Company has developed a high-resolution electronic intermediate system designed for the contemporary needs of the motion-picture industry. This system can be used to scan and digitize frames of motion picture film so they can be interactively manipulated and composited at computer workstations. The digital pictures can be recorded back onto film without compromising image quality.

There are many significant advantages to this technology. By converting film to digital form (1's and 0's in the computer), the images can be endlessly manipulated without losing quality. The system is capable of accommodating the full-resolution and dynamic-range of analog pictures captured on currently available fine-grain 35mm films. With this technology it is as feasible technically to combine 25 layers of imagery as it is to combine a simple foreground and background. Image input and output time is approximately three seconds per frame at full resolution. The system can also be used at one-quarter and one-half resolution, which is comparable to NTSC/PAL and HDTV image quality.

Applications fall into three general categories — painting, image processing and compositing. Painting includes such applications as guide wire and artifact removal. It is also possible to repair scratched or otherwise damaged film.

Image processing includes such applications as the manipulation of colors, contrast, saturation, sharpness and even the apparent shape of images. Single colors can be altered in isolated areas of individual frames. While this capability can be used to resolve problems, it also is a potentially powerful artistic tool which gives the cinematographer a second chance to alter the emotional content as well as the quality of images.

Digital image compositing should make the biggest impact. There will be less stringent requirements for setting up blue-screen photography since it is possible to solve many problems at the image composing workstation. For example, blue-spill — blue reflections on shiny objects that get too close to the blue screen — can be eliminated at the image-computing workstation.

The Kodak system has four main components: a film scanner, an image computing workstation the necessary software, digital data cassette recorders, and a film recorder.

The scanner uses a proprietary CCD trilinear sensor with three linear 4096-pixel photosite arrays. The arrays are covered with red, green and blue filters. These are optimized to match the dyes in contemporary color negative films. A xenon light source and integrating filter provide high-power diffused illumination.

The scanner also employs unique signal processing electronics and a proprietary transport design using frame-indexed, pin-registration and film-surface positioning. The latter features are crucial for seamless compos-iting of different picture elements.

The image computing workstation is based on currently available technology. It incorporates a Sun microprocessor platform with VME backplane and UNIX operating system. The workstation can be in a stand-alone or networked environment. It provides a previewing capability on a video monitor. This allows the operator and members of the creative team to make interactive decisions in a very tight loop. They can look at images composited in various ways, make decisions, and view the results in minutes.

A transputer-based, image-processing accelerator was developed for the workstation to provide high-speed image manipulation. In addition its capability was extended to provide direct memory access (DMA) on the edge nodes. The design flexibility allows users to size the transputer processing array to match their budget and their image-processing interactivity and productivity needs. The system is configured with a minimum of 8 gigabytes of parallel disk storage and uses a high-speed, industry-standard SCSI-2 data bus for data transfer. On-line disk storage can be increased by adding disk drives to the array. Industry-standard peripherals can be used, including the Exabyte 8mm data recorder, and DD-2 digital cassette recorders which can support data transfer rates in excess of 15 megabytes per second.

State-of-the-art software has been developed for the workstation. It uses concepts and symbols familiar to people already working with images at video postproduction facilities, computer-generated image houses and optical effects facilities. Main features include interactivity with selectable windows providing immediate updates of processed images.

The software uses flexible image processing tools, including color grading, filtering, resizing, repositioning and painting. Images can be imported from and exported to other major software packages. Kodak has also licensed the use of adjustable algorithms for blue screen compositing developed by the Ultimatte Corporation. Ultimatte has been a leader in the development of flexible programs for electronic compositing at NTSC, PAL and HDTV resolution. This is the first use of these programs for making film-resolution composites. The latest generation of Ultimatte software provides filmmakers with greater flexibility for creating credible composites.

Previously, blue screen photography was limited to silhouette-style shots against rear-lit, perfect blue screens. The new algorithms allow actors to move in the foreground of front-lit blue screens and cast shadows. They can climb on and around blue set pieces, and move within the background instead of just performing in the foreground.

The final component is the film recorder. The recorder uses three visible gas lasers to copy digital pictures onto a high-resolution color intermediate film. Blue light is provided by a 458nm Argon laser; green light by a 543nm Helium Neon laser; and red light by a 633nm Helium Neon laser. The film recorder also uses unique lenses and beam-shaping optics optimized for this application. The proprietary transport design employs the same precise frame-indexed pin registration and film surface positioning used by the film scanner.

Both the scanner and recorder are designed to work at a resolution of 167 pixels per mm in the film plane. This was selected to preserve the resolution of the original camera film, and also to provide the maximum sample size of 4096 pixels across full-width formats such as Super 35 and VistaVision. Preserving the aspect ratio of the Super 35 camera aperture, the system produces an image with 4096 pixels across and 3114 lines down. This is more than twice the horizontal sampling of the 1125 line HDTV format, which has 1920 samples horizontally and 1035 visible lines vertically. The following table summarizes the image dimensions for the formats supported by the scanner and the recorder.

Format	Horizontal Lines	Vertical Lines	Aspect Ratio
Super 35	4096	3112	1.32:1
Academy Aperture	3656	2664	1.33:1
CinemaScope	3656	3112	2.36:1
VistaVision	6144	4096	1.50:1

For example, an Academy-aperture 35mm frame is scanned to capture 3656 lines of horizontal resolution with 2664 picture elements, or pixels, on every line. To record the range of density captured on the negative, while providing "headroom" for creative digital image manipulation, the system accommodates up to 10 bits of information in each of three color records every pixel.

This feature requires some 40 megabytes of magnetic computer storage for every frame of 35mm film. One frame would use the entire hard-disk capacity of many popular personal computers. It's enough data to write some 8-10 million words in the English language. Remember, both the scanner and recorder can handle one frame of film in approximately three seconds.

There are other flexible alternatives. For example, the system provides an option for scanning, storing and processing 8 bits of data in each color record of every pixel for applications not requiring headroom. The user can also opt to work at one-quarter or one-half resolution, which requires only ¼ or 1⁄16 of the storage space, respectively.

The equipment has been designed in an open architecture mode which provides compatibility with standard peripheral interfaces used in the computer industry. Also, a digital picture file format which simplifies the exchange of images between workstations and between different facilities, has been developed.

Other applications for the high-resolution electronic intermediate system include restoration of vintage films that have been marred by scratches, blotches and other damage. It is even possible to restore torn images or missing parts of images based on the image information in adjacent frames. This should prove to be a valuable tool for protecting and preserving films that have cultural and/or historic significance or that have potential value for future redistribution.

Considerable interest has been expressed to establish image databases of stock footage from live-action and computer-generated image libraries. Stock footage stored in digital format would then be easily accessible. The image quality would be equivalent to first-generation negative film. This would assure that stock footage intercuts smoothly with live-action photography.

Over the long term, it could eventually become practical to integrate a high-resolution electronic intermediate system into the print distribution chain. A digital intermediate could be used to generate a high-quality intermediate film which would be used as a printing master. This would eliminate several generations of film from the release-printing process, resulting in a significant improvement in image quality.

Computer Graphics

by Michael Whitney and Allan Peach

Computer-generated imagery (CGI) has become an important addition to the working world of the cinematographer. CGI is the simulation of real or imagined objects and environments using computer-based mathematical models. Just as a director and cinematographer light and compose shots on an actual three-dimensional set, the CGI director works with an interactive computer display to set the lighting and block the shots on a simulated set. The director can then transfer the computer created imagery to video or film.

Computer simulation of reality can be quite effective, but simulated objects, lighting, and environmental effects only approximate reality. Light may pass right through a simulated object without casting shadows, solid objects may themselves pass magically through one another, and environmental effects may drift from the realistic to the comical within the same scene. The computer artist needs to be aware of the imperfection in the software's simulation of the world. Typically, the more accurately the director simulates a scene, the longer it takes the computer to generate the image. Because of this, the computer artist must be cognizant of the cost of "reality" in setting up a shot.

CGI for motion pictures is an inherently expensive process because of the time it takes to generate and record a single frame of film. Although high-end production work is still best served by supercomputers and advanced workstations, computer-graphics software is fast becoming a prevalent commodity in the personal computer world. This trend, coupled with the proliferation of faster and more inexpensive computers, is slowly reducing the cost of producing quality computer graphics.

Basic Tools and Terms

The atomic unit of computer graphics is the *pixel* (a contraction of *picture element*). Low-resolution displays, often found in personal computers, have resolutions of 640 X 480 pixels. This resolution is sufficient for most NTSC video work. However, motion picture work requires higher resolution displays with resolutions of 1280 pixels X 1024 lines or greater. Upcoming high-definition television systems will have displays approaching 2,000 horizontal pixels by 1,000 vertical lines.

The computer calculates the color for each pixel and displays it by varying the intensity of the Red, Green and Blue *(RGB)* signal. To represent color as perceived by the human eye, each pixel must span a range of 16 million to 68 billion colors (256 to 4,096 intensity values per R, G, B component). Internally the computer stores the RGB values in memory, with between 8 and 12 *bits* representing each R, G and B value. Each pixel, therefore, requires 24 to 36 bits of storage. Even for the low resolution of NTSC video, the computer must calculate and then store over 1 megabyte of data for each frame. A single Academy-aperture 35mm color negative frame, at the theatrical screening resolution of 4,096 pixels x 3,072 lines, requires around 56 megabytes of storage. A 65mm 5-perf motion-picture image requires a screen resolution of 6,000 X 2,500 pixels or higher. With 12 bits per R, G and B value, a frame would require 67.5 megabytes of memory, i.e., 6,000 pixels X 2,500 lines X 3 colors (RGB) X 1.5 *bytes* (1 byte = 8 bits). The computer must calculate this data then move it from its internal memory to the display memory of the film *recorder*.

The film recorder displays the data on a cathode-ray tube (*CRT*) or writes directly to the raw camera stock with a scanning RGB laser. This means that in order to make computer graphics economical, you must not only have an extremely fast computer, but you must also have high bandwidth pathways (called *channels*) between storage devices, the computer and the film recorder. For comparison, personal computers with 2,400 baud modems transfer data at 240 bytes per second. A high-performance CRT-based film recorder, in order to record a single 35mm frame in approximately six seconds, needs the channels to transfer 56 megabytes of data at 10,000,000 bytes (10 megabytes) per second.

Currently, no computer can create computer graphic frames at film resolution in real time. Often a frame may take from several seconds to many hours to compute and record. Whole scenes often take days to weeks of computer time. Because of these factors, computer graphics can be expensive, but the virtues of computer imagery often outweigh the costs.

2-D and 3-D Images

Two-dimensional computer graphics are a staple of video postproduction houses. The low resolution of video allows real-time manipulation of images by the graphic artist. The user interface of a two-dimensional system is usually a *graphics tablet*. The artist uses an electronic stylus to draw or paint on the tablet much as a painter would use a brush and canvas. Because of this, these computers are called *paintbox* systems. Video artists use paintbox systems to create special effects and to manipulate the original video source material. For example, a paintbox system can retouch tape dropouts or remove unwanted objects.

Digital frame stores are memory devices that scan and store complete frames of video in a digital format. Several companies make two-dimensional computer graphics systems, such as the *ADO*, that utilize digital frame stores to do freeze frames, zooms, video compression and expansion, video positioning, changes of aspect ratio, programmable patterns, picture flips and tumbles, etc.

Three-dimensional computer graphics are being used more and more in the motion-picture field. From pioneering efforts such as *Tron* and *The Last Starfighter* to more recent special-effects extravaganzas such as *Terminator* 2 and *Lawnmower Man*, three-dimensional computer graphics can create images that would be impossible to produce using normal special-effects technologies.

Modeling

The creation of three-dimensional computer graphics involves several steps. The first of these is the modeling process. *Modeling* refers to the creation of the simulated objects in the computer's memory, the modeling of optical elements such as light, transparency, shadows, reflectivity, etc., and the simulation of camera placement and movement within the computer-generated world.

The computer constructs objects from a series of points defined by the model maker. The points represent locations in a Cartesian coordinate system. Often the model maker may use several coordinate systems to facilitate the construction and interaction of objects. These stored points (the *object database*) can represent the vertices of polygons or the control points of more complex constructs such as *splines* or *nurbs* (mathematical representations of complex curves). The computer can create a simplified version of the object, called a *wire frame*, by simply connecting the points with lines. This wire-frame model is a useful representation of the object as the computer can render the wire frame quickly. This allows the computer artist to preview the scene in real time or near real time. Eventually, however, the computer must create surfaces on the objects to facilitate realistic lighting and shading.

The computer artist assigns attributes to the object's surfaces. These can include color, shininess (non-reflective to highly reflective), and opacity. Recent features in CGI software allow for more realistic-looking atmospheric effects and the creation of organic objects such as trees and shrubbery.

Objects may have *picture textures* projected or wrapped on their surfaces for a more natural effect. These textures are two-dimensional pictures that give the surface of the object the appearance of being made from real materials such as, for example, wood or concrete. Parameters for *bump mapping* are also modeled in the computer. An example of bump mapping might be the dimples on a golf ball or the pitted surface of an orange. Procedural surface effects are formulas for creating surfaces and are useful replacements for scanned texture maps.

Lighting is also simulated in the modeling stage. The computer artist must take into account many of the concerns of a traditional lighting director. Computer lights come in many forms from distant lights that simulate the sun, to point lights and spot lights that simulate man-made light sources. Lighting the scene involves placing the lights in the simulated three-dimensional space, adjusting their intensity, the angle of their cone, their direction and their color.

The computer can also simulate camera attributes such as depth of field, focal length, aspect ratios, etc. Once the object models are in place, the modeler can position the camera anywhere in the simulated three-dimensional space. This is a major advantage over two-dimensional animation, where each change in camera position requires a new drawing of all the objects in the scene. The computer modeler does not need to reconstruct the objects to create a new shot. He can simply reposition the camera.

The next step in the modeling process is specifying the movement of any animated objects and any movement of the camera. The computer can be an excellent aid in this animation process. The computer animator creates *key frames* and tells the computer the method of *interpolation*. The computer then creates the in-betweens.

In addition, traditional animation studios are turning to computer graphics to assist in the cel animation process. With CGI, the animator can create a computer aided camera move through a three-dimensional world and then print the scene as two-dimensional perspective drawing directly onto animation cels. Artists can then use the computer-generated lines as guides to ink and paint the cels or use other specialized computers to do the ink and paint work. These processes can save hours of an animator's time in figuring out complex motion and perspectives and reduce production costs. Recent examples of computer-assisted animation and digital ink and paint include *Beauty and the Beast, Ferngully* and *Aladdin*.

Rendering

Rendering consists of taking the digital attributes of the model, the lighting and the camera and creating an image. Rendering is a complex process and requires much more computer power than the modeling stage. Before expending the time and money to render an entire shot, the computer artist may wish to render single key frames of an animation sequence to check that the simulated image is the desired one. The artist may also render wire frame or low-resolution approximations of the shot to get a feel of the look of the animation before fully rendering the scene.

Because the objects in the computer-generated scene are only simulations, they act quite differently from real-world objects that must obey the rules of physics. If not properly animated in three dimensions, computer objects may interpenetrate one another, destroying the illusion of solid, real objects. If not properly constructed, seams may show between supposedly seamless parts. The artist may discover unwanted artifacts created by the size and shape of the pixels, the scan lines of the monitor, or errors in texture mapping or surface generation for the first time in the rendering process. The modeling and rendering cycle is often an iterative and *interactive* one, with the CGI designer returning to the modeling stage to correct problems that can only be detected after rendering.

Final rendered images can range from simple wire-frame approximations of objects, to highly faceted objects, to realistic *smooth shaded* objects. The style in which an artist renders an image is often a factor of aesthetics tempered by the pragmatism of meeting a production deadline or budget constraints.

During the rendering process, the computer may also control a scanner to digitize film frames and to composite them with the computer-generated images.

Scanning

The *scanner* is a device that translates an image from previously exposed film into a digital format. Current devices use a CRT or laser to scan a film frame on a point-to-point basis or use a charge-coupled device (*CCD*) to digitize the frame by area or line by line.

The CRT or laser is the *moving spot* illumination source that scans the image at a constant intensity. Controlling the beam diameter can determine the size of the pixels and thus the resolution of the scanned image. As the beam scans the film frame pixel by pixel, light gathered by an optical system passes through dichroic filters and splits into red, green and blue components. The intensity of the light hitting R, G & B light sensors converts to an analog electrical signal. An analog to digital converter translates the analog signal into a digital value for each color.

CCD scanners utilize a technology employed in professional video cameras. Instead of a scanning light source, the CCD scanner uses an incandescent or xenon light source similar to the optical printer. The number of pixel elements in the CCD array determines the resolution of the scanned image. *Grid arrays* of 2,000 pixels by 2,000 lines or 4,000 pixels by 4,000 lines enable scanning an entire frame while holding the film on fixed registration pins. *Line arrays* of 2,000 to 4,000 pixels require that the film be *rolled* past the CCD to scan the entire film frame.

The computer captures the number stream produced by the scanner and creates a pixel array *database* in a format compatible with the database of a simulated image. The time required to scan a frame varies from under five seconds to several minutes depending on the device and the resolution.

The computer can composite both foreground and background elements in what might be called *digital film printing*. Although the computer can use any color to extract a matte, it is most practical to use a spectrally pure color such as Ultimatte blue or green. However, it is not necessary to have a blue- or green-screen exposure limited to one color record of the film as is needed in film-based matting systems. The same qualification applies, however, in that the background screen color cannot be in the foreground subject.

Recording

CRT and laser-based *film recorders* progressively expose each pixel onto film by electronically controlling the position and intensity of a CRT beam or by mechanically deflecting R, G, B laser beams. Recorders (and scanners) that deflect in both the X-axis and Y-axis use traditional registered pin film movements. Other laser recorders deflect in the X-axis only and rely on *rolling* the film smoothly in the Y-axis to record the film frame area. Once the mechanical stability problems are resolved, an advantage of laser-beam recorders is that they have sufficient light output to expose higher resolution lab intermediate film stocks. Film exposure times in existing film recorders vary from under ten seconds to several minutes per frame depending on the device and resolution.

It is important to address several issues before filming a CGI shot: how the computer will translate the calculated pixels into color exposure values and how the spectral emission characteristics of the cathode ray tube (CRT) or RGB laser beams will match the film sensitivity curves. The computer can define color values according to a system of hue, luminance and saturation, or according to a system of Red, Green and Blue values. In either case, three sets of numbers describe the color of each pixel in the final image. *Color calibration*, which is the relationship between the calculated color space and the actual film exposure, is achieved through the use of a color look-up table (*CLUT*), and other matrix transform color corrections.

The CLUT is a graph of film density plotted against calculated color exposure. The technician doing color calibration derives the CLUT from carefully plotted curves determined through densitometry of the exposed negative. Using the CLUT the technician matches the emission energy of the CRT or laser, combined with high-efficiency RGB filters, to provide exposure in the straight-line portion of the film exposure curve. The computer accomplishes this by translating color space numbers into the RGB exposure values determined from the color look-up table. It is possible, through the use of the CLUT, to precisely control film image contrast. It is often useful to use logarithmic representation for the pixel values. Logarithmic pixel values translate easily to logarithmic film density during calibration of scanning and recording devices.

One problem that is typical for high-resolution CRTs is the creation of an unwanted halo by internal glass reflections in the CRT faceplate. The halo affects the image in the form of an unwanted exposure surrounding the highlight areas. Techniques to reduce this problem include the addition of a neutral-density panel bonded to the surface of the CRT, the tinting of the CRT faceplate, and the bonding of a thick clear panel to the CRT faceplate.

Image Processing

Image processing, a branch of computer graphics, in some ways represents the reverse of the computer graphics process we have been describing. Image processing involves the computer modifying the data from a traditionally shot piece of film or video. A film scanner or a digital video process first *digitizes* the images into a form the computer can use. The computer can then manipulate the digital representation by changing the attributes of the pixels that make up the image.

Image-processing techniques can sharpen or defocus an image, solarize or reverse an image's colors, or reposition the image. Additionally , one image can be transformed into another through a technique called *morphing*.

For years the aerospace industry has used image processing techniques to enhance satellite space footage taken under sub-optimal viewing conditions. Today, image processing creates fantastic effects for rock videos and special-effects films.

Summary

Producing effects for motion pictures is at the high end of the computer graphics world. It is here that all the toughest problems of CGI occur. Although computers are becoming more powerful, the software needed to create realistic-looking environments, effects and characters is still technically difficult to produce. Recording and scanning motion-picture-resolution film requires complex equipment, while generating, moving and storing the enormous amounts of data needed by the computer can be time-consuming and expensive. Still, CGI is here to stay, and ever evolving!

It is important that the cinematographer understand the vocabulary of computer-generated imagery. As the computer artist takes a place beside the traditional special effects artist, the aesthetic goal remains the same -- creating visual magic that will intercut with the camera imagery of the director of photography. To fully utilize computer simulation, it will become necessary for all those involved in the various phases of the motion-picture industry to understand its great creative potential, as well as its limitations and cost.

Cinemagic of the Optical Printer

by Linwood G. Dunn, ASC
Former president, Film Effects of Hollywood

The earliest optical printers were custom built by the major studios and film laboratories, and were usually designed and made in their own shops to fit their particular requirements. Modern standardized optical printing equipment, capable of creating the innumerable effects heretofore possible only in the major studios, became available to the entire motion-picture industry in 1943 with the introduction of the Acme-Dunn Optical Printer, designed and built for the United States Armed Forces Photographic Units. Later the Oxberry, Producers Service, Research Products, and other optical printers appeared on the market. Commercial availability of this type of equipment greatly stimulated and widened the scope of the special-effects field. Even the smallest film producers now could make motion pictures with special effects limited only by their imagination and budgets, utilizing the services of growing numbers of independent special-effects laboratories which could now operate competitively using equipment available to all.

Developments over the years of more sophisticated equipment, new duplicating films, special-purpose lenses, and improved film-processing techniques, as well as skilled technicians, have increased the use of the optical printer to a point where its great creative and economic value is common knowledge in the motion-picture industry. In more recent years, the adaptation of computer technology to the optical effects printer has basically simplified the control and accuracy of some of its important functions, thus making it much easier to produce certain complex visual effects at lower cost as well as to greatly expand its creative scope. This has made it possible to program, record, and to repeat the movement of certain of its devices with such a degree of accuracy that area-blocking functions can now produce traveling-matte composite scenes that were heretofore highly impractical, if not impossible. One can truly say that the creative capability of the modern visual effects optical printer is only limited by the creative talent and technical skills of the operator. In recent years such major film productions as *Star Wars*, *The Black Hole*, *The Empire Strikes Back*, and *Cocoon* have all utilized the full capabilities of the modern optical printer to create a whole new world of imaginative creativity through their extensive use of very sophisticated motion-picture visual effects. The following list of some of the work that is done on the modern optical printer will illustrate its vast scope and tremendous importance to modern filmmaking.

Transitional Effects

Employed to create a definite change in time or location between scenes. The fade, lap dissolve, wipe-off, push-off, ripple dissolve, out-of-focus or diffusion dissolve, flip-over, page turn, zoom dissolve, spin-in and out, and an unlimited variety of film matte wipe effects, are all typical examples of the many optical transitional effects possible.

Change of Size or Position

May be used to eliminate unwanted areas, obtain closer angles for extra editing cuts, reposition action for multiple-exposure framing, including montage, and backgrounds for titles.

Frame Sequence Modification

Screen action may be sped up or slowed down in order to: convert old 16 frames-per-second silent films to standard 24 frames-per-second sound speed; change speed of action and length of certain scenes or sections of scenes; provide spot-frame modification to give realism to specific action in fights, falls, chases, etc.; hold a specific frame for freeze effects and for title backgrounds; add footage for comedy effects; reverse direction of printing to lengthen action and for special-effects use; extend scenes through multiple-frame printing for action analysis in instrumentation, training and educational films.

Optical Zoom

Optical zoom is used to change frame area coverage and image size during forward and reverse zooming action in order to: produce a dramatic or impact effect (according to speed of the move); counteract or add to the speed and motion of camera zooms or dolly shots; re-frame by enlargement and/or add footage to either end of camera zooms or dolly shots by extending the range of moves; momentarily eliminate unwanted areas or objects by zooming forward and back at specific footage points (such as when a microphone or lamp is accidentally framed in during part of a scene); add optical zoom to static scene to match camera zoom or dolly in a superimposure. The out-of-focus zoom also is effective to depict delirium, blindness, retrospect, transition, etc.

Superimposure

Superimposure is the capability used to print an image from one or more films overlaid on one film. This is commonly done in positioning title lettering over backgrounds. Also used for montages, visionary effects, bas relief; adding snow, rain, fog, fire, clouds, lightning flashes, sparks, water reflections and a myriad of other light effects.

Split-Screen

Employed for multiple image, montage effects, dual roles played by one actor, and for dangerous animals shown appearing in the same scene with people, as in *Bringing Up Baby*, which shows Katherine Hepburn working with a leopard throughout the picture (in this film, the split screens move with the action). Matte paintings often utilize this technique when live-action areas require manipulation within an involved composite scene.

Quality Manipulation

The quality of a scene, or an area within a scene, may be altered in order to create an entirely new scene or special effect or to match it in with other scenes. There are innumerable ways to accomplish this, such as adding or reducing diffusion, filtering, matting and dodging areas, and altering contrast. Often library stock material must be modified to fill certain needs, such as creating night scenes from day; reproducing black & white on color film through filtering, printed masks, or appropriately coloring certain areas through localized filtering; and the combining of certain areas of two or more scenes to obtain a new scene, such as the water from one scene and the terrain or clouded sky of another.

Adding Motion

Employed to create the effect of spinning or rotating, as in plane and auto interiors and in certain montage effects; rocking motion for boat action, sudden jarring or shaking the scene for explosion and earthquake effects; distortion in motion through special lenses for drunk, delirious and visionary effects.

General Uses of the Optical Printer

The preceding represents some of the special categories of effects that can be produced on the optical printer. The following are a few of the more important general techniques employing this useful cinematic tool.

Traveling Mattes

Used to matte a foreground action into a background film made at another time. The various matte systems in use today require the optical printer in order to properly manipulate the separate films to obtain a realistic quality matching balance between them when combined into a composite. Use of this process has greatly increased as modern techniques produce improved results at reduced costs. Motion control, referred to earlier, has greatly widened the scope of this visual-effects category.

Blow-Ups and Reductions

The fixed set-up optical printer is used for 16mm reduction negatives and prints, and for certain limited release printing from 35mm originals. This is utilized when small volume makes this procedure more economical than through a converted negative, and when maximum quality is of greatest importance. Enlarging from 16mm to

35mm color or black and white is a very important function of the optical printer. Many fine theatrical films, such as the Academy Award-winning *The Sea Around Us*, *The Living Desert*, and *Scenes From a Marriage*, have been photographed in 16mm, and have enjoyed great financial success through 35mm release prints made from 35mm blow-up internegatives.

Special new lenses, film raw stocks and immersed-movement printing have enhanced the overall quality to a point where the 16mm-35mm blow-up medium is presently enjoying very successful commercial usage. Conversions between 65mm and 35mm also are an important function of the optical printer. Productions made in almost any film format are being release-printed in different types to meet certain theatrical distribution requirements. *The Concert for Bangladesh* was the first feature-length film to be enlarged from 16mm color internegative directly to 70mm theater prints.

Anamorphic Conversions

The standard optical printer equipped with a specially designed "squeeze" or "unsqueeze" lens can be used to produce anamorphic prints from "flat" images, or to reverse this function. The possibility of the "flat" or spherical film being converted for anamorphic projection without serious loss of quality has greatly widened this field of theatrical exhibition. The manipulations available on the optical printer also make it possible to scan and reposition any scenes that require reframing when converted to or from wide-screen proportion.

Doctoring, Modifying and Salvaging

Some of the important uses of the optical printer are not recognized as special effects in the finished film, and often are not apparent as such even to skilled motion-picture technicians. One of these applications is the field of "doctoring" by modifying scenes which, for a variety of reasons, may not be acceptable for use. This includes salvaging scenes that are completely unusable due to some mechanical failure or human error during photography, and also the modification of stock film material through the various methods noted to fit specific requirements. Many expensive retakes have been avoided by the ingenious application of such optical-printing reclamation techniques.

The liquid, or immersion, film gate produces dramatic results in the removal of scratches.

Citizen Kane is an excellent example of scene modifications created on the optical printer during the postproduction period. New ideas were applied to existing production scenes for which new supplementary scenes were photographed and integrated to enhance and create various new concepts.

In *It's A Mad, Mad, Mad, Mad World*, an important scene was photographed in which a truck was supposed to back into a shack and knock it over. The breakaway shack was rigged to collapse when wires were pulled on cue. Signals became crossed, and the shack was pulled down well before the truck touched it. A very costly retake was indicated, so the optical printer was called to the rescue. The task of correcting the error through a split screen seemed relatively simple until it was discovered that the camera panned with the falling shack. It then became necessary to plot and move the split matching point frame-by-frame on the optical printer to follow the pan. Through this traveling split-screen technique, the progress of the shack's falling action was delayed until the truck had reached the point of impact. Perhaps the entire cost of the optical printer was saved by this salvaging job alone. Such clever techniques have been used many times to bring explosions close to people working in a scene, such as in *One Minute to Zero*, where a line of so-called refugees was "blown to bits" by artillery shelling. Split screens in motion, and trick cuts, with superimposed smoke and flame, did the job in a most effective manner.

New Systems

The optical printer is being used to develop new horizons in the creation of special camera moves within an oversized aperture. This is particularly effective in the creation of camera movement in a composite scene, such as one involving a matte painting, thereby giving a greater illusion of reality. VistaVision and various 65mm negative formats, including 16-perforation Imax and 8-perforation Dynavision, as well as standard 5 perforation frames lend themselves to this technique.

Copying onto 4 perforation 35mm makes possible spectacular pans, zooms, dolly shots, etc. without sacrificing screen quality, and with full control over such movements, all of which is created on the optical printer in the internegative stage and made during the postpro-duction period. Use of this technique makes it possible to avoid time-consuming and complicated setups during production, with the added advantage of flexibility in later change of ideas.

Probably the most exciting new optical printing development has been in the field of electronics. The adaptation of video image transfer through sophisticated high-resolution scanning systems in conjunction with the new developments in cathode-ray tubes, lenses, film-moving mechanisms, special-purpose film raw stocks and the latest research in electronic image compositing, have opened up exciting new vistas in special visual effects. The modification of filmed color motion-picture images through computerized electronic transfer back to film is making it possible to create photographic effects on film or tape faster, more economically, and with a scope of creativity heretofore not possible. The ability to easily and quickly transfer areas or moving objects from one film to another through their instantaneous electronic isolation and self-matting will be of tremendous economic benefit in this area of film production, as well as in stimulating creativity in the wider use of special effects.

Aerial Image Cinematography

by Mehrdad Azarmi, Ph.D.

An image which is formed by a lens in the air instead of on a film or on a ground glass is known as an "aerial image." Such an image can be seen and photographed but it cannot be touched or felt. The image which is observed through a telescope, a microscope or a simple magnifying glass is an aerial image. Because of its clarity, sharpness and its intangible presence, it has led the cameraman to the development of the technique of "aerial image cinematography," which is, in fact, a method of combining two images: an aerial image, and another image which is recorded on film. The aerial image can be modified, enlarged, reduced or distorted when combined with the cine action footage. Aerial image can originate from a film, artwork or simply from an object. Selection of the tool and the technique is determined by the combination of the elements involved. The technique of aerial image cinematography can be divided as follows:

The Technique	The Required Tool
Film-to-Film	Aerial Image Optical Printer
Film-to-Artwork	Aerial Image Animation Stand
Object-to-Film	Object-to-Film A.I. Optical Printer

Regardless of the method used, an aerial image produced by a lens is always upside-down but not flopped over. This simple rule of thumb aids the cameraman in correct positioning of the object, the artwork or determining the head-tail and cell-emulsion orientation of a roll of film when threading an aerial-image projector.

Film-to-Film

The most predominant aerial image technique is film-to-film, and the use of an aerial image optical printer is inevitable. The process is used in a variety of effects whenever two or more elements are involved, such as traveling mattes, titles, wipes, multi-panels and split screens. The tool employed for this purpose is either a dual-, triple- or quadruple-head optical printer which combines image axes through partially reflecting mirrors. An addition to this equipment, as well as to the animation stands, is a multi-axis electronic motion-control system with a memory bank and playback system which allows for automatic rephotography of certain effects and complicated, time-consuming moves. The dual-headed aerial-image optical printer is used predominantly throughout the industry, and it has proven to be adequate for most purposes. The triple- and quadruple-head printers find their greatest applications in composite photography of traveling-matte shots, such as the blue-screen process, where the operator can actually photograph the background and foreground elements simultaneously with their respective mattes. The cameraman, in this case, has the privilege of observing the composite image before shooting, in order to reassure himself of an accurate matte fit. He can then zoom, enlarge or reduce during the same operation.

In spite of the versatility of the triple- and the quadruple-head printers for traveling-matte shots, most cinematographers prefer to work with a dual-head aerial-image optical printer because of the loss of light in the beam-splitter modules and the complexity of its alignment. Composite matte shots are photographed on a dual-head printer in two separate operations. After a perfect one-to-one, first, the foreground and the female matte are photographed; then, the background and the male matte are shot in sync on the same piece of film. In order to avoid the possibility of any misalignment during both operations, the mattes are intentionally threaded in the same projector head, preferably in the front module, by which the mattes are generated.

Before actual composite photography, the operator may check clippings of the male and female mattes bi-pack in sync in the main projector, looking for a very thin and even white margin where the mattes fit together. He may even go further to the extent of running both mattes in sync and bi-pack, carefully looking for the consistency of the same contour and possible matte shrinkage. Since various elements are photographed in separate modules in film-to-film aerial image cinematography, two advantages are inherent in the system:

1. The process eliminates the possibility of Newton rings, a phenomenon which frequently appears when two pieces of film are sandwiched together in bi-pack.

2. The elements do not necessarily have to be of the same size. Thirty-five millimeter titles, for example, can be reduced to fit a 16mm footage. By the same token, a shrunken matte sometimes can be modified in size to fit the action footage.

Film-to-Artwork

The tool for this method is basically an animation stand with an aerial-image projector installed on its side below the stand. A 45-degree mirror carries the projected image through the condenser lens above the mirror and brings it into focus at the same level as the animation cels. The serial image, in this case, is perceivable only through the camera lens. The cameraperson standing on the side can observe the image by placing a tracing paper on the peg unit; otherwise the image is imperceptible. A new addition to some of the recent electronic motion-control systems allows for an interlock horizontal rear-projection onto the artwork.

Many optical effects can be achieved through this method, particularly combining live-action footage with artwork, where the movement of animated artwork has to correspond to that of the live-action frame by frame. The projector which is equipped with registration-pin movement carries color positive or separation masters. The camera carries color negative stock. The artwork, which has a self-matting function, is illuminated from above front. The top lights have no effect on the background image since there is no reflective surface involved in the projected aerial image. Nevertheless, polarizing filters are recommended for the top lights to eliminate multi-reflections from the field lenses.

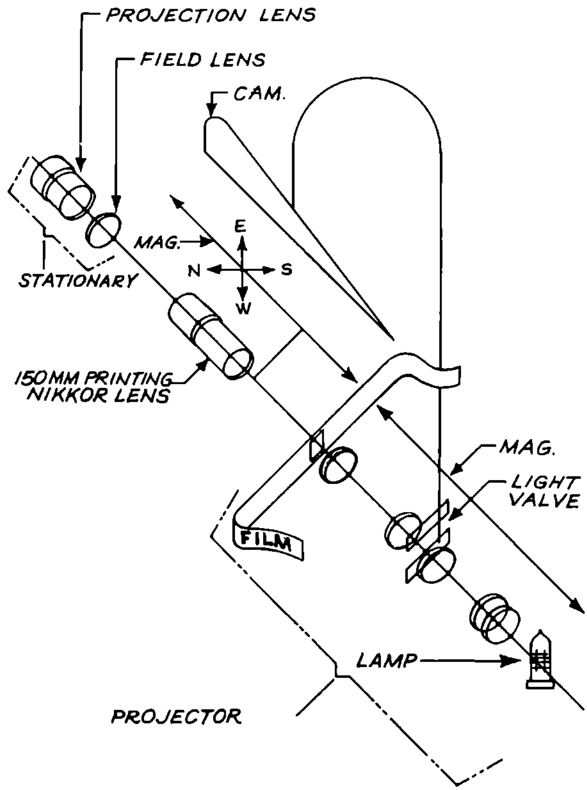
By cross-wedging the artwork together with its background image, the proper exposure and filter combination is achieved for each element. The color aberrations often observed in such tests are normally due to improper flatness of cels. It is essential, therefore, to select the proper material for this purpose. Kodak Triacetate #21 has demonstrated considerable stability with respect to this problem.

Film-to-artwork aerial-image cinematography has its own disadvantages. The camera-field lens-projector in the aerial-image animation stand should be considered a single optical system with a fixed central optical axis. The aerial image must be centered on the condenser lenses and in sharp focus on the cel area. The camera lens must be centered and focused from the proper distance to cover the field condenser lenses. Any deviation of the aforementioned elements can produce less-than-satisfactory results.

Aerial-Image Zoom for Oxberry Animation Stand

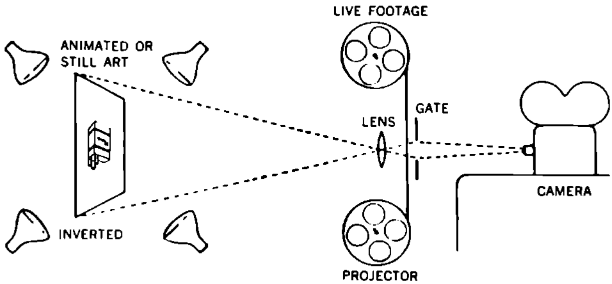
Although it is not possible to zoom the camera while using an aerial image on an animation stand, it is possible to zoom the aerial image itself. The area taken by the camera lens will still be the same 10 ½ field of the table top condenser, but the aerial image generated will be a zoomed version of the frame in the aerial-image projector.

To generate a zoom aerial image, the standard aerial-image projector is replaced by an aerial-image configuration very similar to that of an optical printer. A 150mm



AERIAL IMAGE PROJECTOR ZOOM

printing Nikkor lens is used to enlarge or reduce the frame by over four diameters and this image is then projected by a system consisting of a field lens and a projection lens. The projection lens system must stay at a fixed position to generate the aerial image, but the 150mm lens and projector can be moved to enlarge or reduce the generated image. The zoom aerial image unit is available with an automatic follow-focus system. In order to keep the light intensity constant during a zoom, an automatic lightvalve system is also available. This lightvalve operates off a cam that is shaped to keep the intensity of the projected image constant over much of the zoom range.



Object-to-Film

This method allows the aerial image of an actual object to be composited with live footage. The required tool is an aerial-image optical printer in which the aerial projector is replaced by a standard animation plate mounted some ten feet away from the main projector. This distance allows adequate reduction of an object mounted upside-down on the ground glass while permitting sufficient depth of field for sharp focus through the aerial-image lens installed behind the main projector aperture. In one pass, the footage in the main projector is recorded while the object is backlit, thus appearing as a silhouette whose background illumination serves as printing exposure for the film. The footage is then removed, and the object backed by a black card or velvet is then frontlit and photographed on the same piece of film. The result appears as a matte shot with a perfect fit.

In order to achieve a well-balanced exposure and contrast, both the object and the footage must be cross-wedged. As with "Film-to-Artwork" previously described, the projector film must be color positive or separation masters. The background exposure can be filtered behind the main projector aperture, or large filters can be mounted directly in front of the light sources or behind the animation glass. When front-lighting the object, adequate attention must be paid to the contrast. Flat lighting is preferable, since a real object is photographed with a prerecorded film.

This method can also be used for combining animated art work with live-action footage. However, because of the lack of requirements for depth of field in the artwork, an aerial-image animation stand may prove less cumbersome for this particular purpose.

Special Techniques

Aerial Cinematography

by Jack Cooperman, ASC

Motion pictures often require scenes photographed from the air, principally utilizing fixed-wing planes and helicopters.

In addition, there are occasional demands for shots made from gliders, balloons, and while skydiving. Many fixed-wing aircraft have been adapted for various camera mountings.

When photographing air-to-air it is necessary to consider which camera aircraft is correctly matched to the aircraft being pictured in regard to safety, speed and maneuverability. The cinematographer must also decide what is the right kind of camera mount for the job, budget and type of camera ship available.

Most fixed-wing aircraft permit operating the camera from one side or another. An exception would be specially adapted aircraft with a photographic nose section and/or open tail. In any type of fixed position, rigid mounting is desirable to minimize vibration. All screws, nuts and bolts should be safety wired or taped.

The Astrovision system permits the use of a relay lens unit through either the top or bottom of a Lear jet. Zoom lenses cannot be used with this system. The maximum lens opening is f/6.3/T-7.2. The Vectorvision unit, another relay lens system, will zoom as well as roll the horizon 360° with a maximum lens opening of f/2.8/T-3.

Helicopters are highly favored for aerial photography; they permit a large range of movability and air speeds. Tyler Camera Systems is a major manufacturer of helicopter mounts; a listing of these and other makes are found on page 256. The door/side mounts allow for free movement of the camera in all axes as well as control of camera and zoom lens functions while using the mount. Tyler has two size mounts; Middlemount for video, Arri 16mm, Arri IIC, Arri 35 III; and the Majormount, for Arri IIC, Arri 35 III, Mitchell Mark II (with special horizontal magazine adapter), as well as Imax, VistaVision, 65mm and other heavier camera packages. Continental Camera also has the M & M side mounts for most video, 16mm and 35mm cameras. The Magnum Elite mount handles camera packages up to 100 pounds.

Various belly mounts (which fit under the helicopter) are available. A quick mount/release nose mount by Tyler Camera Systems offers remote controls and camera readouts including tilt and video-assisted viewing. Larger than normal formats such as VistaVision, 65mm Imax, Omnimax, etc., need to be mounted fairly far forward to clear the skids and nose from the field of view. Most nose and belly mounts require the use of a prime lens or a very short range zoom. Zoom lenses should have remote controls for focusing as well as focal length adjustment. Remote aperture control is advantageous on all lenses. The Wescam, Spacecam and other ball mount units incorporating gyroscopic and remote control operation are especially useful for making extremely undercranked shots, long lens shots, and obtaining certain angles not available from other mount positions.

Tyler has a new, three axis gyro-stabilized ball type mount (Skygro). Compared to previous mounts of this style, the Tyler gyro mount has a faster pan and tilt rate and is designed to allow the helicopter unlimited flight maneuvering. The mount can be automatically locked into position, which allows the shot to go from gyro-stabilized and level to becoming part of the helicopter and going off-level as a POV of the helicopter. The mount does not have a separate outside housing and window like previous mounts of this type, thereby eliminating any chance of seeing reflected light on the inside of the window.

Skydiving cinematography is done by specially qualified skydivers, usually wearing a helmet-mounted camera or cameras. The most common 35mm camera used for this purpose is a modified and motorized Bell & Howell Eyemo.

Incident light readings can sometimes be taken in aerial situations. It may prove necessary to have the pilot turn or tilt the aircraft for this purpose. Most exposures are based on a consideration of spot meter readings and calculation of subject gray scale. Light conditions may change during a shot.

The pilot of the aircraft has to understand the shot and how the cinematographer plans to photograph the scene. He will be flying the aircraft for the positions needed. It is not usually safe for the cinematographer to directly control an aircraft being photographed; he should communicate through the pilot of the camera ship to the other pilot.

When working in the United States it is important to know that there are Federal Aviation Administration regulations requiring certification of anything that is added to an aircraft. (Most other countries have similar regulations.)

1. 337: Field inspection of a specific mount on a specific aircraft must be done before each use.

2. STC: Allows mounts on any number of a particular make and model of aircraft.

Before the flight, pilots, camera crew and all other concerned parties should discuss all shots for safety and efficiency. Familiarity with the safety guidelines set up by the Industry Wide Labor Management/Safety Committee is essential.

Guidelines: Fixed-wing Aircraft, Helicopters, and Skydiving

1. Except where necessary for takeoff or landing, the FAA prohibits the operation of an aircraft below the following altitudes:

   A) Over Congested Areas
   Over any congested area of a city, town or settlement, or over any open air assembly of persons, an altitude of 1000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft.

   B) Over other than Congested Areas
   An altitude of 500 feet above the surface, except over open water or sparsely populated areas. In that case, the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure.

   The pilot must obtain a proper waiver before operating an aircraft in the situations outlined above. Thus, the pilot must either have his/her own FAA-approved motion picture manual or operate under an FAA-approved company manual. A certificate of waiver, which is usually incorporated in the manual, must be in effect.

2 A) Before a stunt or sequence is to be performed all persons involved shall be thoroughly briefed. There should be a dry run on the ground at the site.

B) Per FAA guidelines, the persons necessary for the filming will be briefed as to any potential hazards and safety questions prior to the filming.

C) A pre-planned stunt will not be changed in any way without the authorization of the pilot and the aerial coordinator, if any.

D) If there is a question as to the safety of any aerial filming sequence involving low, over-the-camera shots. a briefing will be held between the pilot and concerned persons as to whether the use of a locked-off camera is necessary.

3. Only persons and crew necessary for the purpose of filming will be in the area. FAA regulations require all other personnel to be five hundred (500) feet away from the flying aircraft. All persons without written or verbal permission shall be excluded from the area.
4. Communication between ground and air must be maintained at all times during the operation of the aircraft.
5. Where required by the FAA-approved manual or appropriate governmental agency, there will always be an aerial coordinator on the ground when an aircraft is in the air or taxiing. An aerial coordinator will be appointed by the holder of the manual or the designated chief pilot.
6. If safety becomes a question at any time, the aerial coordinator or the involved pilot shall have the authority and responsibility to call an abort of the operation.
7. A) Aircraft engines shall not be started and the aircraft shall not be taxied in spectator, cast or crew areas unless appropriate measures are taken to preclude creating a hazard to spectators, cast or crew.

   B) Cast, crew and equipment shall be protected from debris thrown back by airplanes taxiing or taking off.

   C) If an aircraft is being filmed with the engine running, adequate safety precautions shall be taken in connection with activity in front of the propeller. which includes designated ground personnel.

8. No smoking is permitted within one hundred (100) feet of the aircraft or support truck.
9. A) Aircraft structures can be damaged easily while on the ground. Never push, handle, sit on or in, or lay any objects of any kind on an aircraft without the pilot's permission.

   B) If a foreign object falls into or against an aircraft, report it immediately to the pilot or aerial coordinator.

   C) Never allow cast or crew to occupy an aircraft while engines are started or running, unless the pilot is in full command.
10. Each end of an operational runway or landing area should be cleared during take-off and landing and appropriate safety equipment when filming the take-off or landing.
11. Acrobatic maneuvers shall be conducted in a direction which will most nearly parallel the boundaries of the designated crew and equipment areas or in a direction away from such area.
12. The front of the studio call sheet should contain a statement to the effect that: "An aircraft is being used and will be flown in close proximity to crew and equipment. Anyone objecting will notify the production manager or 1st AD prior to any filming."

Helicopter Safety Procedures

1. Communication between ground and air shall be established at all times during operation of the helicopter using one ground contact.
2. The individual attached to the helicopter support truck shall be designated as the person to supervise safety around the helicopter.
3. No smoking within 50 feet of the helicopter.
4. Unless you are needed - remain at least 50 feet away from the helicopter.
5. Exercise extreme caution when working around helicopters especially when the helicopter engine is running. Leave and approach the helicopter from the front-with caution. At all times, keep your eyes and head forward.

6. Avoid rear and tail sections of helicopter at all times.
7. Never walk under tail section of helicopter.
8. Do not extend any equipment vertically into rotor blades, such as cameras, lights, sound boom, etc.
9. Carry all equipment parallel to ground within 50 feet of helicopter.
10. Pilots are the authorities concerning all helicopter operations-if you have questions ask them.
11. Never, under any circumstances, throw anything such as grip tape, clothing, paper, etc. around the helicopter-whether it is running or not.
12. The landing area should be cleared of debris and, where necessary, wet down.
13. Avoid rear area of helicopter at all times.
14. Protect your eyes as well as your equipment when helicopter is landing or taking off.
15. Plot plans and graphics will be prepared to locate landing sites, and location, as well as types of explosives or squibs.
16. The pilot in command will have final approval as to aerial traverse and hovering positions of the aircraft.

Safe Practice: Parachuting, Skydiving

The following recommendations and guidelines are to aid in the promotion of safety with respect to parachuting and skydiving film sequences. Adjustments may have to be made in any given case as circumstances warrant for the safety of the persons involved in the parachuting or skydiving activity or on the set or location.

1. Radio communications shall be maintained between the aircraft carrying the jumpers and the landing site at all times. Ground signals (Smoke, panels, etc.) shall be provided as a backup.
2. The "parachuting coordinator" shall be a qualified jumper. When only one jumper is employed, that jumper should be the coordinator.
3. The parachuting coordinator shall determine whether or not security is necessary to exclude nonessential crew and non participating spectators

from the landing area. Open field landings may not require security.

4. The producer shall require each parachutist or parachuting coordinator to hold a United States Parachute Association professional exhibition rating, or present satisfactory evidence of the necessary experience, knowledge and skill required to attain this rating. USPA Exhibition Ratings are issued to members who have a Class D license who have accomplished 10 successive pre-declared jumps into a 10-meter (32 foot) diameter target area, landing not more than 5 meters from target center. All landings must be made standing up.

   A minimum of 350 jumps on the canopy type to be used is recommended.

5. Parachutists who hold a USPA Class D license with an Exhibition Rating, who certify that they will use a steerable square main and reserve canopy, will be permitted to exit over or into a congested area. The selected landing area must permit the jumper to land not closer than 16 feet from any spectator and will not involve passing over non-participating persons on the surface at an altitude of less than 50 feet.

6. All jumps shall be conducted in accordance with Federal Aviation Regulations Part 105.

7. The parachuting coordinator will determine whether or not the visibility, cloud ceiling height and velocity of wind, as it applies to the particular situation, is safe or unsafe. (Landing area size, canopy type, number of jumpers and planned stunt will be taken into consideration.)

8. Before each jump is to be performed, all persons involved shall be thoroughly briefed. There should be a dry run on the ground at the site.

9. All equipment, props, wardrobe, etc., shall be made available to the coordinator prior to the stunt/jump for safety evaluation. Final safety approval rests with the coordinator with respect to equipment and wardrobe used in the jump.

10. The coordinator shall have the responsibility to temporarily hold or cancel the authorized opera-

tions if at any time the safety of persons or property on the ground or in the air is in jeopardy or if there is a contravention of the terms or conditions of any FAA letter of authorization.

11. The FAA requires that each reserve parachute be packed by an appropriately rated parachute rigger. If a parachutist has a malfunction on the job and uses his reserve chute, a spare parachute or the presence of a certified rigger can usually save many shooting hours.
12. All operations involving fixed wing aircraft and helicopters shall conform with the guidelines established by the Labor Management Safety Committee.
13. All pilots must be familiar with the dropping of jumpers, including the peculiarities of the operation to include flight with the door removed, FAR Part 105, rehearsals of all exits, all ground signals, signals to abort jump, pilot's responsibilities, provisions of all Letters of Authorization or waivers. The pilot must analyze weight and balance of the aircraft with jumpers in exit position.
14. Jumps near or into potentially hazardous landing areas (water, power lines, etc.) should be considered carefully.

    Pickup boats and flotation gear should be available when the possibility of a water landing exists and each boat pilot shall participate in the pre-jump briefing.

    On intentional water jumps there shall be one pickup boat for each jumper.
15. Lighting for night shots should be reviewed with the Parachute Coordinator. The landing site for a night shot should be viewed during daylight hours before jumping.

    All the above guidelines and procedures are intended to conform with applicable laws and governmental regulations and in the event of any conflict, applicable laws and governmental regulations will prevail.

Underwater Cinematography

by Jack Cooperman, ASC.

All good underwater cinematographers must have one thing in common: they must also be experienced divers. It is not enough to put good cinematographers underwater and expect good results. They should be good enough divers with enough experience underwater to enable them to be unconcerned with diving techniques. They must be at ease with the camera under all conditions, anticipating being swept around the ocean floor and still be able to operate the camera efficiently.

And it is well to remember that underwater filming can be — and often is — hazardous and difficult. Experience underwater counts for a great deal.

Not enough can be said regarding safety. Knowledge of diving physics, awareness and common sense are mandatory. Following are the safety guidelines set by the Industry-Wide Labor Management Safety Committee for situations where scuba equipment is used in filming:

1. The finalization of an underwater location shall depend upon the safety and health conditions of the location as determined by supervisory film industry personnel, one of whom shall be a certified diver in consultation with the director.
2. Any person using scuba equipment while filming or being filmed underwater shall be a certified diver, with the exception of players who are essential for an underwater close-up. When this exception arises, for safety reasons, these players shall be under the supervision of a currently certified instructor, and shall have received sufficient instructions for the job at hand. The appropriate depth for safe filming shall be determined by the certified instructor supervising the safety of the player or players. Players who are not certified divers shall not be required to work in depths in excess of ten feet.
3. All safety divers shall be duly certified and when scuba is used, he or she shall be equipped with an alternate air supply, i.e., Octopus or bail out bottle, etc.

4. Any person performing a stunt where water safety is involved shall require properly equipped safety diver or divers.
5. Any person performing a stunt where the possibility of being trapped underwater exists shall have stand-by breathing equipment immediately available.
6. For dives below 30 feet each individual diver shall be concerned with following his or her decompression procedure as necessary and safety rules shall be available at appropriate departments and on the job site.

   a. Any individual designated to log dives shall be a certified diver and shall be knowledgeable as to proper logging procedures.

   b. The company will determine the nearest location of decompression chamber and methods of transportation to that chamber and notify all concerned persons.

   c. Functional recall system equipment shall be made available on site.
7. It shall be the responsibility of the company to ensure that any persons using re-breathing equipment or mixed gas systems will have been properly trained in the use of the equipment.
8. Scuba tanks when transported to and from location will be secured in such manner as to prevent them from rolling or allowing the valves to be struck by other objects.
9. When not in use, scuba tanks shall be equipped with valve covers and shall be stored in the shade.
10. Adequate medical oxygen (100% oxygen) and resuscitation equipment shall be available at all times when scuba equipment is in use. Do not use the air in the scuba tanks as they do not contain 100% oxygen.
11. No electrical power other than DC shall be used in the water or in a vicinity which could lead to contact with the water.

In filming underwater theatrical or television productions the cinematographer is concerned with telling a fictionalized story rather than photographing a real experience such as a scientific expedition or a documentary film. When working with a script, actors and a director, and being confined to telling a story the situation does not always permit the freedom to photograph scenes of great natural beauty unless there is a place for them in the script. Filming may be done in a natural ocean location under optimum conditions or in a studio tank with all the facilities one usually associates with a studio operation. The key to a successful underwater production is planning. First, the director, and underwater cinematographer or director/cameraman and talent talk over the scenes above water. After blocking out the action, the players (or their doubles) walk through the action topside.

Entrances, exits and timing should be rehearsed so that everyone completely understands the scene to be photographed.

Sometimes the players are experienced enough in either skin diving or scuba diving to perform underwater scenes, but in many cases doubles or stunt people will be used. The same holds true with directors. If they are not experienced divers they may leave the actual filming to the underwater cinematographer.

Equipment

Any good professional-type motion picture camera can be adapted for underwater cinematography. Underwater films have been successfully made in all formats including 65mm and 3-D. There are many housing designs, both tubular and irregular cubic, for various purposes. For stability underwater they should have lightly negative buoyancy. Film capacity of 400 ft. is most commonly used in underwater camera housing design. Such functions as focusing, aperture, and camera speed ideally should be controlled outside the housing while operating underwater.

It is important to have easy access to the camera so that the lenses and/or filters can be changed or adjusted on deck. Film and batteries will need to be changed easily and quickly. It is a great advantage to have a camera which permits through-the-lens viewing and offers a clear, easily read image. A sports finder may be more convenient when fast action is being photographed.

The camera ideally should be balanced in the housing so that the cinematographer can take a deep breath and go up or exhale and go down with it. Cameras are quite mobile underwater.

The cinematographer can become a crane or dolly because of individual requirements and familiarity with the equipment, many of the people who make a specialty of underwater photography design and/or own their own equipment.

Lenses and Lens Ports

Ports are available both with a flat surface and as a corrected dome. With a flat port the magnification created by the water (air to water refractive index is 1.33) causes the camera lenses to assume the characteristic of slightly longer lenses and objects appear closer by ¼. The corrected dome port permits the lenses to function with their true focal lengths. The dome radius is critical and its center must be on the nodal point of the lens to function correctly, if not diopters will be necessary, usually a +2 will bring objects into proper focus. The dome port can be of advantage when working in areas of low visibility or in a confined space or with extremely wide-angle lenses.

Both glass and plastic ports are available. Glass can be more perfect optically and it is virtually scratch-proof. Plastic is stronger, but is vulnerable to scratching (a scratch on the outside of the port will be filled by water and not be apparent, but a scratch on the inside is a different matter). When the housing is used above or at split level with the water, the front port (preferably flat) can be kept clear of water drops with the use of a wetting agent. Wide-angle or short focus lenses are usually preferred because of the magnification due to water, and the necessity to work close to the subject because of scattering and absorption of light by the water. The increased depth of field afforded is also a factor. For 35mm film, a commonly used lens is the 16mm Zeiss Distagon, and for extreme wide-angle, a 9.8mm is useful, although distortion is more apparent; a dome port is recommended for this lens.

Other lenses up to 75mm are useful for close-ups. Corresponding lenses for 16mm photography are 10mm and 8.9mm; the 10mm is relatively distortion free. For 35mm anamorphic photography, the 30mm and 35mm lenses are preferred. A flat port is recommended for anamorphic lenses. Accurate underwater focusing presents no problem if the distance is judged by eye; if the distance is measured by tape, the lens is focused at 75% of the measured distance (with no diopter).

Care Of Equipment

At the end of a day's work and if possible when changing magazines the camera housing should be washed off with fresh water. This will help preserve the housing and will also minimize the chance of salt spray damaging the camera mechanism and in particular the lens. When the camera and housing are removed from the water they should be immediately placed in the shade. This is especially true in the tropics where even a minimal exposure to the sun can cause heat inside the camera housing to damage the film.

All film manufacturers now have faster, finer grained negative emulsions available in 16mm, 35mm and 65mm. Negative stock is preferred for underwater work over reversal films as it has a greater exposure latitude and yields better prints. It also transfers well to tape and is ideal for television production. For direct projection of the original high speed reversal color films are available.

The Environment

Even under the best possible conditions, filming underwater presents the cinematographer with numerous photographic problems not encountered on land. Atmospheric haze, with the accompanying desaturation of the warmer color tones, loss of detail and contrast, has its underwater counterparts in turbidity and color cast. Turbidity, caused by suspended matter varying from small sand particles to microscopic organisms such as plankton, reduces light by absorption, diffuses the image, and reflects direct front light into the lens ("backscatter"). Turbidity affects the quality of underwater cinematography more than any other factor. Visibility may be reduced from many feet to just a few, and vice versa.

Water absorbs the longer wavelengths of light (reds and yellows); therefore, the farther the light must travel from source to subject to lens, the less reds and yellows will register on the film. This can be partially overcome by artificial lighting and sometimes by selective use of Kodak color compensating (CC) lens filters. Photographic tests with these filters is suggested. Loss of color contrast resulting from the selective filtration of underwater light can be reduced through careful subject color selection.

This will apply to underwater sets, props and even the type of wardrobe worn by actors. Color interest may be added to objects beyond the range of red or orange transmission through the use of bright blue, green and yellow. White must be used with care because its reflective qualities together with underwater scattering will produce a haze effect. (Underwater visibility of production equipment can also be increased by giving it a bright chrome yellow finish.)

Natural Light

Optimum underwater cinematography is usually obtained to a maximum depth of 50 ft. At greater depths things appear more monochromatic. There are also more diving problems and camera housings are subject to greater stress. Natural light reaches the ocean's surface either as direct rays from the sun or as light diffused by clouds or other atmospheric conditions such as dust and water vapor. A clear, sandy ocean floor is a great asset to good underwater camera work because underwater light is reflected from the ocean floor back into the water. When shooting underwater in daylight conditions with tungsten (3200K) film, without additional lighting, it is advisable to use a #85 camera filter. This subtracts some of the blue from the water, permitting a truer rendering of skin tone on humans in the scene. If the negative is fully exposed, some further correction may be possible in printing from the negative.

The intensity of daylight for underwater filming depends also upon the amount lost by reflections from the water's surface.

This depends on such variables as sun angle, surface roughness, and cloud cover. The light loss due to reflection is least when the sun is directly overhead and does not start to become a problem until the sun is below an angle of about 30 degrees. In the latitudes of the United States, sun height is generally optimum between 9 a.m. and 3 p.m. in the summer and 10 a.m. and 2 p.m. in the winter.

Artificial Lighting

Underwater lighting is often necessary or desirable both in studio tank conditions and in the open sea. Fill and set lighting for performers, night effect filming and other conditions that require special lighting are often a part of underwater work. The use of artificial light is an excellent method of restoring or correcting color in underwater cinematography. The effect of underwater filtering varies from area to area, but as a general rule red is lost at about 10 feet. Using artificial lighting will often add the necessary color compensation needed to record an underwater scene more accurately. A number of excellent underwater lamps are currently available on the market. Tungsten halogen units are available in 2000 watt and 1000 watt sizes, with aluminum reflectors in a pressure resistant housing. Smaller lamps, usually battery powered, are also available. These units are generally 250 watt and are useful in shooting very close to the subject or as a fill light. Specially constructed HMI units are also available, extra care and ground fault interrupt protection is necessary due to AC power source.

Large underwater areas can also be illuminated by suspending lights from an overhead grid or netting stationed at the proper depth by means of floats and anchors. Submerging them minimizes movement of the light due to wave action.

Lighting and Exposure

Lighting underwater is similar to topside lighting, except that cross lighting is preferable to front lighting. Front lighting should be avoided because it lights turbidity "backscatter." The exception to this is in crystal clear water where a front light can be used without difficulty. Front light sometimes can be used for fill.

Either a reflected or incident exposure meter is satisfactory. When taking an exposure reading at the subject, remember that water acts as a filter so one must compensate for the distance between the camera and the subject and adjust accordingly. A rule of thumb is ¼ to ½ stop. An underwater reflected light meter which works on a gray scale principle, such as the Sekonic Marine 164B is ideal. This type of meter requires no calibration after the shutter speed and the ASA rating have been set.

Under daylight conditions, exposures are based upon the reading of the general area in which the scene is staged. The reflected light reading is made from alongside the camera and directed toward the action. The importance of the angle of the shot as a factor in calculating exposure cannot be overemphasized when working in ocean waters; there will be exposure variance for up, down and horizontal moves.

Night Effects

Simple underexposure can produce acceptable underwater day-for-night photography. Liaison with the laboratory should help in producing the desired night effect. Underexposure tends to increase the saturation of underwater colors and accentuates the blue component of open water in the background, thereby enhancing the night effect. The illusion can be intensified if light ripples from the water surface are allowed to play across the scene. Scattering will cause them to appear as tiny light beams moving through the water. When shooting night-for-night, overhead lighting can be utilized for a moonlit effect

Studio Tanks

Much underwater production photography may be done in studio tanks. These tanks will vary in size and may either be constructed inside a sound stage or built outdoors on the studio back lot. They are usually about 40 or 50 feet in diameter with depth ranging up to 14 or 15 feet. Outside tanks are generally built above ground, sometimes with provision for a painted backdrop.

Most tanks are equipped with straight or reducing ports from which cameras can be set up to shoot into the tank. The straight port is a flat window looking into the tank. Reducing ports are primarily used in photographing miniatures or shooting into a confined underwater set. They are concave glass providing an angle similar to that of a wide-angle lens, also permitting more leeway in panning. The glass should be crystal clear. Since tanks are located within the confines of the studio there is ample provision for using all types of studio lighting units. Inside the tank smaller units such as those previously mentioned may be used.

Miniatures are usually photographed in a tank and the same rules for filming speeds apply as in topside miniature photography. In filming miniatures, to simulate deep water, it is important to reduce light ripples by stretching a scrim over the tank or letting it float on the water. The deep ocean has no ripples. Light that has not been diffused will cause water ripples and give away the depth of the water, thereby destroying the illusion. Incidentally, even though tanks are equipped with shooting ports the best angles and camera movements are obtained by diving into the water with the camera just as if on a natural sea location.

Safety Bulletin No. 8: Guidelines for Insert Camera Cars

1. An Insert Camera Car shall be a vehicle that is specifically engineered for the mounting of cameras and other equipment for the primary purpose of photography from a stationary or moving vehicle.

2. A camera car shall be safety checked before and after use on a minimum of a daily basis by qualified experienced personnel — specifically brakes, tires, electrical system and towing equipment.

3. All rigging of equipment shall be done in a safe manner by qualified, experienced personnel.

4. An Insert Camera Car used for night filming shall be provided with two portable tail lights which will be affixed to the towed vehicle to provide rear lighting in cases where said vehicle's lights are not operative.

5. Maximum passenger allowances — Operation of Insert Camera

   Cars Transporting Production Personnel: All involved personnel should be made aware that, as mandated by the California Administrative Code: The number of employees "... transported on vehicles ... shall never exceed a number which may endanger the safe handling of the vehicle..." Accordingly, the Industry Subcommittee to Investigate Safety Aspects of Insert Camera Cars herewith recommends the following maximum be applied when transporting personnel by Insert Camera Cars (during rehearsal and principal photography sequences): That number should never exceed nine (9) including the driver. In addition, it is strongly recommended that any person not directly needed for actual shot sequence <u>Not Be Allowed on The Vehicle At All.</u>

6. Equipment not essential to the shots in progress shall not be transported on the Insert Cars.

7. Communications regarding Insert Cars shall be preceded by a meeting on the site of the event with all people concerned. This meeting should include a "walk-through" or "dry-run" with the driver and all of the persons involved in the event. An understanding of the intended action, possible deviations and authority to abort should be made clear. Following the above and before rolling cameras, should any substantive change become necessary, the director will again call all persons involved in the shot to another meeting to confirm everyone's understanding and agreement to said changes.

8. Rear towing — no personnel not being photographed shall be on towbar or exterior of towed vehicle. This does not include towed camera platforms such as trailers designed for said work.

9. It shall be mandatory that a copy of these rules be in the glove box of the vehicle at all times.

10. It is recognized that there can be unforeseen or unique situations which might require on-site judgment differing from these guidelines. Such judgment may have to be made in the interest of the safety of cast and crew.

Arctic Cinematography

Most of the difficulties encountered when using motion-picture equipment in the Arctic are caused by extreme cold and very low relative humidity. Average temperatures may vary from 45° F (7° C) to -45°F (-43° C), temperatures as low as -80° F (-62° C) have been recorded. (Such low temperatures may also be encountered at very high altitudes.)

The lubricating oils usually used in photographic equipment in more temperate climates will congeal in an arctic environment so that moving parts of cameras or other equipment will not operate. Leather and rubber also become brittle at these temperatures. With motion-picture films, loss of moisture from the film emulsion when the original packing material is opened may result in film emulsion shrinkage and brittleness, and subsequent film curl in the camera gate. Such difficulties are not minimized by using films with a polyester base unless these films (or those with a triacetate base) have a gelatin coating on the support to compensate for emulsion shrinkage. It is the effect of the very low relative humidity (less than 5%) and its emulsion drying characteristics that produces film curl. (Small heaters are sometimes used in cameras to prevent film brittleness when working under conditions of extreme cold, but under certain conditions this practice could actually increase the chance of emulsion shrinkage by further reducing the relative humidity in the film chamber.) The film speed is also lowered by extreme cold and may be about one lens opening slower at -50° F (-46° C) to -70° F (-57° C) than at 60° F (16° C). Film becomes progressively more brittle as the temperature drops below 0° F (-18° C), but there is no marked change at any one temperature. Even at sub-zero temperatures, film emulsion that retains its proper moisture content in the original package (equivalent to equilibrium at 40 to 60% RH) is more flexible than film that has been allowed to become too dry. Film can also be bent with the emulsion side in with less chance of breaking than if bent with the emulsion side out. Whether the film emulsion cracks or the film support breaks at very low temperatures depends on (1) how soon the film is exposed after removal from the original package; (2) the care taken in handling the film; and (3) on the type and condition of the camera in which it is used.

Temperatures generally encountered in the Arctic will not cause polyester base films to break.

Preparation Of Equipment

While the difficulties of photography under arctic conditions can be severe, they are by no means insurmountable. Careful advance preparation will pay rich dividends in the form of easier and more reliable equipment operation and better pictorial results. The first step in preparing for filming in the Arctic, high mountain regions, or in unheated aircraft at high altitudes is to select the most suitable equipment with due regard for the work to be done and the results desired.

Each kind of camera has its adherents, and no one type seems to be outstandingly superior to the others. However, considering the working conditions, good judgment dictates that the camera or cameras selected should be compact, lightweight, easy to use, dependable, adaptable, and portable. In choosing a 16mm motion-picture camera, many arctic explorers prefer the ease and convenience of magazine loading. Threading roll film can be very difficult under conditions of extreme cold. Certain camera models are advantageous for low-temperature use because large-radius bends in the film path and low film accelerations help prevent broken film. For best protection of the film emulsion at extremely low temperatures, film travel rollers should have a diameter no smaller than ½ in. (13mm). Electric power, if available from a reliable source such as a generator or vehicular power system, is more dependable than spring-driven or battery power. However, under field conditions, a spring-driven motor may prove more reliable than an electric motor drive that depends on portable or storage batteries which can fail when subjected to extremely low temperatures.

Cameras should be winterized for satisfactory service under frigid conditions. Some camera manufacturers provide a winterizing service for cameras that are to be used at low temperatures over a long period of time. Winterizing is a highly specialized operation, best entrusted to the manufacturer or a competent independent camera service representative. Essentially, the procedure calls for dismantling the camera and removing the original lubricants. The shutter, lens diaphragm, film transport mechanism, and other moving parts are then re-lubricated with materials that will not thicken when the camera is exposed to extreme cold. Powdered graphite is in some cases still used for this purpose. However, so-called "broad-range" lubricants (such as Teflon and silicone) are becoming increasingly popular, not only because of their effectiveness at low temperatures, but also because they can be left in the camera permanently. In fact, such lubricants are being used in manufacture. Hence, a camera that has been lubricated with a broad-range lubricant, either in manufacture or as part of a winterizing operation, need not be de-winterized and re-lubricated when it is returned to use under normal conditions. When cameras are stripped down for winterizing, weakened or damaged parts may be discovered and should be replaced to avoid possible failure under the extra stress of severe arctic temperatures.

It is also sometimes necessary to machine parts to allow greater clearance between components. This is because aluminum and certain alloys have greater coefficients of thermal contraction and expansion than steel. Since small levers and knobs on cameras are difficult to operate when the photographer is wearing thick gloves, extensions can sometimes be added to levers, and small knobs can be replaced with larger ones.

It may be helpful to run even recently winterized motion-picture cameras for a period of three or four hours to break them in thoroughly. A piece of film three or four feet long can be spliced end to end (to form a continuous loop), threaded into the camera, and allowed to run during the breaking in. In cameras intended for use with film magazines, the loop should be formed in a dummy magazine. After the breaking-in period, the camera should be checked for speed and general behavior. It should be noted that, although magazine-type motion-picture cameras can be winterized, the magazines themselves are not winterized and may jam under conditions of extreme cold. If film magazines are used, each day's working reserve carried into the field should be kept as warm as possible under the cinematographer's parka. Another possibility is to carry the film supply in an insulated thermal bag, along with one or two small hand warmers.

Before your location shoot, a test run should be made in a refrigerator or freezer capable of reaching temperatures as low as -30° F (-34° C) or -40° F (-40° C). Even "winterized" cameras can fail in use because some detail was overlooked in preparation, so this final test run is quite important. The film and camera should be cooled for at least 24 hours prior to the test. This long period of pre-cooling is often overlooked, and the test becomes invalid.

Motion-picture cameras should be given as much protection from icy winds as possible during use. When battery-driven motors are used on cameras, the motors and batteries should be kept as warm as possible. A flat black finish on the cameras has some advantage in the Arctic because it absorbs heat when the sun is shining. Covers made from black felt material or fur and fitted with eyelets or other suitable fasteners protect the camera from frigid winds and help to retain its initial warmth for a time. Snaps and slide fasteners are not recommended for use in sub-zero temperatures. Small magazine-type motion-picture cameras can be hung inside the coat to obtain some warmth from the body; you may even need to wrap a chemical heating pad around the camera. Inspect the camera's lens each time it is removed from the clothing to take a picture. The amount of "body static" generated under cold, dry conditions can cause the lens to attract lint from the clothing.

Tripods should also be conditioned properly for use in the Arctic. When lubrication is required, there are oils available for use at temperatures down to -70° F. Tripod heads for motion-picture equipment should be winterized if they include gyros, motors, or other revolving parts. As noted previously extreme cold causes leather and rubber to become brittle. A wax leather dressing of good quality should be rubbed into leather carrying cases and leather-covered cameras to prevent the absorption of moisture. Rubber should be eliminated wherever possible.

Silk or lightweight cotton gloves under heavy woolen mittens are recommended. Gloves or mittens made from unborn lambskin are excellent for arctic weather. Silk gloves will keep the hands warmer and will afford considerable protection when the outside mittens are removed for loading the camera, adjusting the lens, etc.

Equipment and Filming Technique

In the Arctic or on mountain climbing expeditions, as the altitude and the subsequent cold increase, breathing becomes difficult, and it involves a great effort to work normally. Reactions are slow. Therefore, everything pertaining to the use of the camera should be made as simple as possible. Exposure estimates may be poor when the faculties are dulled, so exposure and other data should be printed on a card and fastened to the camera or its cover in plain view.

Certain general cold-weather recommendations are in order for any camera, still or motion-picture. Breathing on a lens or any other part of the camera to remove snow or other material will cause condensation that freezes instantly and is very difficult to remove.

An important factor to keep in mind is the ever-present danger of frostbite, a particular threat when hands or face come in direct contact with the metal of the camera body. Cameras that are used at eye level and must be brought close to the face for proper viewing and focusing should have their exposed metal areas covered with heavy electrical tape, plastic foam, or some other insulating material. Under no circumstances should the photographer touch the camera or other metal equipment with ungloved hands, because the skin will freeze to the cold metal almost instantly. A painful loss of skin almost always results.

A thoroughly chilled camera cannot be used in a warm room until its temperature equals the surrounding warmer temperature. Conversely, a warm camera cannot be taken out into a blizzard because the blowing and drifting snow will melt upon striking the warm camera, and soon the instrument will be covered with ice. Loading film, even during a driving snowstorm, can be accomplished with the use of a large, dark plastic bag, big enough to fit over the head and shoulders.

A deep lens hood is very desirable for filming in the snow. It will help keep the lens dry even during a fairly severe storm.

Film

Great care must be used in handling film in sub-zero weather. The edges of cold, brittle film are extremely sharp, and unless caution is exercised, they can cut the fingers severely.

It is important that film be loaded and exposed promptly after removal from the original packing, not left in the camera for long periods of time. If motion-picture film is allowed to stand in the camera for a day or so, the film may dry out and break where the loop was formed when the camera is again started. The film is adequately protected against moisture loss as long as the original packaging is intact. When loading the camera, make sure the film and the camera are at the same temperature — if possible, load the camera indoors.

Static markings are caused by an electrostatic discharge, and they appear on the developed film emulsion as marks resembling lightning, tree branches, or fuzzy spots. When static difficulties occur they can usually be traced to the use of film which has a very low moisture content.

Static markings are not likely to occur if the film is loaded and exposed within a short time after the original package is opened. In general, field photography under arctic conditions involves subjects of extremely low brightness scale and very high levels of illumination. For this reason, high-speed emulsions are not generally used outdoors. The best choice of film is a medium-speed material such as Eastman

Plus-X Negative Film 5231/7231, Eastman Color Negative Film 5248/7248, Eastman Ektachrome Film (Daylight) 5239/7239, Agfa Color Negative Film XT100, Fujicolor Negative Film F 125 8530/8630, Fujicolor Reversal Film RT125 (16mm only-8427), or Fuji Negative Film FG 71112/ RP 72161. Exposures should be held to a minimum and overexposure should be avoided.

When pictures are to be made under low-level lighting conditions, such as at twilight, or indoors under existing artificial illumination, a high-speed film, such as Eastman 4-X Negative Film 5224/7224, Eastman Color EXR High-Speed Negative Film 5296/7296, Eastman Ektachrome High-Speed Film (Daylight) (16mm only-7251), Eastman Ektachrome High-Speed Film (Tungsten) (16mm only-7250), Agfa Color Negative Film XT32O, Fujicolor F 500 Color Negative Film 8570/8670, or Fujicolor Reversal Film RT 500 (16mm only-8428) should be used.

Storage

If a cold camera is taken indoors where it is warm and humid, condensation may form on the lens, film, and camera parts. If the camera is then taken back outdoors before the condensed moisture evaporates, it will freeze and interfere with operation; the condensate can also cause metal parts to rust. One way to solve this problem is to leave the camera, when not in use, in a room at about 32°F (0°C).

T. R. Stobart, who filmed the first conquest of Mt. Everest, prefers to seal the camera in an airtight polyethylene or rubber bag and then take the camera into the warmth of indoors. Any condensation takes place outside the bag, not inside, and the camera remains both dry and warm. This method has the advantage of keeping the camera from becoming "saturated in cold" for long periods of time. There is no problem in taking warm equipment back out into the cold, provided the snow isn't blowing.

When a camera is left in its case outdoors, the case should be made reasonably airtight. In the Arctic, blown snow becomes as fine as dust or silt and can enter the smallest slit or crevice. If allowed to enter the camera around the shutter or other moving parts, the snow will affect the operation of the equipment. The speed and timing of motors should be checked frequently. Batteries should be checked every day and recharged at a base every night, if possible.

Tropical Cinematography

Heat and humidity are two basic sources of potential difficulty when using or storing photographic goods in wet tropical climates. Heat alone is not the worst factor, though it may necessitate special equipment care and processing techniques and may shorten the life of incorrectly stored light-sensitive materials. High humidity is by far the greater problem because it can cause serious trouble at temperatures only slightly above normal, and these troubles are greatly increased by high temperatures.

Associated with these conditions are several biological factors — the warmth and dampness levels encountered in the tropics are conducive to the profuse growth of fungus and bacteria and encourage the activities of insects. Many photographic and other related products are "food" for these organisms — gelatin in films, filters, leather, adhesives, and so on. Even if fungus, bacteria, or insects cannot attack materials directly, they can develop an environment that can. Fungus can also either directly or indirectly induce corrosion in metals, attack textiles and leather, change the color of dyes, attack glass, and cause a great variety of other forms of deterioration. The probability of damage is greater with frequent handling and transportation, especially under the difficulties met in hunting and scientific expeditions and in military operations. Exposure to harm is greater when equipment is used out of doors, on the ground, or in makeshift facilities.

Atmospheric condition, with respect to moisture content, is usually described in terms of "relative humidity." This is the ratio, expressed as a percentage, between the quantity of water vapor actually present in the air and the maximum quantity which the air could hold at that temperature. Thus, if a given sample of air contains only half as much water as it would at saturation, its relative humidity is 50 percent.

When the temperature rises, a given space can accommodate more water vapor and hence, the relative humidity decreases, and vice versa. When air (or an object) is cooled sufficiently, a saturation point (100 percent relative humidity) is reached, and below this temperature drops of water or "dew" are deposited. In any locality, the temperature is much lower at high altitudes, so that dew is likely to form on objects following their arrival by air transport, especially when high relative humidity is present at ground level. In tropical climates, this "dew point" is often only a few degrees below the actual temperature during the day and is reached when the temperature drops at night.

The amount of moisture absorbed by films and by nonmetallic parts of equipment is determined by the relative humidity of the atmosphere. Therefore, the moisture absorption of photographic or other equipment can be reduced by lowering the relative humidity, either by removing some of the moisture with a desiccating agent or by raising the temperature of the atmosphere where the equipment is stored.

Extremes of relative humidity are a serious threat to all photographic materials, even at moderate temperatures. At high temperatures, the effects of high humidity are greatly accelerated, particularly if the relative humidity remains above 60 percent. Extremely low relative humidity, on the other hand, is not quite so serious, but if it falls below 15 percent for a considerable time, as is common in desert regions, an electric humidifier should be installed and set to maintain a relative humidity of 40 to 50 percent in the storage area.

Storage of Photographic Materials

Sensitized photographic materials are perishable products when stored under extreme conditions of high temperatures and high relative humidity. Proper storage is therefore important at all times. Fortunately, adequate protection of sensitized materials can be accomplished at relatively low cost and without extreme methods. Lightweight portable refrigerators or other cooling units are available from expedition outfitters and other similar equipment suppliers. Desiccants are available in bulk or kit form for reducing the moisture content of the atmosphere where film is to be stored. Further, portable electric dehumidifiers are also available to reduce the relative humidity in larger quarters, such as work rooms, to aid in the comfort of the occupants. And finally, the film packaging reduces the possibility of damage when the material is stored under recommended conditions. Usually, there will be little or no adverse effect to the film if it is stored and handled as described below.

Black & white films can be stored at normal room temperatures in an air-conditioned room. Color films should always be stored in a refrigerator at 55° F (13°C) or lower. To avoid moisture condensation on the chilled surfaces of the material, take film cans out of the cartons and allow 35mm rolls to warm up from 3 hours for a 20°F to 5 hours for a 75°F temperature rise above storage temperature. 16mm rolls take about ⅓ those times.

When the original packaging seal has been broken, films should be exposed and processed as soon as possible. Since the air in a refrigerator is moist, partially used packages should be returned to the refrigerator in a sealed container containing a desiccant to absorb the moisture within the container.

In general, do not keep more film than necessary in stock, particularly when good storage conditions are not available. Photographic materials can also be affected by the chemical activity of fumes and gases. Consequently, films should not be stored in newly painted rooms or cabinets. All films should be processed as soon as possible after exposure. If you are unable to do this for some reason, enclose the films in an airtight jar or can together with a desiccant and place them in a refrigerator. Exposed films can be kept for several days in this way.

Preparation and Protection of Equipment

To save time and avoid damage, cameras and other equipment should be made ready well in advance of departure. It is well worthwhile to have the equipment thoroughly overhauled and cleaned, preferably by the original manufacturer, who should be advised as to the type of climate in which it will be used. Cases, packing material, and moisture-absorbing material (desiccant) should be obtained for the equipment and supplies. Protection during transportation and storage is readily obtained by the use of hermetically sealed cans, metal-foil bags, or other water/vapor proof containers, and a suitable desiccating agent. If the containers have been properly sealed and contain an adequate quantity of desiccant, they will protect the contents practically indefinitely. There is, however, one reservation and caution: if precision instruments that require lubrication with certain types of light oils are subjected to high temperatures while in such packing, the oils may evaporate, leaving a gummy residue on the instrument bearings. This situation may prevent proper equipment functioning until the equipment can be cleaned and re-lubricated properly.

The protection of equipment that is in active use requires a somewhat different approach. The relative humidity can be lowered in an equipment storage cabinet that is not used for film storage by burning electric light bulbs or operating an electric resistance heating unit continuously in the lower part of the cabinet. The number of lamps should be adjusted to keep the temperature about 10° above the average prevailing temperature. Air spaces and small holes should be provided at the top and bottom of the cabinet and through the shelves to allow a slow change of air to carry off moisture introduced by the cameras and equipment. The positions of the holes should be staggered on the different shelves in order to produce a more thorough change of air. Since high relative humidity favors the growth of fungus on lenses, filters, and other surfaces, storage in such a cabinet will help reduce the fungus growth and may prevent it entirely.

Electric dehumidifiers are now appearing in stores in many of the larger cities in tropical regions. With these units, whole rooms and their contents can be dehumidified, provided they can be closed to outside air penetration. In dehumidified rooms, the humidity will not increase rapidly during short power failures, as it would in heated closets or cabinets. In a small, tightly sealed room, an average unit in operation for 12 hours out of 24 can keep the relative humidity below 60%. This should be checked about once a month with an RH meter or sling psychrometer. When it is not practical to use a hot cabinet or electric dehumidifier, equipment should be stored in an airtight case containing plenty of desiccant. Two cans of silica gel the size of shoe-polish cans will do a very good job of drying equipment in a sealed ten-gallon paint can (one with a gasket and a "pound shut" lid).

A half-pound bag of silica gel works well in a gasketed 55-gallon "open top" drum that can be sealed with a cover. However, where shipment and handling are involved or where the containers are to be opened briefly a few times, double or even triple the quantity of gel will provide a reserve of protection. Properly dehydrated containers will momentarily feel cool to an inserted hand due to rapid evaporation of the normal skin moisture. The sensation is brief, but can be easily detected if one is looking for it. Its absence means the silica gel needs replacement or regeneration.

If none of these methods are practical, and the equipment must of necessity be left in an atmosphere of high relative humidity, the equipment should be opened and exposed to the sun at frequent intervals in order to drive out moisture. The exposures, however, should be kept short in order to avoid overheating. Cameras loaded with film should not be exposed to the sun any more than necessary.

Cameras should always be protected from excessive heat because many of the lenses used on cameras are composed of several elements of glass cemented together. Because some cements melt at 140°F (60°C) and begin to soften at 120° F (49°C), it is obvious that the lens elements might become separated or air bubbles might form if the lens were heated to such temperatures. Cameras should not be handled roughly or subjected to sudden jarring when used at high temperatures because any slight shock might change the position of the lens components.

Maintenance of Equipment

One of the best protective measures that can be supplied in the tropics is to thoroughly clean every piece of photographic equipment at frequent intervals and expose it to air and sun whenever practical. This is particularly important for retarding the corrosion of metal surfaces and the growth of fungus or mold on lens surfaces and on leather coverings. Lens cleaning fluids and papers now on the market are recommended for cleaning lenses. During the tropical dry season, or in any desert areas, any dust should be removed from the lens surfaces with a sable or camel hair brush before the lens tissue is used, to avoid scratches. Lens cleaning tissues containing silicones should not be used for coated lenses. They leave an oily film that changes the color characteristics of the coating and reduces its anti-reflection properties. This film is almost impossible to remove. Leather coverings and cases can best be kept clean by wiping them often and thoroughly with a clean, dry cloth. Frequent cleaning and polishing will minimize corrosion on exposed metal parts.

Black & White Film

The exposure of black & white film in tropical areas is strongly influenced by the illumination in the subject shadow areas. The moisture and dust content of the atmosphere are important because shadows are illuminated only by light scattered by particles suspended in the air, except where supplementary lighting or reflectors are used. Thus, where the atmosphere is very dry and clear, objects that do not receive the direct light of the sun appear, both to the eye and to the camera lens, to be in deeper-than-normal shadow. In regions like the southwestern United States or central Mexico, for example, the brightness range of average outdoor subjects is much greater than it is in less clear climates. In photographing people, this effect and the high position of the sun combine to put the eyes in deep shadow and even sometimes give the effect of backlighting. Therefore, it is best to avoid taking pictures, particularly close-ups of people, when the sun is overhead; if you must take close-ups of people, use reflectors or booster lights to soften the shadows.

Exposure meters should always be used with a reasonable amount of judgment and experience, and this is especially true in locations with such unusual atmospheric and lighting conditions. In the jungle areas of South and Central America, the local farmers often clear and burn large quantities of trees and brush during the dry season. The smoke, composed of solid particles, hangs in the lower atmosphere and is not easily penetrated even with filters. Also, at the height of the wet season in many localities, the water haze becomes almost as impenetrable as a heavy cloud. Distance photography is best done a few weeks after the close of the wet season and before burning begins, or a few weeks after the first rains of the wet season have settled the smoke particles and before the onset of the wet season haze.

If extensive photographic work in the tropics is planned, the development of a few test exposures may prevent major failures. It is usually sufficient to determine a basic exposure which can then be modified to suit other films or conditions. Allowance should also be made for different types of subjects. Beach scenes, for example, generally require about one stop less exposure than an average subject.

Color Film

In general, the exposure of color films should follow the same basic recommendations given for temperate zone exposure, with due regard to lighting and scene classification. There are, however, some differences in the lighting conditions and scene characteristics in the tropics which justify special considerations.

1. During the rainy season, a light haze is generally present in the atmosphere. When this haze is present, the disk of the sun is clearly discernible and fairly distinct shadows are cast. Under these conditions, the exposure should be increased by about one-half stop over that required for bright sunlight.

2. Frequently the brightness of beach and marine scenes is appreciably greater than that encountered in temperate zones. With such scenes the camera exposure should be decreased one full stop from that required for average subjects. It should be remembered that the term "average subject" as used in exposure tables applies to a subject or scene in which light, medium and dark areas are roughly equal in proportion. It should not be taken to mean "usual" for a particular location or area. For instance, the usual desert scene is a "light subject" rather than "average subject," and should be exposed as such.

3. When the sun is high overhead, heavy shadows are cast across vertical surfaces, very much like those occurring in side-lighted subjects. Therefore, the exposure should be increased one-half-stop more than normal, just as is recommended for side-lighted scenes. For close-ups having important shadow areas, a full-stop increase in exposure is needed.

4. Many objects in the tropics, not only painted buildings and light colored fabrics, but even the leaves of many plants and trees, have a high reflectance for direct lighting. Consequently, with front top or back lighting they should be considered average subjects.

5. Very often the colors of nearby objects will be affected by the green light reflected from nearby bright green foliage. Similarly, in courtyards or narrow streets, the side that is in the shade gets much of its illumination from the opposite sunlit wall, which may be strongly colored. There is little that can be done to correct for this situation, but it should be recognized as a possible cause of poor results in color pictures.

Day-for-Night Cinematography

The speed of modern color films makes it possible to shoot night-for-night scenes. However, there are night scenes that are impractical to illuminate artificially and actually film at night. Shooting such scenes day-for-night eliminates the additional problems and expense of night shooting and can deliver excellent pictorial results.

Techniques for filming day-for-night scenes in color or black & white vary greatly because of the many factors involved. Cinematographers naturally differ in their interpretation of what constitutes a night effect. The overall effect must be one of darkness. Processing laboratories differ in their negative preferences, although most prefer sufficient density on the original negative since it is always possible to "print down" for a darker effect, but impossible to obtain a rich, full-bodied print from a thin, shadowless original negative (if black shadows are desired, the scene must print at center scale or higher).

Choice of filters and degree of underexposure will vary according to sky conditions, color and contrast of subject and background, the strength, quality and direction of sunlight, and the particular effect desired. Very generally speaking, the most convincing day-for-night shots, in either color or black & white, are made in strong sunlight, under blue skies and with low-angle back-cross lighting.

Direct backlighting results in a "rim-light" effect which, although pleasing in a long shot, lacks the necessary three-dimensional, half-illuminated facial effects required in medium and close shots. Front lighting will flatten and destroy all shadows. Side and front-cross lighting is permissible but not as effective as back-cross illumination. Since production does not always permit shooting when conditions are exactly right, and since day-for-night shots must sometimes be made all day long, often the choice of sun angle must be compromised. Under these conditions, avoid front lighting as much as possible and stay with any sun angle that results in partial illumination, preferably with shadows toward the camera.

Skies give the most trouble, since they will invariably read too high and are difficult to balance against foreground action. Graduated neutral density filters, which cover the sky area only, and Pola Screens, which will darken the sky with the sun at certain angles, are both useful for either color or black & white films because they do not affect color values and can be used in combination with other effect filters.

Neutral-density filters will tone down a "hot" sky, even if it is bald white. A partial or graduated neutral-density filter covering only the sky will therefore be very useful for bringing the sky into exposure balance with the foreground. Care must be taken, however, that action does not cross the demarcation line between the filter material and the clear glass area. Pola Screens are most useful when the sun is directly overhead at right angles to the camera.

A Pola Screen should not be employed if the camera must be panned through a wide arc, since the polarization will vary and the sky tone will change in density as the camera revolves. Typical underexposure is 1½ to 2½ stops, rarely more. Brilliant sunlight will require greater underexposure, gray days less. The underexposure can be handled in several ways. One is by ignoring the filter exposure increase required, if it is close to the amount of underexposure desired. For instance, the filter being employed may require two stops increase in exposure for a normal effect. The increase is ignored and the diaphragm set for the exposure without the filter, thus delivering the necessary underexposure for the night effect. Or, a neutral density of the desired strength is employed and its exposure increase ignored.

Proceed as follows: insert the effect filter, or combination of filters for the desired effect, and allow for their exposure increase as in normal filming. Add the desired neutral (a .30 for one stop, .50 for a stop and one-half or a .60 for two stops). Ignoring the neutral filter's exposure increase will automatically underexpose the negative by the necessary amount. This is a quick and effective method in fast production shooting where night effects are suddenly required and little or no time is available for computations.

If the sky is not sufficiently blue to filter properly, and if it is impossible to use a graduated neutral-density filter, try to avoid the sky as much as possible by shooting against buildings or foliage, or choose a high angle and shoot downward.

The contrast between the players and the background is very important since a definite separation is desirable. Dark clothing, for instance, will merge with a dark background and the player will be lost. It is better to leave a dark background and players in lighter, although not necessarily white, clothing than to have a light background and players in dark clothing. The latter combination will result in a silhouette, rather than a night effect. This is the reason that back-cross lighting is preferable, so that the background is not illuminated and the players have a definite separation through edge lighting, which also imparts shimmering highlights.

Black & White Film

The illusion of night in black & white cinematography is obtained by combining contrast filtering with underexposure. Since the sky is light by day and dark by night, it is the principal area of the scene requiring correction. Any of the yellow-orange or red filters may be used. A very popular combination is the light red Wratten 23A plus the green 56. This combination does everything the red filters accomplish — plus it darkens flesh tones, which are rendered too light by the red filters alone. When combining filters, remember that red filters add contrast but green filters flatten; if a greater flattening effect is desired, add a heavier green filter. Since flesh tones are not important in long shots, they are sometimes filmed with heavier red filters, and only the medium and close shots are made with the combination red-green filters. Care must be taken, however, that clothing and background colors do not photograph differently when filters are switched in the same sequence. If in doubt, shoot tests before production filming begins. Remember that only a blue sky can be filtered down. No amount of color filtering will darken a bald white sky. Use graduated neutral densities, or avoid the sky under these adverse conditions. The 23A-56 combination is usually employed with a filter factor of 6, rather than the 20 normally required (5 for the 23A and 4 for the 56, which multiplied equals 20). The factor of 6 automatically underexposes this filter combination approximately 1½ stops and achieves the desired effect without further computation. If a red filter is used alone, bear in mind that it will lighten faces, and use a darker makeup (approximately two shades) on close shots.

Reversal Color Film

Typical blue night effects can be obtained with reversal color films balanced for exposure with tungsten light by removing the Wratten 85 filter and under exposing 1⅓ stops. If the bluish effect is too great, an ultraviolet-absorbing filter can be used to filter out the excess ultraviolet. Flesh tones in closeups can be adjusted by using gold reflectors or 3200°K fill lights to light actors faces. Care must be taken that the actors are not over-lit or that such lights appear as ambient light with the sun acting as a moonlight key.

Negative Color Film

A cinematographer shooting day-for-night with negative color film should check with the processing laboratory before the production begins. Laboratories have a far greater range of color correction available than the cinematographer has at his disposal during the original photography. They may add or subtract any color, or combination of colors, provided the original negative has sufficient exposure. Once the 85 filter is removed, however, it is often impossible to restore normal color balance to the film.

If the 85 filter is removed, it should be replaced with an ultraviolet filter, which will prevent overexposure of the blue sensitive layer and keep the negative within printing range. Warmer effects may be obtained by substituting a light yellow filter for the 85. A Pola Screen may also be used to darken a blue sky and provide the required underexposure (by ignoring its filter factor). It will have no effect on a bald sky, but it will act as a neutral-density filter and provide the needed underexposure. Remember that approximately ⅔-stop exposure is gained by removing the 85 filter. This must be included in exposure calculations.

Infrared Cinematography

Because cinematography by infrared light has had limited pictorial use, this will be a brief review. For more information, refer to Kodak publications number N-17 "Kodak Infrared Films" and M-28 "Applied Infrared Photography." Infrared for photographic purposes is defined as that part of the spectrum, approximately 700 to 900 nanometers, which is beyond the visible red, but not as far as would be sensed by humans as heat.

All infrared films are sensitive to heat and should be kept refrigerated before exposure and during any holding time before processing. While no longer listed as a regular catalogue item, Eastman Kodak still manufactures a B & W infrared sensitive film, Kodak High-Speed Infrared Film 2481, and a modified color sensitive film, Kodak Ektachrome Infrared Film 2236. Both of these films are on Estar base. Before deciding to use either film in a production the manufacturer should be contacted regarding its availability, minimum order quantities and delay in delivery.

Black & White Films

For pictorial purposes, the greatest use of infrared sensitive film for motion-picture photography has been for "day-for-night" effects. Foliage and grass reflect infrared and record as white on B & W film. Painted materials which visually match in color but do not have a high infrared reflectance will appear dark. Skies are rendered almost black, clouds and snow are white, shadows are dark, but often show considerable detail. Faces require special makeup and clothing can only be judged by testing.

A suggested EI for testing prior to production is daylight EI 50, tungsten EI 125 with a Wratten 25, 29, 70, or 89 filter, or daylight EI 25, tungsten EI 64 with 87 or 88A (visually opaque) filter. Infrared light comes to a focus farther from the lens than does visual light. An average correction for most lenses is 0.25 % of the focal length of the lens .0125mm (.005 inches) for a 50mm lens.

Color

No human can see infrared; color film can only record and interpret it. Kodak Ektachrome Infrared Film 2236 was originally devised for camouflage detection. Its three image layers are sensitized to green, red, and infrared instead of blue, green and red. Later applications were found in medicine, ecology, plant pathology, hydrology, geology and archeology. Its only pictorial use has been to produce weird color effects.

In use, all blue light is filtered out with a Wratten 12 filter; visible green records as blue, visible red as green, and infrared as red. The blue, being filtered out, is black on the reversal color film. Because visible yellow light is used as well as infrared, focus is normal, and the use of a light meter is normal for this part of the spectrum. What happens to the infrared reflected light is not measurable by conventional methods, so testing is advisable. A suggested EI for testing prior to production is daylight EI 100 with a Wratten 12 filter.

Ultraviolet Photography

There are two distinctly different techniques for taking photographs using ultraviolet radiation, and since they are often confused with each other, both will be described.

In the first technique, called reflected-ultraviolet photography, the photograph is made by invisible ultraviolet radiation reflected from an object. This method is similar to conventional photography in which you photograph light reflected from the subject. To take pictures by reflected ultraviolet, most conventional films can be used, but the camera lens must be covered with a filter, such as the Wratten 18A, that transmits the invisible ultraviolet and allows no visible light to reach the film. This is true ultraviolet photography; it is used principally to show details otherwise invisible in scientific and technical photography. Reflected-ultraviolet photography has almost no application for motion picture purposes; if you have questions about reflected ultraviolet photography information is given in the book "Ultraviolet and Fluorescence Photography," available from Eastman Kodak Co.

The second technique is known as fluorescence, or black-light, photography. In motion-picture photography, it is used principally for its visual effects. Certain objects, when subjected to invisible ultraviolet light, will give off visible radiation called fluorescence, which can be photographed with conventional film. Some objects fluoresce particularly well and are described as being fluorescent. They can be obtained in various forms such as inks, paints, crayons, papers, cloth, and some rocks. Some plastic items, bright-colored articles of clothing, and cosmetics are also typical objects that may fluoresce. For objects that don't fluoresce, fluorescent paints (oil or water base), chalks or crayons can be added. These materials are sold by art supply stores, craft shops, department stores, and hardware stores. Many of these items can also be obtained from Wildfire, Inc., 10853 Venice

Blvd., Los Angeles, California, 90034, which manufactures them specially for the motion-picture industry.

Fluorescence may range from violet to red, depending on the material and the film used. In addition to the fluorescence, the object reflects ultraviolet light, which is stronger photographically. Most film has considerable sensitivity to ultraviolet, which would overexpose and wash out the image from the weaker visible fluorescence. Therefore, to photograph only the fluorescence, you must use a filter over the camera lens (such as the Wratten 2B, 2E or 3, or equivalent) to absorb the ultraviolet.

The wavelengths of ultraviolet light range from about 10 to 400 nanometers. Of the generally useful range of ultraviolet radiation, the most common is the long-wavelength 320 to 400nm range. Less common is the short to medium-wavelength range of 200 to 320nm. In fluorescence photography you can use long-, medium-, or short-wave radiation to excite the visible fluorescence depending on the material. Some materials will fluoresce in one type of ultraviolet radiation and not in another.

Certain precautions are necessary when you use ultraviolet radiation. Warning: You must use a source of short- or medium-wave ultraviolet with caution because its rays cause sunburn and severe, painful injuries to eyes not protected by ultraviolet-absorbing goggles. Read the manufacturer's instructions before using ultraviolet lamps.

Eye protection is generally not necessary when you use long-wave ultraviolet because this radiation is considered harmless. However, it's best not to look directly at the radiation source for any length of time, because the fluids in your eyes will fluoresce and cause some discomfort. Wearing glass eyeglasses will minimize the discomfort from long-wave sources.

There are many sources of ultraviolet radiation, but not all of them are suitable for fluorescence photography. The best ultraviolet sources for the fluorescence technique are mercury-vapor lamps or ultraviolet fluorescent tubes. If an object fluoresces under a continuous ultraviolet source, you can see the fluorescence while you're photographing it.

Since the brightness of the fluorescence is relatively low, the ultraviolet source must be positioned as close as practical to the subject. The objective is to produce the maximum fluorescence while providing even illumination over the area to be photographed.

Fluorescent tubes designed especially to emit long-wave ultraviolet are often called black-light tubes because they look black or dark blue before they're lighted. The glass of the tubes contains filter material which is opaque to most visible light but freely transmits long wavelength ultraviolet. These tubes, identified by the letters BLB, are sold by electrical supply stores, hardware stores and department stores. They are available in lengths up to 4 feet and can be used in standard fluorescent fixtures to illuminate large areas. Aluminum-foil reflectors are available to reflect and control the light.

Mercury-vapor lamps are particularly suitable for illuminating small areas with high ultraviolet brightness. When these lamps are designed for ultraviolet work they usually include special filters which transmit ultraviolet and absorb most of the visible light. Mercury vapor ultraviolet lamps are available in two types, long-wave and short-wave. Some lamps include both wavelengths in the same unit so that they can be used either separately or together. If you use a light source that does not have a built-in ultraviolet filter, you must put such a filter over the light source. The filter for the radiation source is called the exciter filter.

You can use a Kodak Wratten Ultraviolet Filter, No. 18A, or Corning Glass No. 5840 (Filter No. CS7-60) or No. 9863 (Filter No. CS7-54) for this purpose. The Kodak Filter, No. 18A, is available in 2-and 3-inch glass squares from photo dealers. The dealer may have to order the filter for you. The Corning Glass is available in larger sizes from Corning Glass Works, Optical Photo Products Department, Corning, New York 14830. The filter you use must be large enough to completely cover the front of the lamp. The scene is photographed on a dark set with only the ultraviolet source illuminating the subject. In order for the film to record only the fluorescence, use a Kodak Wratten gelatin filter, No. 2A or 2B, or an equivalent filter, over the camera lens to absorb the ultraviolet. When used for this purpose, the filters are called barrier filters. Since the fluorescence image is visible no focusing corrections are necessary. Focus the camera the same as for a conventional subject.

Determining Exposure

Many exposure meters are not sensitive enough to determine exposure for the fluorescence. An extremely sensitive exposure meter should indicate proper exposure of objects which fluoresce brightly under intense ultraviolet if you make the meter reading with a No. 2A or 2B filter over the meter cell. If your exposure meter is not sensitive enough to respond to the relative brightness of fluorescence, the most practical method of determining exposure is to make exposure tests using the same type of film, filters, and setup you plan to use for your fluorescence photography.

Films

While either black & white or color camera films can be used for fluorescence photography, color film produces the most dramatic results. The daylight balanced films will accentuate the reds and yellows while the tungsten-balanced films will accentuate the blues. Since fluorescence produces a relatively low light level for photography, a high-speed film such as Agfa XT320, Eastman EXR 500T (5296), Eastman HS Day (5297), Fujicolor F 250 D (8560) or Fujicolor F 500 (8570) is recommended.

Special Considerations

Some lenses and filters will also fluoresce under ultraviolet radiation. Hold the lens or filter close to the ultraviolet lamp to look for fluorescence. Fluorescence of the lens or filter will cause a general veiling or fog in your pictures. In severe cases, the fog completely obscures the image. If a lens or filter fluoresces, you can still use it for fluorescence photography if you put the recommended ultraviolet-absorbing filter over the camera lens or the filter that fluoresces. It also helps to position the ultraviolet lamp or use a matte box to prevent the ultraviolet radiation from striking the lens or filter.

Shooting 16mm Color Negative for Blowup to 35mm

by Irwin W. Young
Chairman of the Board, Du Art Film Laboratories Inc.

Note: Shooting 16mm for blowup to 35mm requires preparation and planning. Cameras, lenses and magazines should be thoroughly checked and tested. When shooting 16mm for blowup to 35mm, preparation is more critical than if shooting 16mm for 16mm prints.

The difference in picture quality between 35mm films shot in 16mm negative and those shot in 35mm negative is due primarily to differences in graininess. The 16mm frame, blown up to 35mm, is enlarged approximately 3 to 4 times its original size, greatly exaggerating grain size. To maintain the finest grain structure in 16mm color negative, proper exposure and normal processing is mandatory to insure maximum latitude and detail with minimum grain in the shadow area of the blowup. When in doubt, if light is available, it is advisable to lean to overexposure. In fact, contrary to what occurs in black & white negative, where density is created by a buildup of grain, color negative has less grain in areas of higher density. An overexposed color negative of up to one stop would tend to produce a blowup with the least amount of grain.

Flashing and toning should be avoided. These procedures increase grain, especially in the areas of no exposure. An underexposed negative shows more grain than a properly exposed negative. This grain is most apparent in weak shadow areas. Force processing increases graininess to the extent of the forcing. 16mm color negative has considerable latitude and it is recommended that scenes that are underexposed up to one stop be processed normally. This underexposure has a lesser effect on the grain size in the negative than force processing. There are a number of psychological factors which affect the viewer's awareness of grain. When the picture is not sharp, the eye, struggling to focus the image, tends to focus on the grain, making it much more apparent.

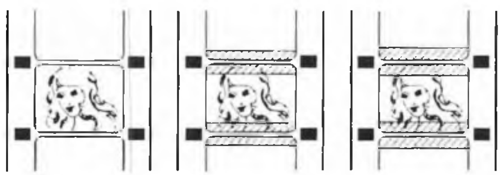
Definition is also a function of contrast. Low-contrast pictures tend to be less sharp and, therefore, appear more grainy. High contrast limits the detail in the highlights and shadows. If possible, it is advisable to have a black reference and a white reference in a scene. These reference points can be quite small. The eye, looking at a picture, searches for these reference points and, if there are none, tends to focus on the grain.

Special effects which require the blowup negative to be more than one generation away from the 16mm original should be avoided. The build-up in grain and loss in picture quality due to this additional generation is generally undesirable.

Composing 16mm for blowup to 35mm

The aspect ratio of a picture frame is the relationship between its width and height. The ratio of the standard 16mm and 35mm frame is 1.33:1. Reducing the height of the picture while maintaining the width will increase its aspect ratio. This is done in 35mm projection by using a mask to crop equally the top and bottom of the picture frame. 35mm prints are projected at a 1.85:1 aspect ratio in the United States and at 1.66:1 in Europe. On TV, the picture is viewed at a 1.33:1 aspect ratio.

This diagram shows the area of a 16mm camera frame that the viewer will eventually see when screened at an aspect ratio of 1.33, 1.66, and 1.85.



1.33:1 1.66:1 1.85:1

When shooting a 16mm film for 35mm blowup, the camera person should compose the subject being photographed for wide-screen projection.

A properly composed 16mm negative can be blown up to the standard 35mm aperture size (style A, PH22 195-1992 ANSI). This negative produces a 35mm print in a 1.33:1 aspect ratio. This print can be used for TV and projected theatrically in the United States and Europe with the appropriate mask. The aspect ratio of the projection mask and the framing position of the 35mm projector determines what part of the frame will be screened. The standard Academy leader is used by the projectionist to center the picture in the aperture of the projector. If equal cropping of the top and the bottom of the picture eliminates important picture information, vertical scanning can be used in making the 35mm blowup negative. Scanning enables you to chose the part of the picture you want projected wide screen. Here you have the choice of losing picture information only at the top or bottom or in a varied combination of the two. Blowup negatives that are scanned for a 1.85:1 or 1.66:1 aspect ratio require a frame line which fixes the desired aspect ratio. This frame line guides the projectionist in framing the picture properly. Prints from these negatives compared to a standard print look as follows:

1.33:1 1.66:1 1.85:1

35mm prints made from a 1.85:1 or a 1.66:1 negative cannot be used for television unless the image is enlarged in the telecine chain when transferring to videotape before broadcast. Cropping would have to be done on the left and right side of the picture to achieve a 1.33:1 aspect ratio. More cropping on the left and right side is required on a 1.85:1 aspect ratio print. Prints from a scanned 1.66:1 negative are acceptable in theatrical screening for both domestic and foreign use. Prints from a scanned 1.85:1 blowup negative when screened foreign at 1.66:1 aspect ratio show a black border at the top and bottom of the projected image.

We recommend that all scanning is done at a 1.66:1 aspect ratio and that the blowup negative be made with a frame line producing 35mm prints in which the picture information is framed in a 1.66:1 aspect ratio. Since there is not much difference in picture size between a 1.66:1 and 1.85:1 aspect ratio, this type of blowup negative enables you to make satisfactory prints for both domestic and foreign release.

Super 16mm

The Super 16mm format was designed to provide the greatest possible picture area on a 16mm original for enlargement onto 35mm for wide screen theatrical presentations. It achieves a wide-screen format on single-perforated

16mm camera film by extending the picture area of the unperforated area of the camera original. The Super 16mm aperture produces an original image with an aspect ratio of 1.66:1. The blowup from this image can be cropped slightly in projection to yield the 1.85:1 aspect ratio. The increase in the useful picture area of a Super 16mm frame results in a substantial increase in the image quality obtainable in a 35mm wide-screen blowup.

To optimize image quality when shooting Super 16mm color negative for blowup to 35mm, follow the same recommended exposure practices as when shooting regular 16mm color negative for blowup to 35mm.

Super 16mm is a complete system requiring appropriately modified laboratory, editing and screening facilities as well as a modified camera. Principal camera modifications are: enlarging the aperture, remarking the viewfinder and re-centering the lens mounts. It may be necessary to modify the pressure plate and other parts of the film transport mechanism in both the camera and magazine to prevent scratching in the extended area of the frame. Lenses should be carefully chosen to be sure that they provide a wide enough coverage to accommodate the wider frame. Many wide-angle 16mm lenses cause vignetting in the Super 16mm frame. Cameras are available which have been specifically designed for adaptability to Super 16mm and some conventional 16mm cameras can also be modified for Super 16mm.

Super 16mm cameras and magazines should be thoroughly tested before use in production. Editing and projection equipment must be modified to display the entire Super 16mm frame. Super 16mm film sent to the laboratory should be clearly identified so it can be handled properly. When a picture shot in Super 16mm has a television or 16mm release, the Super 16mm image must be converted to an image with a 1.33:1 aspect ratio by sacrificing part of the width of the frame. This is achieved by re-centering the frame via an optical printer so that an equal amount is cropped on each side of the frame.

Composing Super 16mm for blowup to 35mm

This diagram shows the area of a Super 16mm camera frame that the viewer will eventually see when screened at an aspect ratio of 1.33:1, 1.66:1, 1.85:1.

1.33:1 1.66:1 1.85:1

The aspect ratio of the picture frame of a Super 16mm negative is 1.66:1.

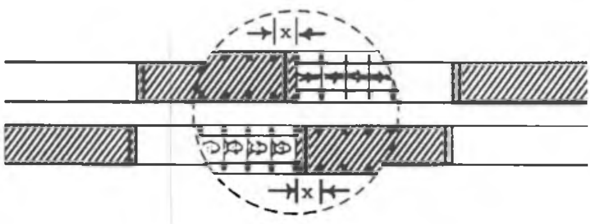
When shooting Super 16mm for blowup to 35mm, the cameraperson should compose the scene for wide-screen projection. A properly composed Super 16mm negative should produce a 35mm negative having an aspect ratio of 1.66:1. Projecting a print made from this negative at 1.85:1 will crop equally the top and bottom of the picture frame. If important image information is eliminated, vertical scanning can be used in making the 35mm negative. Blowup negatives that are scanned for a 1.85:1 aspect ratio require a frame line which fixes the desired aspect ratio. Vertical scanning in Super 16mm should be avoided because foreign prints are screened at a 1.66:1 aspect ratio.

This aspect ratio enables you to show all the information recorded on the Super 16mm negative. Television and standard 16mm prints show the picture information in a 1.33:1 aspect ratio. The Super 16mm image, in order to be converted to this aspect ratio, must sacrifice part of the width of the frame.

Titles

To be sure that your titles are suitable for different aspect ratio requirements, compose the titles so they will not be cut off horizontally when projected at a 1.85:I or be cut off vertically when viewed at 1.33:1 for television. If an action background is used for main and end titles, the action scene should be blown up to a 35mm master positive. The titles with clear letters on opaque black background should be shot in 35mm hi-con. Using the master positive and the 35mm hi-con titles a dupe negative of the main and end titles is manufactured. Where titles do not have action backgrounds, it is often advisable to photograph the title scene completely in 35mm to maintain maximum quality.

Splicing for a blowup requires extra care.



SCRAPE PICTURE ONLY — NEVER SCRAPE EMULSION FROM BLACK LEADER.

For a blowup, the 16mm original can be spliced in the standard 16mm A & B format. Besides normal care in splicing for cleanliness and assurance that the splice will hold, the conformer must be sure when making a 16mm splice for blowup that the cemented overlap of the splice maintains the proper pitch (x) between the perforation of the splice which is the first frame of picture negative and the perforation of the first frame of black leader.

If this pitch or distance between these two perforations is not the same standard as the pitch between any two perforations where a splice does not occur, there will be a vertical jump in the picture at the screen change. The reason for this is that the registration pins on all 16mm full-immersion optical wet gates are either one or two perforations away from the frame being exposed. Thus, the frame being printed is in a position established by a perforation on the opposite side of the splice.

If the splice is off-pitch, as described above, the first frame or the first two frames after the splice are improperly positioned, with the adjustment coming on the following frame when the pin is registered after the splice. This problem will not show up when you make a 16mm contact print from your A & B original because, on the 16mm continuous printer, the sprocket teeth register the film and the raw stock at the area of exposure. To help minimize the possibility of jumping splices, physically check your splicer before you conform the negative. Be sure that the distance between the pin that positions the black leader and the pin that positions the negative is correct.

Splice some negative outtakes in A & B roll form and from this negative make a test print using the optical printer with the 16mm immersion wet gate that will be used to make the blowup. If jumps occur in this print at the splice, recheck all adjustments in your splicer and re-test.

Zero-Cut Editing

To completely avoid the possibility of jumping splices, the negative can be cut into A & B zero-cut format. The zero-cut method, with a minimum of four frames for an overlap, will eliminate the splice-jump problem, but 16mm contact prints made from zero-cut negatives will have a one-frame dissolve at the scene changes. Quite often this dissolve is noticeable when viewing the print.

Since Super 16mm contact prints with sound cannot be made directly from a Super 16mm negative, there is no purpose in cutting your Super 16mm original negative in the conventional A & B roll format. To avoid the possibility of jumping splices it is advisable to cut the Super 16mm negative in A & B zero-cut format.

Laboratory Procedures

The work print and the 16mm A & B original should be delivered to the laboratory in rolls up to 800 feet in length. The workprint rolls should represent the 35mm reel-length format, where up to 2000 feet of 35mm goes on each reel. This conforms to standard theater projection practice. The laboratory prepares a contact 16mm answer print, which is screened by the filmmaker and the timer for corrections. NOTE: Super 16mm contact prints with sound cannot be made from a Super 16mm negative.

Using the corrected color timing and, if required, the filmmakers' scanning data, the 16mm or Super 16mm cut negative is optically enlarged to a 35mm master positive from which a dupe negative is made. Before the blowup, an additional printing operation is necessary, to create a clear picture frame in the 35mm negative. This is done so that the prints made from the negative have a black frame line to help the projectionist center the picture on the screen. If the blowup negative has been scanned, the frame line size is determined by the picture aspect ratio used in scanning. If it has not been scanned, the filmmaker can decide upon the frame size. The processed negative is then synchronized with the 35mm sound track for the manufacture of 35mm release prints.

Stereoscopic Motion Picture Technology

by Christopher James Condon, 3-D Consultant
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Three-dimensional (stereoscopic) films, when expertly photographed and projected, can result in motion pictures with amazing roundness and depth. Recent "state-of-the-art" examples shown at theme parks have proven that these films can be the most realistic visual medium — sometimes even exceeding the capabilities of our "two-eyed" perception. This exciting effect can now be achieved in local cinemas if the process is better understood by producers and exhibitors. First they must be willing to put forth cooperative effort, integrity, reasonable resources and planning.

The basic technology of filming and projecting stereoscopically has been widely known for many years, and has been greatly simplified during the past two decades. There are two main systems for 3-D cinematography. The lightweight, mobile *single-camera* (dual image) system is suitable for theatrical feature films. The heavier, more complex *dual-camera* method is more useful for large-screen theme park or venue films. The various three-dimensional camera systems currently available are:

1.) HINES-LAB offers a very sophisticated dual camera rig for rental. This system requires that one of the cameras be pointed downward toward a horizontal beam splitter. This camera must be operated in reverse. The other camera points forward. This rig accepts most interlocked 35mm, 65mm (five and eight-perf), and video cameras, and allows the widest-angle lenses of any 3-D system. State-of-the-art convergence and 3-D videotap options are available. The Disney 65mm dual camera 3-D system is similar, as is the huge IMAX 15-perf 3-D system.

2.) STEREOSPACE 2000. A dual 65mm camera system. Uses a vertical beam splitter. This system features MOS as well as studio self-blimped versions and has interchangeable lenses of 50mm, 70mm, 85mm, 100mm, and 150mm focal lengths. Projection is by interlocked 70mm projectors.

3.) STEREOVISION has a number of 3-D camera systems. StereoVision Wide Screen is a distortionless high definition single-strip 35mm 3-D system. By far the world's most widely used, it is a true dual optical channel, patented camera lens, not a relay system. It stacks both the left and right images precisely onto each frame. Can be blown up to 70mm. Focal lengths are 15mm extreme wide angle, 20mm, 24mm, 32mm, 50mm, 62mm, and 90mm. The symmetrical image spacing of .374" allows easy optical effects printing. Available in BNCR style camera mounts such as hard front Arriflex 35, BL4, Ultra-Cam, Mitchell BNCR, MovieCam and others. Special models are also available for Panaflex, Arriflex IIC, PL and BL. StereoVision also has a 35mm Academy (1.33:1) format 3-D system compatible with video format. StereoVision 70 shoots two side-by-side images onto each standard 65mm frame, and is fully compatible with Russia's Stereo-Kino. No beam splitter is needed, increasing depth-of-field sharpness. All of the above systems require only one projector using a patented special distortionless polarized dual optical channel lens.

Also available is a StereoVision dual camera 35mm rig and a single-camera StereoVision Tenperf 65. The latter is a 10-perf above/below single 65mm 3-D camera system, supplied with 55mm, 80mm, and 135mm 3-D lenses. This camera shoots two 5-perf 70mm stereo images, above/below, rendering the same size images as heavier more complex dual 70mm rigs. It uses a special 10-perf 70 projector and a 10KW Xenon lamp. StereoVision also supplies a large variety of 3-D projection optics for 35mm and 70mm projection, which it rents directly to theaters.

4.) DIMENSION 3 was designed by stereographer Dan Symmes. It has a focal length of 35mm and has similar characteristics to StereoVision Wide Screen 35. This system is in the prototype stage and is available in BNCR mount. Other mounts are available on special order. (.374" symmetrical image spacing.)

5.) MARKS DEPIX is a 35mm single-camera system (two stacked images). Focal lengths are 18mm, 32mm, 50mm, and 85mm. It uses a unique method of separating the images by polarization. This results in a two-stop loss of light, however. (Spacing is .387".)

6.) ARRIVISION is a 35mm relay 3-D system that converts to various focal lengths. It is attached to the camera base by means of a special support bracket and uses removable optical components and cams to obtain 18mm, 32mm, 50mm, and 85mm focal lengths. Arrivision is designed to be used with specially modified Arriflex cameras only. (Two stacked images, .366" spacing.)

7.) OPTIMAX III attaches to the 35mm camera with a support bracket. It has relay focal lengths of 16mm, 24mm, 35mm, 50mm, and 85mm. (Two stacked images, .387" spacing.)

8.) IWERKS 3-D is an 8-perf 70mm system using the DUAL camera beam splitter method for photography. Focal lengths are 50mm, 60mm, 80mm, 100mm, and 150mm. Iwerks offers 870 3-D projectors that are state-of-the-art, 30 frames per second.

9.) IMAX 3-D is a very large format (15-perf 70) huge dual-camera rig. A range of focal lengths is available. The IMAX company has also developed a dome 3-D process, which uses liquid crystal viewing glasses. Interlocked dual Imax projectors are currently used for extremely large 3-D screen images. A single projector, dual-image projector has been developed.

10.) STEREO-KINO 70 is a system that was developed by N. I. K. F. I. in Moscow. It is a single-camera, side-by-side image system with a wide range of focal lengths. The cameras range from small "handheld" to studio self-blimped. Special 70mm 10KW projectors are used, compatible with Stereo-Kino projection optics, designed for minimum distortion. (26.4mm spacing.)

11.) STEREOSCOPE is a single-strip 35mm 3-D system designed by stereographer John Rupkalvis. It is intended primarily for special-effects photography, using longer that normal focal lengths. (.374" symmetrical spacing.)

A number of special optical effects companies also have built dual-camera 3-D rigs. These are intended mainly for 3-D matte photography, miniatures and motion-control work.

All of the above systems (except for IMAX Dome 3-D) are intended for use with the current "state-of-the-art" polarized projection method, requiring a silver screen and neutral polarizing glasses. Nearly all of the major theme parks and other special venues use this method. Approximately 2,000 theatrical venues in the USA and Canada also have silver screens, waiting for a new wave of better 3-D movies. Further information is available from the individual companies.

Very special photographic technique is essential for effective 3-D cinematography. Some 3-D consultants may prefer computers, formulas and convergence tables. Books such as Lipton's "Foundations of the Stereoscopic Cinema" can be of help. However, for truly effective results, without costly 3-D errors, producers are advised to engage only an experienced 3-D consultant in the pre-production stage, as well as during the shoot and postproduction.

Optical "Flat" Projection

Single-strip 35mm 3-D films can easily be converted for standard flat projection by making an optical internegative for non-3-D prints. For converting 35mm wide screen, the usual method is to optically reprint one of the two stereo images anamorphically, as was done with the Techniscope process, or crop slightly for 1.85 or 1.66 flat format. For single-camera 70 side-by-side, simply convert one side to 70mm blow up or 35mm 1.85 to 1.66 reduction. For dual-camera systems, no change in the print is necessary. Either left- or right-eye reels can be shown independently as "flat" films.

3-D Projection

Precise theatrical projection is a very important factor in the success of a 3-D film. Proper installation and alignment of the special 3-D projection optics requires expertise. Pre-screening of the 3-D print is absolutely necessary. Improperly aligned 3-D images can cause audience eye discomfort. Imbalanced or underpowered illumination can ruin the dimensional effects and can spoil the enjoyment of even the best 3-D photography.

The StereoKino Group of Moscow has achieved great success in single-camera 70mm stereo-cinematography and 70mm stereo-cinema projection and has established 60 special 3-D theaters in the former USSR. Stereo-Kino was recently awarded, for the first time in this field, a Technical Achievement Award by the Academy of Motion Picture Arts and Sciences. At least two American co-productions are planned.

The future success of theatrical stereoscopic motion pictures depends upon a high degree of professional excellence. It will also require international standards and cooperation between innovative writers, art directors, creative directors, proven stereographers, trained 3-D camera personnel, dedicated distributors, the finest exhibition engineers, and skilled projectionists.

3-D Cinematography

by Daniel L. Symmes
Spatial Technologies Incorporated

3-D films create an illusion — a synthesis of how humans see. Basically, all true 3-D (with the exception of holography) takes two (or more) images of a given scene. The viewpoints (lenses) are generally separated horizontally (interaxial) by around 2.5 inches, relating to the distance between our eyes (interocular). The two images are then selectively viewed: the left image is seen only by the left eye and the right by only the right eye. The visual selection is generally accomplished with polarizing projection filters and appropriate polarizing viewing glasses. The two images are seen by the brain as a representation of the depth of the original scene. If the screen image were life-size, the film would be viewed as a stage play and simulated 3-D would be no problem; it would also not have the dramatic impact of close-ups, moving viewpoints, and intercutting scenes photographed by lenses of different focal lengths.

Since the screen image is larger than life-size and is viewed by persons at various distances and angles relative to the screen, it is necessary to control the synthesis of the 3-D image. This is accomplished by adjustments of convergence, interaxial distance, focal length, and camera distance from the subject. Proper adjustments present an image that a viewer's brain accepts as "real" or produces a dramatic effect intended by the filmmaker.

While the basic principles of 3-D may be easy to grasp, the actual techniques of 3-D cinematography are quite complex. Mathematical manipulation provides perhaps 75% of the needed information; the balance comes from experience, tests, and instinct. Obviously, this process requires experienced supervision. This, and the fact that 3-D is a special effect, illustrate the need for a 3-D consultant.

It is the consultant's job to know from experience what does and does not work. Eye fatigue is the most common problem associated with 3-D, and while it can be caused by poor projection techniques, it is generally initiated in production. It is not the consultant's job to tell the director of photography how to do his job or to tell the director how to shoot his film. As with special-effects systems, there are rules and techniques that can help a production avoid costly and damaging problems. The consultant will help the director and cameraman achieve on the screen what they have in their minds.

Preparing to shoot in 3-D should be approached as thoroughly as conventional filming; lenses must be checked for resolution, distortion and T-stop accuracy. Any deficiency in these areas should not be accepted just because you are working with specialized equipment. There are no excuses for poor optical performance. In addition, you should test exposure and color balance between the two images; focus and convergence limits and accuracy; and for odd optical phenomena. These areas relate specifically to 3-D optical systems and apply to single- and double-camera 3-D. Optical problems can include flare, ghost images and other visible distortions that would also be unacceptable in normal (2-D) photography. If you intend to use polarizing filters on the filming system for reflection control, sky effects, and so on, it would be wise to test for exposure imbalance between the two images and other anomalies. Systems using mirrors, and even prisms, sometimes yield odd results due to polarization (see "Filters" section).

The primary concern in 3-D filming is preventing eyestrain in audience members. This involves far more than merely looking at reference charts or making an "informed" guess. The real questions come down to where to converge, how close the subject may come to the camera, and how far back the background can be. As a very general rule it is best to converge on or near the main subject.

Unfortunately, some scenes shot this way will cause eyestrain. The only effective method of determining convergence is with a combination of mathematical and experiential skills. Strict mathematics fall short because numbers need to be interpreted. However, a 3-D consultant without sound mathematics is only guessing. This aspect cannot be overemphasized and is the shortcoming of many current 3-D productions.

Many films made since the late 1970s, including the most recent, show excessive parallax (too much "depth"). Without glasses, images are double to an extreme. With glasses, many spectators feel the excessive depth in the way their eyes have to exercise. This is often described as eyestrain.

Yet, if one watches 3-D films of the 1950s (*House of Wax, Hondo, Phantom of the Rue Morgue, Miss Sadie Thompson*, etc.) without glasses, there is an impression of being able to see the image with a minimum of "doubling". In other words, the picture looks fairly clear. With 3-D glasses, the depth effects are extremely satisfying. Obviously, *parallax must be controlled* for confortable viewing by the entire audience, not just a few with super eye muscles.

The perception of 3-D is an individual and therefore subjective experience; no two people see 3-D quite the same way. What may be great to one viewer may seem poor to another. Directors and producers must be made aware of this so they may avoid making decisions based on potentially biased perceptions.

A final factor that is often overlooked is the proper projection of both dailies and release prints. The cameraman should be aware of projection problems that may reflect on his work. Improper projection can result in expensive, needless reshooting. Working with 3-D projection equipment suppliers and a consultant, you should have the picture brightness up as high as possible. Balance the illumination of the two images. Make sure both images are the exact same size and focus. Make sure the proper metallic screen (high gain or silver) is installed and that it is clean. See that the 3-D projection optics and projectors are aligned properly so the two images register properly on the screen. Lastly, be sure to use good-quality 3-D glasses.

With proper handling and expert consultation, 3-D can be an entertaining experience.

Synchronizing Methods for Picture and Sound Systems

by John Mosely, CAS

Early Systems

As far back as 1897, Edison had the idea of combining sound and picture. He accomplished synchronization by mechanical means, making the first use of a "Double System," i.e. a system in which picture and sound track are recorded separately. Many demonstrations were given prior to World War I. Eugene Laust introduced the first "Single System" during the same time period with picture and soundtrack recorded on the same film.

These devices were regarded as curiosities by the serious motion-picture makers, who created their "photoplays" as silent dramas, telling their stories punctuated with title cards when needed. The silent films were customarily projected in the theater to the accompaniment of pianos or theater organs. It was not until the famous collaborative experiments between the Bell Telephone Laboratories and the then-fledgling Warner Brothers Pictures that the sound motion picture became a serious challenge in the theatrical market. The Warner Brothers threw down the gauntlet on August 6, 1926. However, the date that is considered to be the formal introduction of sound to theatrical feature films is October 26, 1927, when the Warners launched *The Jazz Singer*.

During the early days, two sound recording and reproducing systems were used side by side: the disc recorder, which was a synchronous version of the phonograph recorder, and the film recorder. Initially the disc record gave better sound quality and was in commercial use in theaters all over the world until the early 1930s. By that time, the sound-on-film systems had improved sufficiently to displace the disc as a theater reproducing system. Being able to cut the soundtrack in the same way as the picture was a major editorial advantage and film recording quickly became the preferred medium. However, since it was impossible to hear a film recording immediately after it was made, the disc recorder survived for this purpose until the introduction of magnetic recording in the early 1950s.

Synchronous Motors and Selsyns

In both cases, the above systems were driven by synchronous motors. These normally took the form of a 220-volt 3-phase AC motors designed to run at 50 or 60 Hz, depending upon the geographic area of the world where they were intended to operate. (60Hz for North America and parts of Asia and 50Hz for the rest of the world.) The stator windings of these motors produce a rotating magnetic field in the armature area of each motor. The speed of rotation is the same for all motors and the armatures are shaped so that each and every armature turns in unison with the rotating magnetic field. This makes all motors turn in synchronism. After these motors come up to speed, they function as though they were mechanically interconnected.

The selsyn electrical interlock system adds refinement. In contrast to the synchronous motor, if one armature is held stationary, all armatures that are connected on the same circuit or "bus" will remain stationary and the electrical fields of all armatures will rotate in unison. This is achieved by giving the armatures windings and poles similar to the stator windings. Six wires are brought out and all armatures are connected in parallel, making them operate as though they were mechanically interconnected. An additional synchronous motor is mechanically linked to a selsyn mounted on the same bed. This combination is called a "distributor." In operation, all of the fields are electrically excited, after which the armature of the distributor motor is made to rotate. Thus, all of the selsyn motors are electrically interlocked from a standing start mark, then come up to speed together and drive together under the rotational power of the distributor motor. In addition to being used as a camera and recorder drive during photography, the selsyn system has been used for practically all scoring, rerecording, ADR, Foley and double system projection. Since the rotation of a selsyn system is strictly a direct function of the drive motor, it will be appreciated that these systems can be made to operate over a wide speed range and bidirectionally. Virtually all dubbing (re-recording) systems have taken advantage of this phenomenon.

A third multi-duty motor system was used for a time in which the motors contained multiple windings, enabling them to be used as synchronous, selsyn and DC systems. When operated as a synchronous motor, the armatures are connected so as to form fixed poles which rotate in the magnetic field of the stator in a manner similar to the armature of a synchronous motor. When operated as a selsyn interlock motor, the armature windings are connected so as to conform to the selsyn system. When powered by DC, these motors operate as a compound DC motor and as a 3-phase 220-volt AC generator. By interconnecting these motors appropriately, a selsyn drive system results. In practice, when operating from DC, the speed of the drive motor is established by a rheostat in the supply lines. The correct speed is verified by a visual tachometer, usually a reed meter. Due to the bulk, weight and power requirement of all these systems, they have been largely replaced in the field, slowly over the last 20 years, by crystal motors in cameras and by stepping motors and servo systems in postproduction equipment.

Regardless of which system is used, the start of each take is marked by a clapper board or slate. The slate has the picture information written on it, usually in chalk. The top contains a hinged piece of wood. The clapper operator waits for camera and sound recorder to be running at full speed, then announces the take followed by the word "Mark." At that point, the upper section is brought swiftly down so that it makes a loud crack. The editor looks for the frame where the slate closes and places a china marker cross on it. The sprocketed magnetic film, which is a direct transfer of the ¼" tape, is placed in a sound reader. The editor listens for the announcement to make certain that it is the correct take and then finds the start of the sound where the top hits the board. This point is also marked with a china marker and the two films run together with sound and picture synchronized.

Early Sync-Pulse Systems

The advantages of ¼" tape as a recording medium for motion pictures and television were recognized as early as 1948, both by Colonel Richard Ranger and Sherman Fairchild. In both the Ranger and Fairchild systems, a synchronizing pulse is taken from the camera's synchronous motor power source and recorder on the tape as an index of camera frame speed versus sound timing.

The synchronizing recording of the Ranger system is in the center of the studio track and is recorded with a special magnetic head oriented approximately 90 degrees with respect to the audio recording. This orientation produces a synchronizing signal that is self-canceling, or in push-pull with respect to the audio signal, and therefore does not cause any interference. On playback, the synchronizing signal is amplified to control the frequency of an oscillator. When no signal is present, the oscillator is locked to the line frequency, which is also used as a reference. Any variation in frequency from the reference is used to correct the speed, thereby maintaining proper synchronization.

The Fairchild "Pic-Sync" system uses a 14 Khz carrier signal that is mixed together with the audio signal. In reproduction the two signals are separated, with the audio going through a low-pass filter. The carrier signal goes through a high-pass filter and is demodulated to obtain the sync signal. This signal is amplified and fed to a small synchronous motor coupled to the reproducing tape drive capstan and either adds or subtracts power to the power driving the tape to maintain synchronism. A starting device using special beep tones, spaced one second apart, is used to start the tape in sync with the picture.

The Swiss company Perfectone introduced a system in 1959 whereby a synchronizing signal was recorded in push-pull on the edges of the tape, allowing room for a 200 mil sound track down the middle of the tape that is completely isolated from the sync signal. The playback device is the same as the Ranger system.

It was particularly common for manufacturers of documentary cameras to include a pulsing device driven by the camera. An interconnecting cable feeds the sound recorder with a 50 or 60 Hz pulse, which would be reproduced by the Ranger system. There were a number of other devices on the market for a time which were proprietary to individual manufacturers, but their use was relatively insignificant.

Current Synchronization Systems and Time Code

Virtually all motion-picture sound cameras today are driven by crystal motors that maintain precise speed accuracy. Field sound recorders rely on 50 or 60 Hz synchronizing tracks or SMPTE/EBU time code. Time code displays 8 digits denoting hours, minutes, seconds and frames. There are 8 additional digits available by selection (known as "User Bits") that can be allocated for special purposes although they bear no direct relationship to a particular frame. For example, production date, number, etc. can be entered as user bits. Time code can be selected to run at 24, 25 and 30 frames and there is a special frame rate of 29.97 (called the "drop frame") for use with NTSC color television systems.

Lightweight battery-operated synchronous tape recorders manufactures by two Swiss companies, Nagra and Stellavox, are in general use throughout the motion picture industry worldwide. With the growing use of video systems for editing and for electronic cinematography, the SMPTE/EBU time codes are gaining popularity. The great advantage of time code is that every frame of picture and track is individually marked, thereby simplifying synchronization. Some motion-picture cameras record time code on one edge of the film continuously, whereas all professional video recorders contain a dedicated time code track. A compromise system is also in use, whereby an intelligent slate is used. The take information is written on the slate conventionally, but running time code is displayed in the middle of the slate. The same time code will be feeding the sound recorder. By physical examination of the picture and by using an electronic reader on the track, the required frame can be easily identified. Time code is usually placed in the center of the ¼" tape between two audio tracks. The time-code track is scanned by a time-code reader which displays the time and frame information. It is not possible to use mono tape recorders with time code, since time code interferes with the audio signal. However, there is a compromise arrangement that is economically advantageous, which will be discussed in a later paragraph.

Digital Audio Tape (DAT) Recorder

It must be appreciated that analog tape recorders have evolved and improved over the last fifty years. By contrast, digital recorders, which represent a revolution in technology owing their genesis to binary computers which relate all signals to zeroes and ones, burst upon the market during the last decade. They are theoretically perfect for recording sound. Unfortunately, practice has not followed theory, and although they all have many desirable features, they do not necessarily sound as good as their analog counterparts. However, during the last two years, great improvements have been made in how some of these systems actually sound. A direct comparison to live sound, called an "A/B" test, is very revealing. Some of the best sounding digital recorders happen to be the DAT systems. DAT recorders were originally designed for the consumer market and were tried out in Japan. From a technical standpoint, they can best be described as a tiny video-type recorder using rotating heads. They quickly demonstrated their ability to make two channel stereo recordings having extremely high quality, in fact even better than compact discs. Furthermore, the inherent design of the drive mechanism guarantees absolutely constant speed, without any variation or "wow and flutter," two variables that have plagued analog recording since their inception. This aspect of the DAT recorder makes it particularly suitable for synchronous recording. Like the crystal-controlled camera motor, it can be relied upon totally to maintain constant speed and does not need any additional external reference, as do other systems outlined in previous paragraphs.

A number of professionals obtained machines from Japan and were greatly impressed by their initial performance and obvious potential. Their wide dynamic range (exceeding 90 dB) and virtually flat frequency response across the full audio spectrum, with very low distortion, made them ideal candidates to replace conventional two-track analog reorders with and without synchronization systems. As an additional advantage, these machines no longer need noise-reduction equipment, which adds significantly to the cost, weight and alignment complexity of analog equipment. A two-hour DAT cassette fits into the palm of the hand and weighs only two ounces, including its box. Conversely, two hours of professional analog tape weighs some eight pounds and is now technically inferior.

There are already machines on the market from a variety of manufacturers that are classified in the professional category, i.e. they contain balanced inputs and outputs, as well as digital interface connections that conform to the AES/EBU Standards. They have already filled a small place in the field, displacing their bulkier analog machines for recording dialogue and effects for film and television and even music. During the currency of this edition of the manual, it is highly probable that DAT recorders will become the recording device of choice for both film and television sound.

Most of these professional machines do not contain playback heads, which in digital parlance are called "read after write" or "confidence" heads, so it is impossible to monitor the signal coming off the tape while recording. Although there is a school of thought that would regard this shortcoming as cause to dismiss the product, it must be pointed out that this digital format has proved itself already to be extremely reliable. One must recall that in the old days before tape, the same situation existed for fifty years and very good recordings were made.

This group of professional DATs has considerable economic advantage over the existing conventional analog recorders by almost a factor of five. Therefore, if individuals are worried about the lack of a confidence head (read after write or simultaneous playback), they can always employ a second machine. The AES/EBU Standards permit interlocking machines and a number of features for logging and identification. These are not available on analog machines, but are standard fare with professional DATs. Their small size also enables them to be used as self-contained individual recorders in place of radio microphone systems that cause so much trouble to the production recordist.

There are a number of second-generation professional battery-powered machines which came onto the market during 1992 that do contain confidence heads that also contain an additional SMPTE/EBU time-code track. These machines will be in the same price range as the current full-feature analog machines and may be regarded as direct replacements, assuming that their sound quality is satisfactory. This can not be taken for granted. The advantage of recording time code is that the soundtrack will be continuously associated with its corresponding frame of picture and may be edited at random, without resorting to the current practice of synchronizing each track with its picture from a start mark. As electronic editing becomes more popular with film, this additional feature may become indispensable.

Synchronizing with Non-Time Code DATs

From the previous section, it will be apparent that even the simplest DAT recorder can be relied upon to run at constant speed without an additional synchronizing device or special track. Therefore, a standard clapper can be used for synchronization. All DAT machines have an additional advantage in that they contain two high-quality audio tracks that are actually technically superior to the best current analog recorders. This feature will alleviate the use of a second machine when it is required to record effects or a second dialogue track concurrently.

All film manufacturers have agreed to mark their negative films with a machine-readable bar code. During the currency of this edition, the use of intelligent readers will undoubtedly grow and it may be desirable to use time code for the soundtrack. Should the recordist require time code, there are the following three possibilities:

1. Use a machine that contains the additional track.

2. Record time code on one of the audio tracks. (Crosstalk between tracks exceeds 80 dB and therefore will not cause a problem to the audio.)

3. Make an interface box that will place time code on one track for a few seconds while simultaneously driving a time-code slate so that the same numbers are recorded on the film as the tape for post-synchronization. Incidentally, if this option is chosen, it would be sensible to place a voice slate on the other track so that one has both human and machine-readable data at the same point on the track. This box should be placed at the input of the DAT recorder. The same device can be used on an analog recorder, too.

Sound-Recording Hints

Before embarking upon any recording, it is mandatory to check out thoroughly all of the equipment that will be used. People often have difficulties in the field which could have been avoided if every piece of equipment, including the cables, had been completely checked before leaving for work. If one is uncertain about the use or performance of the equipment, ask for a technician to be available to explain everything and to verify that all of the individual components are operating correctly.

It is important to understand the problems that are commonplace in recorded sound and to understand how to avoid them. Recorded sound in the motion picture/television context inevitably is quite different to natural sound, since constraints are placed upon the recording process by the functioning of the overall equipment and the environment. The principle consideration in recording sound for motion pictures is that the dialogue shall be clear and clean, i.e. free from defects and intelligible at all times. For example, a quiet whisper that is clearly audible in a field in the country is not likely to be heard above the sound of crunching popcorn or a theater's air-conditioning system. It is therefore necessary to bring up the lowest sounds so that they are easily understandable. Conversely, very loud sounds will overload the recording system and cause distortion, which is unpleasant to hear and may damage the equipment. If the movie patrons cannot understand the sound, they will not enjoy the picture. Although the dubbing or rerecording process will rectify many defects, the end product, like a good meal, can only be as good as the basic ingredients. Therefore, it is well worthwhile to take a lot of trouble to obtain good original sound.

The unit of reference for sound is the decibel or "dB" and is a logarithmic relationship between two voltages or powers. In simple terms, a change of 6 dB will double or halve the sound level for practical purposes. The threshold of hearing is given as 20 dB, while the threshold of pain is given as 120 dB. Therefore, it can be said that the dynamic range of hearing for a normal human being is around 100 dB. The frequency range of normal human hearing is from 20 Hertz (Hz) to 20 kilohertz (kHz). This represents approximately 10 octaves musically. Speech is generally in the range of 200 Hz-3 kHz. It is common for people to experience a loss in their ability to hear high frequencies as they get older.

One of the most irritating sounds often heard is excessive sibilance, that is, the exaggerated sound of the letter "S." It occurs in nature, and some people are more prone to have sibilant speech than others. A good test of actor and equipment is to get the actor to say "Sister Susie gathers sea shells by the sea shore." If you can record that sentence clearly and without sibilance, you do not have a problem. Microphone selection, placement and movement usually solve the problem.

The letter "P" can also present problems, which are manifested by a popping sound. Here again, the problem is usually resolved by microphone placement and movement. Some microphones are particularly sensitive to this phenomenon, since the "P" sound often is accompanied by a steep wavefront which distorts the sensitive element inside the microphone. To circumvent this problem, some microphones are supplied with "Pop Shields." If you have one, use it.

Distorted or unnatural sound is usually but not always caused by defective equipment. Listen to the natural sound before assuming that your equipment is defective. If everything appears to be in order and the distortion persists, check your batteries. Low battery voltage will cause the equipment to malfunction. Therefore, it is important to make certain that your batteries are fresh and producing their full output at all times.

Before starting to work, make certain that the recorded sound quality is satisfactory. The best judge of this all-important characteristic is the human ear. If something doesn't sound right, the chances are that some piece of equipment is not functioning correctly. Normally, one will work backwards from the tape output towards the microphone(s). Listen carefully to what you are recording near the sound source, then listen through your headphones. If the sound is not the same at this juncture, change the microphone. If the trouble persists, change the microphone power supply, preamplifier, mixer and headphones in that order. Obviously, the sound must be clean before it enters the recorder. If there is a crackling sound, shake the cables to discover if they are causing problems. Inspect the connectors to make certain that they are clean and dry. The pins should be shiny and certainly not discolored or oxidized. If a cable appears to be stiff or brittle, it may well have poor insulation and is likely to add noise to the signal, so change it. Lastly, set a comfortable listening level on your headphones. The level should be high enough so that you hear the softest sounds clearly, but not so loud that the loudest sounds are uncomfortable. Once this level has been found, do not change it, as this becomes the reference by which you will be making subjective judgments all the time. Allow yourself sufficient time to experiment before the shoot commences, so that you are entirely comfortable with your equipment operationally. During the shoot, you should concentrate on the sound subjectively and not have to worry about technicalities.

All equipment must be fully tested and properly aligned before commencing operations. Depending upon the type of equipment chosen, it may be necessary to perform periodic alignment procedures in the field. Should this be the case, make certain that the required test equipment and/or personnel are available. On the whole, the newer digital equipment requires less maintenance in the field. Remember that if a bad recording is turned back to the studio, the front office, producer, or director will blame the sound person, not the equipment. If you have any reservations, take spare equipment with you, as well as plenty of tape and extra batteries of all sizes.

Microphone Placement

For the best sound pickup during dialogue recording, the microphone should be about one or two feet in front of and above the actor. This distance will vary according to the camera angle. The tighter the shot, the closer the microphone should be. However, even for a distant shot, do not go too far back. Roughly speaking, the efficiency of pickup of most microphones decreases with the square of the distance. A little practice will soon teach you the best position to place the microphone. In general terms, one is best off to use a condenser microphone with a cardioid (heartshaped) pattern pickup. It is also advisable to use a foam windscreen over it to ensure that movement of the boom or fishpole does not pick up wind noise. It is preferable to use a shock mount between the microphone and the boom so as to isolate mechanical sounds when the boom is moved.

When operating outside, it may well be necessary to add a windscreen and sock. These components should be in the kit. When working in noisy environments, it will be necessary to use hyper-cardioid or even shotgun microphones. Remember, the tighter the pattern of pickup, the more precise the boom person has to be before the subject sounds "off mic." "Off mic" is a term that is used when a sound is no longer natural. It is easily recognized and can usually be corrected by a minor movement of the microphone towards the sound source. The boom person should wear headphones connected to the microphone so that any problem will be apparent immediately.

The actual angle of pickup will vary with different microphones. As a starting point, place the sensitive face at 45 degrees in front of and above the actor. If there is sibilance or the actor starts to overload the system by shouting (i.e., the sound becomes brittle or distorted), roll the sensitive face away from the actor, so that the voice hits the sensitive face at 90 degrees on its cross-axis, keeping the face at 45 degrees. If the overload persists and the sound is normal but loud to the ear, the overload may be removed by inserting an attenuator or "pad" between the capsule and its pre-amplifier. (This accessory will reduce the input voltage to the microphone's pre-amplifier. Some sensitive capsules have the ability to put out very high levels when placed close to the sound source. Certain microphones contain built-in attenuators that are operated by a switch on the microphone.) Do not use a larger pad than is necessary to clear up your overload problem, since any additional gain or level that is needed to restore the sound to the required listening point will add hiss or noise to the system. Again, the solution and correct movement will be learned by trial and error. Do not change microphone types within a scene, or the sound quality will change and the resulting recording may be unacceptable. If there is a rumbling sound, use the low-frequency roll-off or high-pass filter that is available on most professional microphones and mixers. Do not point the microphone towards the floor, lest you pick up additional noise and excessive low frequencies. This sound is known as "boominess." It is preferable to record flat, i.e. without equalization, since alteration of the sound spectrum, if necessary, is better done during the postproduction mixing operation. However, should you find it necessary to use equalization, limiting or compression, do not change it within a scene. Remember once again that if the sound is not clear in your headphones, it will not be clear later. Time spent learning how to get a good pickup, particularly under adverse conditions, will produce dividends during postproduction and to your reputation.

When one is recording more than one actor speaking in the same sequence, it may be necessary to find a compromise position for the microphone in order to avoid one actor sounding off-mic. It will be appreciated quickly that the skill of the boom or fishpole operator can make or break a recording. Under certain circumstances the actor may move into a part of the set that is acoustically bad. Tell the director about it before you shoot and get a bad track. The director may decide to allow you to correct the deficiency or re-shoot the sound later in a dialogue replacement facility. Remember that poor sound quality often results from the microphone being too far away from the speaker, badly angled or being in a bad acoustic environment. Avoid placing it directly over or behind the head of the actor.

In exterior shooting, one is more likely to have problems of picking up extraneous sounds from cars, planes, people and the elements. Under these circumstances, try a more tightly patterned microphone, or different angles below or to the side of the camera field of view. Do not forget that the preferable microphone position is slightly above and in front of the speaker. Body and radio microphones are often used in outside and wide angle shots. It is helpful in avoiding the sound of clothes rustling, to put a loose knot in the microphone cable about an inch below its head and to place it under a collar or on the front of a bra. Always try to avoid the chest cavity since this will inevitably sound boomy. Avoid using more than one microphone in the same pickup area in order to avoid interference between them, which results in a strange swishing or "phasing" sound that cannot be removed later. When, and not until, the sound is clean and as artistically or subjectively required in the mixer's headphones, turn to the recorder.

Use of Tape Recorders

Analog recorders are fitted with mechanical VU or peak meters, whereas DATs usually use electronic peak reading fluorescent bar meters. The basic difference between the VU and peak meter is that the VU meter reads the average level in a given time period, whereas the peak reading meter registers the highest part of the signal at all times. Discussion of the various merits falls outside this manual. In general terms one should expect a VU meter to read rather slowly. The level should be adjusted on dialogue so as to peak at around -1 and not above 0 VU, whereas a peak meter, which will respond rapidly, should never peak above zero. When using a DAT recorder, examine it carefully to find out if the sampling frequency is switchable. Always choose the highest sampling frequency available, at least 48 kHz, making certain that any record pre-emphasis circuitry is switched off.

Before starting to record sound, record a tone on the tape. Most mixers contain an oscillator for this purpose, as do most professional recorders. Customarily, -6 dB is used with VU meters and -8 dB on peak analog recorders. For DATs, -18 dB is the customary setting level for reference and aim to peak at -2. Never hit zero. In all cases, one is desirous of finding a reference level that will result employ the full dynamic range of the recorder without overloading its electronics or the tape. Whereas most analog recording systems tend to go into overload rather gently, digital machines reach their maximum permissible level and then break up completely. Therefore, it is very important to experiment with your recorder until you are fully familiar with its limitations and then work within them to obtain the best possible, clean, intelligible sound recording. Adjust the input level so that your average recording is reasonably high on the scale, making certain that the peaks never quite hit the overload point. Once again, trial and error is the best teacher. Beware of overloading either the electronics or the tape. This is the most frequent cause of bad recordings made in the field. Experience alone will give you the right point between a noisy recording that is recorded at too low a level and adistorted recording that is recorded at too high a level. Under extreme circumstances, the dynamic range of the incoming signals may be too great to control manually. Should this be the case, it may be necessary to employ a limiter, which determines the maximum level that may be passed through the system, or a compressor, which raises the low-level signals and lowers the high-level signals. It is vital to make certain that these devices do not give an unnatural sound, and they should be regarded, like the equalizer, as tools of last resort in the field. Avoid making large and rapid changes of levels, as these will sound unnatural and be difficult to rectify in postproduction.

Make certain that all tapes are properly identified and that they are packed with log sheets that contain full details of the recording. It is preferable to leave analog recordings on the takeup reel, or "tails out," for two reasons. The first is to make certain that the tape is tightly wound, so that it does not become physically deformed during storage. Under extreme conditions, the base of the tape can become so deformed that it will not lie on the reproducing head properly. Should this occur, the sound will vary in level and quality and may be unusable. The second is to minimize "print-through," a phenomenon to which analog tape is prone. This means that sound recorded, usually at a high level, is heard one and even two turns of the tape before and after the actual sound in the form of repetitions. This effect is a function of the tape formulation and varies from type to type. Print-through tends to be diminished in a tightly wound tape. You will quickly discover that most machines do not rewind tape at a speed to be high enough to be satisfactory for storage. By leaving the tape tails out this problem is eliminated.

Conversely, given the nature of the DAT system, it is advisable to rewind DATs fully. In both cases, inspect the tapes to make certain that the wind is even so that the tape does not become physically distorted. Place DATs in their safe, non-recordable mode by sliding the safety tab towards the center of the cassette.

Finally, remember that when all of your equipment is functioning correctly, your ears should be the final judge of the quality and acceptability of your work.

Filming Television Screens

by Bill Hogan
Sprocket Digital

When filming television screens or computer displays there are two principle obstacles to achieving consistent and clear images on the filmed result. These two problems are the difference in frame rates between the television image and the film camera and the incorrect color temperature of the television display. The following explanation and description of standards for television sets and computer displays is meant to provide an understanding and methodology to allow the filming of these displays with the highest quality possible.

Frame Rates

North America and many other countries of the world use a television delivery system that has 30 television frames per second, each comprised of 525 lines. Motion picture film for theatrical or television display is usually photographed at 24 frames per second.

This difference in frame rates is the predominant difficulty in photographing television sets as part of a scene. The artifact that is most visible is the appearance of horizontal bars on the photographed TV image. This is caused by double exposure of some parts of the television screen. To understand what causes this double exposure and the horizontal bars it is necessary to understand several other facts about the television signal.

With 30 frame television there are 525 lines scanned each 30th of a second. But to avoid flicker in the display a method is used that is somewhat analogous to the two bladed shutter in the film projector. This 30th of a second television frame is further divided into two television fields. Each of these television fields lasts for a 60th of a second. The displayed television image is "refreshed" or scanned now at 60 times per second and the result is no flicker. This is accomplished by starting the scanning beam (a single point of light or energy) in the upper left corner of the television screen and moving it left to right a single line at a time. When this beam of light reaches the right side of the screen, it jumps back to the left side of the screen during a period when it has been "blanked" or turned off. This is called the horizontal blanking period. This occurs every television line or 525 times per television frame.

In order to provide the refresh rate of 60 times per second, this beam skips every other line of the 525 lines that comprise a television frame of a 30th of a second. In other words, the scanning beam scans line 1, skips over the position that would be occupied by line 2 and scans line 3. This continues to the bottom of the TV image until all of the odd-numbered TV lines have been scanned.

At this point a 60th of a second has passed. The scanning beam is now at the lower right corner of the screen. The beam is "blanked" and is moved to the upper left corner again — ready to start scanning again. This time period of the beam moving from the lower right corner to the upper left corner is called the vertical blanking period or vertical interval. This happens 60 times per second — twice per television frame. This scanning beam now starts its scanning process over one line at a time, but during this 60th of a second the beam is positioned to scan lines 2, 4, et cetera — all the even-numbered lines are now scanned.

Now let us look at how the film camera views this television image. The camera that is chosen for this example has a 180-degree shutter. If we run this camera at 30 frames per second with a shutter opening of 180 degrees, the camera is exposing the film every 60th of a second. From the television scanning explanation above it can be observed that the film camera is "blind" to one of the television fields and is only photographing half of the 525 lines that occur in a television frame. The resulting TV screen image on the film will be good (with no "shutter bars") because the film camera and the television scanning are occurring at the same frame rate. When the film camera and the television system are operating at different frame rates the result is double exposure to portions of the television screen image.

Best results are obtained when the shutter opening coincides with the beginning of the scanning of one of the two television fields. In other words, the shutter is open for only one complete television field — not part of one field and part of the next field. In order for this precise phasing (shutter open vs. closed) to occur, external specialized equipment is used in conjunction with the film camera and the video equipment.

There are four combinations of film rates and television rates that are possible. These are outlined below:

1. 30 Frame Video and 30 Frame Film: This combination features standard NTSC 30 frame video (US Standard) and the film camera also operating at 30 frames. This approach is appropriate if the film is going to be used for a 30 frame per second telecine transfer, but if used for 24 frame projection there will be a 20% "overcrank," and if there is sound the pitch will be altered. Any US television monitor can be used. Shutter phasing and synchronization are required and the camera shutter angle is optimum at 180 degrees.

2. 25 Frame Video and 25 Frame Film: This requires the video signal to be the European PAL-625 line system and also the VTR and monitor to be capable of operation on this standard. If the film shot is projected at 24 frames there is only a 4% "overcrank," and the sound pitch change is usually considered undetectable except to musicians. Shutter phasing and synchronization are required and 180 degrees is the preferred shutter angle. This is the system that is chosen for most TV monitor filming in Europe and much of the rest of the world that operates on 50 Hertz power.

3. 30 Frame Video and 24 Frame Film: This features standard 30 frame NTSC video and a camera specially designed to have a fixed 144 degree shutter or a camera whose shutter can be precisely set to 144 degrees. This specific shutter angle allows the film camera to only photograph one set of scan lines per film frame but is extremely difficult to adjust. Anything mechanical that causes the camera to vary in speed or cause drag on the shutter will result in inconsistent results. Also camera panning and zooming will cause portions of the TV image to be double-exposed or not exposed at all, resulting in small black or white bars to be present in the TV image. Again, shutter phasing and synchronization are required and a very precise 144 degree shutter angle must be maintained.

4. 24 Frame Video and 24 Frame Film: This video/film combination requires a specialized video format, but the film camera is run at a standard speed and the resulting film is standard in all ways. The choice of shutter angle should be 180 degrees and there is a one-to-one relationship between TV frames and the preferred film rate of 24 frames. Shutter phasing to the TV signal should be used. Most TV sets and monitors can be adjusted to operate at this 24 frame rate, but caution should be used with an unknown model. Live video cameras and computers have been modified to

run at this 24 frames, offering a wide choice of source material.

24 Frame video was first used for feature production in about 1960. Since that time steady progress has been made in sophistication and choice of the tools for this one-to-one relationship with 24 frame film. Because 24 frame video is a modification of standard NTSC television equipment, the TV image has the same scanning frequencies as 525 line television. This results in the 24 frame image having a total of 655 television scan lines per 24th of a second. Thus, the precise vertical scan rate or frame rate of the television signal is actually 24.01 frames per second.

The synchronization between the film camera and the video system can be achieved in two ways. This is the shutter phasing that was referred to above. The first method is to obtain a shutter signal from the film camera and have the video system follow the film camera. This allows the film camera to operate on its internal crystal and to "pull down" the video system to exactly 24 frames. With this method no connection is made to the sound recorder. The disadvantage of this method is that the video source is limited to videocassette playback. In recent years this method is almost never used. One major drawback is that only one film camera can be rolling simultaneously.

The second mode of operation is the preferred method and offers the greatest flexibility of operation. In this mode the film camera is driven by a signal from video/film camera synchronization equipment. A signal is still received back from the film camera, used to phase the camera shutter opening to the TV signal scanning. A major advantage of this method is that any number of film cameras can be operating in sync and the choice of 24 frame signal sources is unlimited. As the film and television equipment are operating at a slightly higher frequency (24.01 frames per second), a 60.02 hertz frequency should be sent to the sound recorder to keep the sound in sync on long takes. Without this signal the sound will fall behind the picture about one frame every 45 seconds.

Both the above modes of operation can accommodate process or rear screen projection with the appropriate connections.

No attempt will be made here to describe the equipment available to synchronize the film and video equipment. This equipment is constantly changing and is available from many camera manufacturers and specialists in the field of video playback for film shooting.

Color Temperature

Color temperature of the filmed television image is the other most important aspect that needs to be understood and corrected for.

The correctly adjusted professional broadcast monitor will be adjusted to a color temperature of 6500 degrees Kelvin. But the normal range of TV sets and monitors can vary widely in their color temperature. To be used successfully, these TV screens must be set up for the correct color temperature of 6500 degrees. Test equipment is available to facilitate this adjustment. If filming is done with this adjusted monitor with a tungsten-balanced film designed for 3200 degrees Kelvin, the resulting TV screen image will appear to be very blue or high in color temperature. Monitors not adjusted to the correct color temperature will result in very unpredictable results.

There are five ways to compensate for this color temperature difference.

The first method is to readjust the TV screen to a lower color temperature — as close to 3200 degrees as possible. Most TV monitors are limited in adjustment range. This method is usually unsuccessful and today is almost never attempted.

The second method makes use of the fact that this higher color temperature of the television image is near the color temperature that is expected when shooting with daylight-balanced color negative that is now widely available. With this method the television image is left unaltered and the director of photography lights the rest of the scene with daylight-balanced lighting. The television image and the scene now match closely in color temperature and allow the use of daylight balanced film.

The third method is very similar to the second, but after lighting with daylight-balanced lighting the cinematographer uses a tungsten-balanced negative with a Wratten #85 filter on the camera. This method is sometimes used on commercials, but suffers from the loss of exposure caused by the filter.

The fourth method also uses tungsten-balanced film and lighting, but a change in the color temperature of the TV screen is made by placing Wratten #85 filter material on the TV picture tube. This is usually unsatisfactory because of loss of TV brightness and the visibility of reflections on the filter material.

The fifth method is the preferred choice. It involves precompensating the color temperature of the playback material. With this procedure the color TV screen is adjusted to the preferred color temperature of 6500 degrees Kelvin. If there is more than one TV screen in the scene, they are all carefully adjusted to this same color temperature. The next step is the preparation of the video playback material. Precompensation of the color temperature of the playback material is accomplished by using a viewing filter that has been arrived at empirically with much trial and error. This viewing filter raises the apparent color temperature of the color monitor, which causes the telecine colorist or video camera operator to add a specificate amount of "color compensation" to the video that will be displayed on the TV screen.

When this color-compensated video is seen on a properly adjusted 6500-degree TV screen it will appear very "reddish-orange." But to the tungsten-balanced negative the picture will be the correct color.

When the TV screen is to appear as a black & white set, another problem occurs. A black & white screen will appear to be of even higher color temperature — from 9000 to 11,000 degrees. There is no practical method to compensate for this very high color temperature. The most common method and the preferred solution is to place a color screen in what would appear to be a black & white cabinet. The playback material is made to appear black & white if it originates as a color image and then color compensation is added to the black & white image. This color-compensated footage will now appear to the color negative as a perfect black & white image.

General Notes

Playback material can come from any source. The best quality is generally obtained from film original that is transferred specifically for the scene involved and is color-compensated for video playback. Live camera original footage at 30 fps can be standards-converted and color-compensated with equal success. A jerky motion artifact will be noticed on 24 frame film material that was transferred to 30 frame video and then was standards-converted back to

24 frame video for video playback. This is an undesirable source of material.

Always test new or unfamiliar equipment. This includes new or untested TV screens and computers. This is a rapidly changing area and success is guaranteed only with the proper choice of equipment and with companies familiar with the latest advances.

Television Film Cinematography

by Edward P. Ancona, Jr.

Since the publication of the article on this topic in previous editions of the American Cinematographer Manual, there have been significant advances in receiver quality and in the sophistication of the telecine equipment which transfers the film image to television. However, it is important to remember that the typical home viewer is seeing and hearing films less than the optimum conditions under which the creative production team saw them.

Production staffs see their films in professional motion-picture review rooms and the resulting television transfers on professional monitors with carefully adjusted, stable color and brightness settings. Most home viewers, however, watch the show on receivers which may be only casually adjusted and in a room with the lights on. Such viewing conditions act primarily to limit the picture contrast range which can be effectively reproduced in the home. Therefore, the director and cinematographer should be aware that the available range of photographic effects is limited, and film photography for television must be adapted to exploit those styles and techniques which are most effective for the home viewer.

This is not meant to imply that the television system is incapable of high-quality transmission and reproduction. With a high-quality telecine transfer, good signal reception, and optimum receiver adjustment and viewing conditions, the reproduced image can be a close duplicate of the film in luminance range and color. Indeed the sophisticated contrast and color controls on the modern telecine can often achieve color and density "timing" changes in dimensions unavailable in the film laboratory. It is not uncommon on major television film productions for the director and cinematographer to attend the telecine transfer operation to guide the video operator, similar to the color timing operation in the film laboratory.

Contrast

Telecine reproduction of a film will often result in a television image wherein contrast appears higher than in the image seen in direct projection. This is due partly to inherent limitations of the electronic devices which convert the projected image to a television signal, partly to the optics of the telecine system and partly to the subjective effect of the smaller, brighter television image. The chief effect of this increase in contrast is a loss of shadow detail. Darker areas in the picture may appear plugged up, subtleties of mood lighting are lost, and story points or critical facial detail in dark scenes may be obscured. Again it is important to note that not all of the loss is in the telecine reproduction of the film — only a small proportion of home receivers will be carefully adjusted and viewed in a darkened room to accurately display the full range of the transmitted signal.

This increase in contrast requires that the cinematographer use more fill light than would be used for theatrical presentation only, and particularly that the approach to the more extreme moods or effects be limited. The use of underexposure, forced processing flashing and low fill-light levels to produce a realistic or "available light" look may be quite effective in direct theatrical projection but plugged up and ineffective in the typical home viewing situation. This is not meant to imply that television photography should be "flat." A wide range of moods and effects can be successfully reproduced on the typical home receiver, but the darker elements or areas of the scenes must be more fully lit and exposed if they are to be displayed effectively.

Higher lighting ratios can be employed for effect, and night scenes are best approached by adjustment of the lighting ratio rather than by shooting "day-for-night" or underlighting scenes and printing down. The ideal night effect photography for television would result in prints which have the same density range as fully lit scenes. The use of little or no fill light on the key position, sketchy background illumination, lighted windows, etc., all create the effect of a night scene without the necessity of printing down.

Special Print Films for Television

In previous years when black & white films were the dominant medium for television, it was standard practice to make "television gamma" release prints which were developed to a lower contrast than for normal theatrical release. Although these prints, on direct projection, looked somewhat flat with transparent shadow elements, their television reproduction appeared more like that of the theatrical prints in a theater. The reduced density range of the television gamma prints enabled the telecine to "see" into the shadows more easily, thus reducing the requirement for lower lighting ratios on the stage. Until recently, color prints could not be processed for a lower gamma without seriously upsetting their color tracking, and the only way to reduce the density range of the print was to reduce the luminance range of the original scene by lower lighting ratios and careful control of set and wardrobe reflectances.

Modern telecines are equipped to reproduce negative films by inversion of polarity and a change of reproduction contrast. The negative film is obviously of considerably lower contrast than a color print and the resulting reproduction therefore is much more open, with shadow detail well reproduced, and often with brilliant color quality.

The term "film look" really refers to the appearance of a print as seen in direct projection. There is much to be said for the subjective appearance of this image with its smoothly graduated highlight and shadow contrast. It is not intended to be an accurate duplicate of the original subject contrast and color values, but in the hands of a skillful cinematographer it is an extremely effective storytelling vehicle. As stated in the opening paragraphs, the aim of telecine operation is to produce a television image which is a close duplicate of the film print as seen in direct projection. The appearance of negative or interpositive films on a telecine, while seductively appealing with their open lowlights and high color saturation, can be distinctly different from the "print look." It is possible to modify the telecine characteristic so that negative transfers will come close to duplicating the look of a print, and it is emphasized that the cinematographer should be aware of these differences and see samples of negative transfers if his or her picture is to involve that process.

There is now available a color positive film which has been manufactured to a lower contrast and which does not require special processing for "television gamma." The lower maximum densities of this film benefit telecine reproduction of the image as compared to the reproduction from normal projection contrast print film. The contrast is not so different, however, that it cannot be satisfactorily analyzed for color "timing" in the film laboratory. Care must be taken during review-room laboratory timing of these low-contrast prints not to "print down" in an effort to achieve the shadow densities of normal-contrast print stock. When correctly timed for optimum telecine reproduction, the low-contrast stock on direct projection will have rather transparent shadow regions and will not have the solid blacks of the normal-contrast print stock. The telecine reproduction, however, will restore the shadows to their correct appearance but with considerably improved shadow detail over that obtainable from the normal-contrast stock.

Automatic Telecine Operation

The telecine operation at major broadcaster's installations or in most video postproduction houses serving the broadcast and cable television industries is characterized by an effort to reproduce the film as faithfully as possible within the physical limitations of the telecine device. Despite the misgivings of some cinematographers, the video operator does not make arbitrary changes in the character of the image; with a well-photographed and timed print, the operator will make an essentially "hands-off" transfer. However, some broadcasters may, for reasons of crew and time economy, resort to an automatic telecine operation wherein the brightest element of every scene is automatically set to 100% video level, and the darkest to 0%. This unquestionably can distort the continuity of the original print timing.

Although it is dismaying to have to prescribe for such a situation, if the cinematographer knows that a film is likely to have its major release to such syndication, he or she can incorporate a "reference white" and "reference black" in every scene, which will force the automatic telecine into a preferred state of adjustment. A reference white would be a near-white object in wardrobe or the stage illuminated by the key light. Almost any scene will have shadowed or unilluminated black areas and these will become the reference black for the scene. With such white and black objects in the scene, the automatic video telecine will arrive at an adjustment which will place face tones and other luminance values correctly.

Perhaps the concerns of this section are less pertinent now, since, practically without exception, all major television productions will be transferred on high-quality telecines with skillful operators, and most syndicated material will be similarly transferred and delivered on videotape.

Television Film Apertures

In almost any receiver, the accumulated effects of mask shape and off-center scanning or excessive height or width of scanning would result in the display of excessive picture information that was transmitted. While this area loss is different in each receiver, the average loss, or to put it another way, the area displayed by the average receiver, has been noted with the establishment by SMPTE of a "safe action area" and a "safe title area" (see "Cinematographic Systems"). Masks of the shape and relative size of these SMPTE-recommended safe areas should be used in the camera viewfinder as a guide to the composition and framing of scenes being filmed for television.

Since these areas represent only selected average conditions, it must be noted that some receivers will display everything to one edge or another of the transmitted area. Therefore, foreign objects such as microphones, stage lights or camera sunshades, or negative defects such as scratches or fog should not appear inside the transmitted area, and release prints should be free of physical defects such as scratches, wet gate printer marks or soundtrack applicator splashes in this area.

Daily prints of shows which are being shot for television and which are being reviewed by the cinematographer or others specifically for action framing may be inspected with a projector aperture of the dimensions of the safe action area. (This would apply also to review of theatrical wide-frame features being scanned for television, when the review is for evaluation of the editorial and positioning aspects of the scanning.) Ordinarily, however, television daily prints should be reviewed with a projector aperture of the dimensions of the transmitted area, since the film camera action framing is usually carefully monitored during shooting with the camera viewfinder safe action area mask. The production staff should also be aware of possible negative defects or extraneous objects outside the safe action area but still within the transmitted area. New titles photographed for television should lie preferably within the safe action area, although this should be most applicable to commercial copy where full visibility on all receivers is desired. On theatrical features released to television, title copy within the safe action area would ordinarily be acceptable.

There is an artistic compromise to be faced in the reproduction of CinemaScope or other wide-frame images on standard television. The choice is between "scanning" the wide-frame image to produce a standard 3 x 4 aspect ratio image or using the "letterbox" format where the wide-frame image is shown in its correct aspect ratio in the center of the receiver, but with wide black areas above and below the frame. While the letterbox format does reproduce the original framing and composition, it is far from the grandiose large-screen presentation which is part of the original conception; therefore, the tradition has been to "scan" the wide-frame images for television presentation. For the most part, this is done skillfully, with care taken for good framing of the recomposed images, and also with careful regard for the editorial considerations introduced with the need occasionally to cut or pan from one side of the wide frame to the other.

Shooting Videotape for Transfer to Film

by Gavin Schutz, Image Transform, Inc.

The process of transferring videotape to film involves a number of complex steps, not the least of which is the method of converting 30-frame video into a signal that can be recorded into 24-frame film. Some of the fields of the video signal must be discarded. Digital signal processing techniques are employed to treat the video signals to make them look better on film.

The cinematographer will need to know several things about the nature of video signals and how they correspond with film attributes. The following section will deal with some of these parameters, and also address how the finished videotape will look when it is transferred to film. The general rule for shooting videotape that will be transferred to film is no different from general practice: make the video as good as possible. This will involve giving attention to some factors that are not normally a problem when shooting film. These are all covered below.

The most common question that is asked about tape to film is "How much resolution is lost in the process"? This is a difficult question to answer because it depends upon what you call resolution, and what your frame of reference is. In contrast to film origination, in video there are two types of resolution, static and dynamic.

Resolution

Static Resolution is the amount of detail present in a scene that contains no motion. In the television world, the static resolution is measured in terms of bandwidth of the video signal, or the amount of TV lines that are used to build the signal. For example, NTSC is a 525-line 4.5 MHz system, while PAL is a 625-line 5.5 MHz Signal. This means that PAL has more static resolution than NTSC.

Film resolution is measured in line pairs per mm, and is an attempt to quantify the maximum number of black to white transitions in a millimeter of film frame. This parameter contains many variables, such as the optical transfer function of the film and other difficult-to-quantify assumptions about the film. Fortunately, the line pairs per millimeter can be converted into megahertz of bandwidth to allow for comparisons to video. For example, it is generally recognized that the equivalent "bandwidth" of 35mm motion-picture film is in the general area of 35MHz. This is about six times the resolution of most broadcast video systems.

This means that a camera original negative captures about six times the detail of a professional video camera. Figures 1 and 2 show the differences in resolution between film and video. Figure 3 is a comparison between the formats.

Video Resolution

	Static	Dynamic
Units	MHz TV Lines	Field Rate Frame Rate
Values	NTSC 4.5 MHz PAL 5.5 MHz	NTSC 30 FPS PAL 25 FPS

Figure 1

Film Resolution

	Static	Dynamic
Units	Line pairs per mm	Frame Rate
Values	About 35 MHz	24FPS

Figure 2

In the Image Transform System, there is no significant loss of static resolution. This means that all static detail present in the original video master is transferred to the film. The use of patented wideband digital decoding and component signal processing ensure that all detail present in the video is preserved in the Transform process. However, it is important to realize that the end result will not have the same static resolution as original film, simply because the amount of information recorded on the videotape is less than would have been recorded on the 35mm film. Fortunately, there are some things that can be done to the video signal that will help its appearance when taken to film. These are addressed below.

Dynamic resolution is defined as the amount of temporal information contained in a scene having movement. Dynamic resolution depends upon the update rate of the images. Both film and video images are sampled in time, and this leads to a finite loss of dynamic resolution (compared to real life) in both cases. Dynamic resolution is directly proportional to the frame sample rate. In the case of film, the sample rate is 24 frames per second. In NTSC, it is 30 and in PAL, 25 frames per second. Film has dynamic resolution the video systems. is why moving images appear smother in video rather than the stepped film images. (Fig. 3)

Video Film Resolution		
	Film	Video
Static	35MHz	NTSC 4.5 MHz PAL 5.5 MHz
Dynamic	24 FPS	NTSC 30 FPS PAL 25 FPS

Figure 3.

Interlace Artifacts

This difference in dynamic resolution is compounded by the interlace structure of the video signal. The frame rate of 24 for film versus the 30 frame update rate of NTSC is bad enough, however in most cases pictures originating on video are updated at the field rate. This results in having effectively 60 pictures per second (at half the static resolution) instead of the normal 30. The challenge here is to take the 60 pictures per second and reduce them to 24 pictures per second without rendering the motion artifacts unacceptable.

The information contained in a video frame is made up of two discrete interlaced fields. Care must be taken to preserve the integrity of each of these fields, as they are both used to produce the final film frame. By a process known as adaptive interpolation, video fields are averaged with other fields from other frames to produce the new frame. This averaging process is possible (and necessary) because of the fact that there are more video frames than there are required to be film frames. In the Transform process some of the fields are discarded, and the interpolation process is used to smooth the motion around the discarded fields. Obviously, the more information there is to work with, the better the dynamic resolution (smoother motion). Because of this, care must be taken not to pan the camera excessively fast, because this will result in a different picture for every field. When this frame is transferred to film, there will be two images on the film frame. Clearer, sharper images will be obtained from slower pan rates. This applies to both vertical and horizontal pans.

Digital Effects

Advanced digital effects generators and paint systems currently in use tend to operate on the video signal as if it were not an interlaced system. These devices produce a new image every field instead of every frame. While resulting in much smoother motion of video tape, this method can result in a film image that is fragmented and sometimes blurred.

Because of the throwaway field sequence (see Fig. 5), an apparently smooth video effect generated in field mode rendering can appear disjointed and unnatural when transferred to film. The amount of degradation depends upon the type of video effect. Very slow horizontal or vertical movement is usually acceptable. As the rate of movement is increased, the artifacts become more objectionable.

The best way to avoid these temporal related artifacts is to refrain from using the more ambitious digital effects that are available. Any effect that is characterized by rapid vertical, horizontal or temporal motion will cause these discontinuities. They will be very noticeable in the film and should be avoided, if at all possible. Some of the more recent digital effects devices offer two modes of rendering motion — field and frame mode. When generating material that will be transferred to film, use the frame rendering mode.

Note that vertically crawling title sequences (such as credits) represent about the absolute worst case, and illustrate all of the problems noted above. When editing in the credits, fade them in and out rather than having them crawl vertically.

Graphics Rendering

Graphic and CGI (Computer Generated Images) effects should be rendered in frame mode (i.e. make sure that both fields of a video frame are the same) rather than field mode because this allows better interpolation.

In the case of CGI where the effects are rendered a field at a time, there is a way to ensure against any motion artifacts. Because these images are usually rendered a field at a time and are recorded by videotape machines in animation mode, it is sometimes possible to artificially "build in" a 3:2 sequence. In this method an image that has been rendered by computer is recorded for three fields of video. The next image rendered is then recorded for two video fields. the resulting animated image is the functional equivalent of a 24 frame film transfer, and (as discussed below) can be taken to film without motion artifacts of any kind.

Because the rendering of complicated graphics (such as animated sequences) or integrating video with sequences that contain original film material is a complex process, it often pays to consult with the facility that will be doing the tape-to-film transfer before integrating or generating the CGI sequences. In some cases, techniques can be employed on some of the latest graphics platforms (such as the Quantel Harry) that will produce a "perfect" film transfer (i.e. a perfect correlation between the video and film images).

The use of variable-speed video or time-compressed video material should be avoided as it introduces easily noticed motion discontinuities in video which are made worse in the tape-to-film process.

Film to Tape to Film

Another aspect that needs to be considered is the problem associated with editing material that originated on film with material that has been originated on videotape (i.e. film to tape to film). In many cases material that has been shot on videotape will be intercut

It can be seen that an extra field is inserted into the video to make up for the difference in frame rates between 24-frame film and 30-frame video. In figure 4 this is the field labeled "3".

The tape-to-film system must detect which field was inserted in the telecine process and use it as the throw-away field. If this is successful, the resulting film transfer will be perfect — there is no way to tell the difference between it and original film. In most cases, the sequence is repetitive and will not change for the duration of the transfer. Moreover, there are only two ways the sequence can be mapped out: 2/3/2/3. or 3/2/3/2. This is illustrated in figure 5. The problem arises when material from different sources is edited together on videotape. It is then possible that, once the pieces are assembled together, the field sequence is disrupted, giving a sequence such as 3/

Frame Rate Conversion

24 Frames per Second

Film Frame 1			Film Frame 2		
1	2	3	4	5	6
Field 1	Field 2	Field 1	Field 2	Field 1	Field 2
Video Frame 1		Video Frame 2		Video Frame 3	

30 Frames per Second

Film to Tape Field Sequence

Figure 4

Frame Rate Conversion

30 Frames per Second

Video Frame 1		Video Frame 2		Video Frame 3	
1	2	3	4	5	6
Field 1	Field 2	Field 1	Field 2	Field 1	Field 2

Field 3 is dropped

Film Frame 1	Film Frame 2

24 Frames per Second

Tape to Film Field Sequence

Figure 5.

2/2/3, 2/3/3/2, etc. The result is that a disrupted Frame 3 sequence will produce very noticeable discontinuities in all scenes that contain any motion because the wrong field will be discarded during the tape-to-film transfer. Unfortunately, there is no way of knowing that the sequence has been disturbed until the video is actually being transferred, simply because it is not possible to predict where the videotape edits will occur and what the sequence is at that point. Other examples of this occur when foreground/background matting is done and one of the elements is out of sequence with the other.

In order to produce the best possible transfer, it is desirable that the tape-to-film house used for the transfer is able to dynamically determine the sequence and adapt the throwaway field sequence accordingly. This is done at Image Transform by computer-controlled signal processing. It is offered as part of the scene-to-scene color correction process.

Video Signal Processing

Scene-to-scene color correction, dynamic enhancement, smear correction and phase correction are some methods used in the tape-to-film process to overcome limitations of the video environment. These techniques are employed to help make the videotape look as much like film as possible. For example, the gamma and clipping levels are changed to emulate the transfer function of film. Where possible, the use of electronic processing to the transfer process should be kept to a minimum. This will help avoid an overprocessed look in the product.

Always bear in mind that a motion-picture screen is much larger than a television monitor and care must be taken in the video production to allow for the best possible end result. Small defects in the video can be quite objectionable when projected on a large screen.

Lighting and Cameras

In most cases, it is sufficient to shoot using established practices for video production. It is valid to say that the quality of a film print will be indirectly proportional to the quality of the video source material. When shooting the video, use the full dynamic range available and avoid crushing the blacks or clipping white areas of the scene. Ensure that the camera clip levels for each color are set the same.

Scene-to-scene color correction is usually performed as part of the tape-to-film process to ensure that the resulting film is colorimetrically correct. This includes scene-to-scene manipulation of RGB gain, gamma and pedestal, as well as hue and saturation control. In the process of transforming tape-to-film, color matrixing and transfer characteristics of the video are changed to help make video look more like film.

In order to achieve best results, the video should be shot with adequate and even lighting, using the best available cameras. The choice of camera will depend upon the nature of the subject material. The choice of CCD or conventional (tube-based) video cameras will depend on the available light as well as the amount of control that the director of photography has over the scene. Inadequately lit scenes may suffer from decreased resolution and excessive noise. In general, CCD cameras are better suited to low light levels. Proper care should be directed to minimize noise and other artifacts introduced as a result of using the cameras outside of their normal range. The video medium does not have the same dynamic range as film.

Recent developments in the field of CCD technology have made these cameras very popular. They do not suffer from registration, overload, lag or comet-tailing like their tube counterparts. In the case of tube cameras, make sure the registration is set correctly as this is one of the few problems that cannot be corrected during the transform-to-film process.

Most modern video cameras come with a knob called "enhancement," "aperture" or "coring." These adjustments are to increase the apparent resolution of the picture, and make the images sharper. They also make them noisier, and when overused, they will put a dark black edge around subjects in the pictures. These artifacts will look very unnatural when transferred to film. When adjusting these controls, make sure that they are not subject to overuse. Most good video cameras will require a minimum amount of this type of correction. In-camera enhancement and coring should be kept to a minimum. A good guide when setting up camera enhancement is focusing to an optical multiburst chart, and setting the enhancement to provide a flat frequency response at 400 TV lines on the waveform monitor. Avoid using an image in the viewfinder or monitor to set enhancement levels because overcompensation can occur as a result of poor monitor resolution.

Videotape Formats

There are many different video formats available for recording video. These include the ½" consumer and ¾" industrial formats, up to the 1" composite and D-1 component professional formats. The former (½," ¾") are generally not suitable for transfer to film because they lack the necessary bandwidth and do not have the required signal-to-noise ratios needed for a good transfer to film. Some industrial films, however, are shot on ¾" videotape and transferred successfully to 16mm film for in-house distribution. The results can be acceptable when projected on small screens. Materials supplied on one of these formats usually need some form of noise reduction and enhancement prior to being transferred.

Scene-to-scene color correction requires 1" C format, D-1, D-2 or D-3 videotape. Material supplied on other formats will need to be dubbed to one of these formats if scene-to-scene color correction is required. The use of high-energy, low-noise, low-dropout professional grade videotape is recommended, and the number of generations should be kept to a minimum.

There is no doubt that the best available formats for tape-to-film transfers are 1" C format, or one of the digital formats that have been shot with studio-quality cameras. If 35mm theatrical release is desired, the use of one of these formats is mandatory.

The use of component systems, such as the Sony Betacam SP and the Panasonic M II format, as well as other systems where the video signal is recorded as a series of luminance and chrominance (i.e. not composite video), can be successful to full 1" production. When considering the use of industrial and consumer formats, consult with the transfer facility prior to beginning production.

Images produced by the Betacam SP system often approach that of 1" quality without some of the 1" limitations (such as cost and ease of use in the field). Higher chrominance resolution and the lack of cross-color effects are big advantages. These advantages, however are only maintained if the signals stay in component form all the way through origination, postproduction and editing. They are lost if the signal is encoded at any stage.

One method of producing extremely good pictures is to shoot video using a component system, then master to the digital D-1 tape format. Great success has been achieved by shooting using a Betacam SP camera/recorder, then editing component using SP playback machines and the D-1 as a master record machine. There are several postproduction facilities that specialize in component editing systems. Make sure that the signal is always kept component — never encoded to NTSC. Many documentaries and full-length feature presentations have been shot in this way.

The use of downstream noise reduction during editing should be avoided as this is an integral part of the film transform process. Doubling up on noise reduction will produce images that appear blurred and unnatural, as well as decreasing the available resolution and leaving objectionable artifacts.

All of the active picture area is preserved in the tape-to-film transfer process. There is a slight loss of picture area in the printing process; however, the negative will contain all the information originally in the video picture.

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