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Traveling-Matte Photography and the Blue-Screen System

A TUTORIAL PAPER

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Introduction

Traveling-matte photography is so complex a subject that the author's intention here is only to familiarize the reader with some of the basic concepts and problems. Personal experience, skill and knowledge of the most intricate phases of photographic science on the part of individuals have led to unique and often patentable methods of achieving the same type of composite photography in different ways.

The technical details of the traveling-matte process will be presented here in five parts:

Part 1: Description of Traveling-Matte Systems
Part 2: Specifications for Equipment and Photography for the Blue-Screen Color-Difference System
Part 3: Special Photographic Phase
Part 4: Common Problems in Making Traveling Mattes
Part 5: Conclusion: Problems and Future Requirements for Traveling-Matte Photography
Part 6: How Electronics May Simplify This System in the Future

This entire exposition is based on investigations which were begun by Petro Vlahos during his former association with the now-defunct Motion Picture Research Council. Since several articles describing most of the dual-film traveling-matte systems have already been published, this presentation will deal principally with the blue-screen system. They are intended to enable reasonably experienced motion-picture technicians anywhere to set up a blue-screen system for making traveling-matte shots comparable to those achieved by major studios. It is hoped that the study will also be helpful to many previously experienced in traveling-matte photography, affording a better understanding of the complexity of composite photography, and that it will lead to better results and notable improvements in motion-picture productions.

Traveling-matte photography contributes greatly to story-telling impact, and its use is much too limited compared to its inherent potentials. It is hoped, therefore, that this paper will stimulate increased use of the art and result in improvements of such significance as to increase the confidence of motion-picture producers generally in traveling-matte photography.

Part 1: Description of Traveling-Matte Systems

Traveling-matte processes are the subject of increasing interest among film makers due to recent improvements in techniques. Some of the advantages of traveling-matte processes are: (1) almost unlimited scope; (2) sharp focus in backgrounds; (3) control during printing of color balance between foregrounds and backgrounds; (4) reduction of production time on the set; and (5) photography of backgrounds subsequent to filming the corresponding action, if desired.

The attributes and advantages of the traveling-matte process and process projection are often compared. Each technique has its proper application and one can rarely substitute for the other and cannot replace it. Although process projection is invariably limited by the size of the process screen and requires that there be considerable stage space behind the screen, it has the advantage that the background can be observed by the director and the cast as they work before it; also, the resulting composite picture is available with the dailies with no special optical work required.

All traveling-matte systems have certain common characteristics: the action phase is photographed against a plain backing indoors on a sound stage. Various types of backings have been used in conjunction with various kinds of illumination, but the end result is the same: a duplicate negative which contains the foreground action that was photographed against a plain backing, and including the background scene photographed separately but combined with the action in optical printing steps.

In order to combine the foreground action photography with the background photography in traveling-matte procedure, it is necessary to have a silhouette or matte of the progressive foreground action. In the optical printing step, this silhouette matte serves to prevent exposure of the background scene in that area occupied by the foreground action. In the initial pass through the printer, the matte causes that area of the positive print film to remain unexposed, so that the foreground action may be printed into the unexposed area during the second pass of the film through the printer.

The strip of film that bears the silhouette of the foreground action is called the matte, and the fact that the opaque silhouette thereon can and does progressively change in form and in position within the film frame as the film moves through the printer gives it the term traveling matte.

In practice, from a negative of an action staged in front of a plain backing (Fig. 1) a matte is made in which the backing area in each picture frame is completely opaque, and the action clear or transparent. This matte is variously termed a matte master, cover matte, action printing matte, or most commonly: Female Matte (Fig. 2). A black-and-white print made from this matte is, of course, just the reverse — clear and transparent where the former is opaque. This second matte is known as the background printing matte, male silhouette, or most commonly: Male Matte (Fig. 3).

One of the chief difficulties with any traveling-matte system is the achievement of great accuracy. Mattes must be precise in order to insure the perfect

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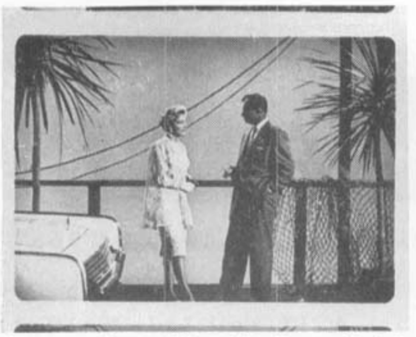


Fig. 1. Action as filmed in front of plain (blue) backing.

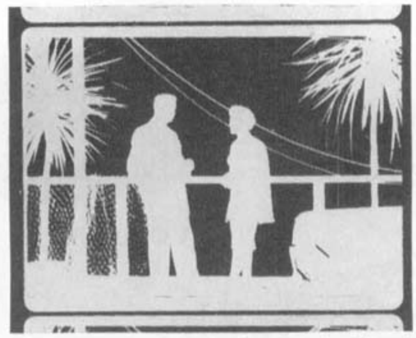


Fig. 2. Female matte of action in Fig. 1; also called "matte master."

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.

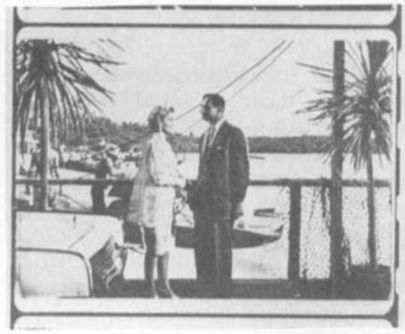


Fig. 5. The final composite print: Fig. 1 plus Fig. 4, via Figs. 2 and 3.

registration necessary to prevent "fringing" in the final composite print.

The two basic traveling-matte systems presently in use are identified by the number of negative films used in the camera during photography of the foreground action. They are known by the self-explanatory terms *single-film system* and *dual-film system*.

The single-film system, widely used for a number of years, employs any camera that is normally used for standard 35mm flat or squeezed photography, or such systems as VistaVision and Technirama; also 65mm cameras used in such photographic systems as Todd-AO, and Super- and Ultra-Panavision. Essentially, the single-film system requires that color negative be used in the camera and that the foreground action be photographed against a plain but colored backing — the color depending upon the illumination used. The most successful of these single-film processes is the blue-screen process which involves a backing or background screen of blue color.

The dual-film system utilizes two separate negatives in the camera plus a prism or beam-splitter that divides the light entering the lens and directs it as required to each of the negatives. Thus the matte and the foreground action are photographed simultaneously with one camera.

In American studios, and in some studios overseas, dual-film matte systems utilize the Technicolor 3-strip camera, which readily provides the required dual-negative facility. In England, a "beam-splitter" camera manufactured by the J. Arthur Rank Organization is used extensively for traveling-matte production. Procedure with these cameras is limited to the use of 35mm film and a 4-perforation pulldown. Instead of a plain blue backing, an ultraviolet, infrared or sodium-light and screen combination can be used for the background.

In theory, at least, the dual film system seems generally preferred, because the required matte is produced on black-and-white negative simultaneously with the photography of the action, which may be recorded on either color or black-and-white negative. The latter will record an image of the foreground action only, as though photographed against a black backing.

Freedom From Restrictions

The principal advantages of dual-film matte systems lie in the complete freedom from restrictions regarding foreground material, and the reproducibility of transparent objects.

Single-film matte systems have their advantages, too. The fact that only a single negative is required in the camera does not restrict the system to the 35mm medium alone. Also, use of a single film obviates the need to align and register two film movements in the camera. Recent modifications of the blue-screen matte process make it possible to reproduce transparent objects and eliminate blue fringing. If the required blue color in the backing is obtained on a transparency screen by means of projection-type arc lamps, it is also possible to project for viewing and timing purposes the intended background scene while the action is being photographed.

A more detailed description of this method and each matte system follows. Specific details of the photographic aspects of the blue-screen process will appear in Part 2.

Single-Film Matte Systems

Blue-Screen System: This system has been used in motion-picture studios for a number of years with varying degrees of success. Foreground action is illuminated the same as for conventional cinematography and no filters are required on either the lamps or the camera lens. The backing may be of canvas, painted blue and illuminated from the front with arc light, or a blue translucent backing illuminated from the rear by a bank of incandescent lamps.

The single color negative in the camera receives normal exposure from the illumination on the foreground subjects and action which it records. The blue backing against which the action is played causes the blue-sensitive layer of the color negative to be properly exposed, with little or no exposure in the green- and red-sensitive layers. Following photography, three black-and-white negatives are made from these positives, and, by combining the negatives and positives and using high-contrast film, the required male and female silhouette mattes are produced.

Since the production of mattes by this method is dependent on the difference between the color of the backing and the foreground objects, no costume, prop or other object that is blue in color can be used in the foreground composition. For the same reason, transparent objects such as glass, nets, loose hair, etc., must be avoided in the foreground composition or action. A very rapid motion will result in a blurred image, and the moving object will either disappear entirely or be followed by an undesirable blue fringe. Extremely careful registration is required when printing the action negative in order to avoid fringing in the print, because the blue-screen area in the scene is also recorded on the action negative.

The Color-Difference Blue-Screen Matte System

Until very recently, the blue-screen process was not too highly regarded, but it was made to work when the occasion demanded and it had the advantage that it could be used with any camera or film system. Modifications made since by the Motion Picture Research Council were aimed at overcoming some of the major difficulties. The principle modification involves laboratory procedures in which a color-difference matte is produced — which special technique now gave this process its name: Color-Difference Matte System.

In the improved system, the backing, lighting and photography are identical with those for the old blue-screen matte process; but here the similarity ends. The blue backing plays no direct part in the photography of the action. Its only purpose is to facilitate the making of the required male and female mattes. Since the backing is blue in color, it causes exposure on the blue color layer in the emulsion of the color negative, leaving the green and red layers unaffected. As far as these color layers are concerned, the backing might just as well be black. If it were not necessary to use the blue layer to reproduce color in the foreground, the system would be able to reproduce transparent objects and be free of the tendency to create blue fringing. This, then, is the principle of the "new color-difference" blue-screen system: the blue record is not used directly.

The Color-Difference Matte

In the laboratory, the color-difference matte is produced by bi-packing a black-and-white green color separation positive with the original negative. This matte registers as density only those areas in the scene where the blue content is less than the green content. This matte together with the green positive represents a faithful duplication of the blue color content within the scene — except, of course, where the blue content does not exceed that of green. All colors except blue and violet will, therefore, reproduce in normal values. The blue backing reproduces as black and makes possible normal reproduction of transparent objects in the scene such as smoke, glass, etc. Unlike results with the older blue-screen system, objects in rapid motion in the scene will reproduce normally and without fringing.

Advantages and Disadvantages

Photographic tests, which involved a full range of colors and also a number of common transparent objects have been completed, and indicate the potentials and the limitations of the improved blue-screen system. The chief advantages can be summarized as follows:

(1) Any film or camera system may be used.

(2) Transparent objects are fully reproducible.

(3) There is no color fringing.

(4) No filters are required on action or background illumination.

(5) Backing can be extended under feet of players, props or other objects within the scene, as in the old system.

Limitations are:

(1) Rich blue or violet colors cannot be reproduced. If there are no transparent objects in the scene, the threshold of recognition of the color difference matte can be raised so as to reproduce medium blues and violets while still maintaining a major discrimination against the blue backing.

(2) Separation positives are required, and the male and female mattes may require two or more steps to produce.

Dual-Film Matte Systems

Common Considerations: Dual-film matte systems (ultraviolet, sodium, infrared) approach the ideal since the color negative is exposed only by the foreground action illumination, while the black-and-white negative is exposed entirely by the backing illumination. It is therefore possible to transfer the foreground action to the dupe negative without the use of mattes.

Since the black-and-white negative is exposed only by the background illumination, a finished female matte comes out of the camera. A first-generation print made from this negative will produce the male matte, which may be used directly in printing the background scene to the dupe negative. It would seem that no traveling-matte system could be any simpler or more direct than the dual-film system outlined above.

In practice, however, dual-film systems are not quite this ideal or direct, since there are certain limitations in lighting the action and the backing, and in the complexities of the matte production department.

Since the color negative must not be exposed by the backing illumination, this illumination must be in the form of radiation to which the color negative is insensitive. This limits the backing illuminant to three choices: (1) ultraviolet energy just beyond the blue end of the spectrum; (2) infrared energy just outside the red end of the spectrum; or (3) a band of illumination within the visible spectrum so extremely narrow that it can be removed without affecting the color rendition of the color system. Sodium light has this property.

From a practical standpoint, each of the three dual-film systems can produce excellent results with varying degrees of complexity on the set and in the matte department.

The Ultraviolet System

In the Hollywood studios, the ultraviolet system employs a Technicolor 3-strip camera that provides for the two negatives required.

Because lamps generally used for illuminating the foreground action radiate a substantial amount of ultraviolet, an appropriate filter must be placed on each lamp to screen out the ultraviolet in the illumination reaching the foreground objects in the scene.

The backing, usually a translucent screen, must be capable of transmitting ultraviolet and for best results all the lamps behind the backing must be filtered to eliminate visible light reaching the screen. The ultraviolet fluorescent lamps that can be used for this purpose have a rated life of several thousand hours and require no filters.

Ultraviolet light, being of a shorter wavelength than visible light, will cause the photographed matte image to be slightly smaller than the color action image. Thus an enlarging compensation must be made in the printing step unless specially corrected lenses are used on the camera to offset the image reduction.

Certain transparent objects are not transparent at all to ultraviolet light, and often the background scene does not show through as expected.

While it is theoretically possible to print the foreground photography to the dupe negative without a matte, this produces a mild veiling or fogging of dark areas in the background scene when present color films are used, and requires the use of a light cover matte or female matte to correct it.

The Infrared System

The infrared system also employs the Technicolor 3-strip camera. Filtering requirements are somewhat similar to those required for the ultraviolet system, and for best results, every lamp used to illuminate the foreground action requires a filter to screen out the infrared.

Infrared filters are far more difficult to obtain than those for ultraviolet and are many times more expensive. A U.S. patent (No. 2,461,127) was granted in 1949 to L. B. Pickley on such a system and the use of infrared filters in traveling-matte photography is understood to infringe on this patent unless the proper license is obtained. Where no filters are used on the foreground lamps, an inferior matte can be obtained which requires several additional steps in the procedure in order to produce an acceptable silhouette.

In the infrared system, the backing, when illuminated by infrared radiation, should appear entirely black to the eye. Of interest here is a special black nylon velvet material now available, which is highly reflective to infrared and makes excellent backing for this process. In use, the backing is front-illuminated by unfiltered incandescent lamps; the properties of the nylon backing material effectively cancel out the exposure potential of the visible light, making use of filters unnecessary.

As with ultraviolet, the wavelength of infrared poses a correction problem. Because infrared is of a longer wavelength than visible light, unless special corrective lenses are used on the camera the resulting matte image will be slightly oversize and must be properly reduced in the optical printing step.

The action negative may be reproduced on the dupe negative either by means of the color intermediate film or through black-and-white separations. A light female matte is generally required to prevent veiling of the background scene.

The Sodium Light System

This, the last of the important dual-film traveling-matte systems, as originally proposed, requires the use of dymium filters on the foreground action lamps and on the camera. And, as with the preceding systems, the Technicolor 3-strip camera is employed.

The background, against which the foreground action is played and photographed, is opaque, and painted with a special yellow color and illuminated from the front by sodium-vapor lamps similar to those used in some street lighting systems. These lamps have a rated life of 4,000 hr and the illumination is of very narrow range, near the middle of the visible spectrum.

The lamps used to illuminate the foreground action require no filters. But there is a special prism used in the camera which directs nearly all of the foreground action light to the color negative, resulting in normal exposure.

The sodium illumination from the backing is reflected by the prism to the black-and-white matte film, and therefore does not affect the color negative. Since the black-and-white matte negative receives only the sodium lamp illumination, the image registered on the film ultimately appears as a silhouette. With this system, the matte image is unaffected by the wavelength of the illumination and is the same size as the color image, requiring neither reduction nor enlargement. Also, most transparent objects within the scene reproduce normally.

While all three dual-film systems are capable of rendering excellent results, the sodium-light system offers the advantage of requiring no filters on either foreground or background lamps; the matte image is the correct size; and little if any difficulty is experienced with transparent objects.

Part 2. Specifications for Equipment and Photography for Blue-Screen Color-Difference System

Introduction

The traveling-matte systems described in Part 1 and the various techniques which may be subsequently employed by the laboratory have as a basic requirement a properly exposed negative photographed on a thoroughly prepared set.

It is important that the director of photography have a good understanding of the major problems involved in traveling-matte photography in front of a blue screen. This does not mean that he need worry about the follow-through in the special photographic department or laboratory, for his contribution lies in correct handling of the original foreground action photography.

Savings in production can be achieved and quality of the final composite print can be substantially enhanced if, prior to commencement of shooting and under the guidance of a well-informed director of photography, all participants, including the art department, set dresser, prop man, wardrobe, paint departments and others, are familiar with the specifications and rules governing this special type of photography.

There are two basic reasons for publishing in detail here the instructions on photography for the blue-screen traveling-matte process:

First, prior to the closing of the Motion Picture Research Council in Hollywood, the staff physicist, Petro Vlahos substantially improved the old blue-screen method to what is now described as the color-difference traveling-matte system (outlined in Part 1 and described in detail in Part 3).

Also, Technicolor Corp., under their Technical Director, Wadsworth E. Pohl, has made further improvements in the system, leading to excellent results even for large-volume production. In so doing, Technicolor has elevated this highly scientific work beyond the confines of major studio special photographic departments to the point where any producer, anywhere, can use this type of composite photography.

All technical data given here are based on practical experience obtained during production, but this article is intended *only* as guidance for those undertaking work in this special phase of motion-picture production.

Fundamental Equipment and Preparation for a Blue-Screen Setup

The following data refer to the latest Stewart T-Matte (transparent) blue screen commonly used in the major studios.

Elements used in the blue-screen process are a single-film camera, the foreground action and lighting, the blue screen itself, and the lights behind it, as shown in Fig. 6.

Foreground action is exposed with normal white light in front of a plain blue backing that occupies that area on the film frame reserved later for the background action — more generally referred to as the "plate." The transparent blue screen must be a perfect blue filter that will pass only that color of the white light behind it that will give maximum exposure in the blue-sensitive layer of the Eastman color negative in the camera.

The Stewart T-Matte blue screen represents an ideal solution and, compared to the painted blue canvas screen, has advanced the art of blue-screen photography enormously. It is basically the same as the type of screen manufactured for years for transparency photography, namely a multilayer plastic sheet to which a specific nonfading blue pigmentation is added.

Figure 7 shows the light transmission and filter curves of a Stewart blue screen together with the filter characteristics of the Wratten 47 + 2B filter combination, which is that used in film laboratories for blue record separation work.

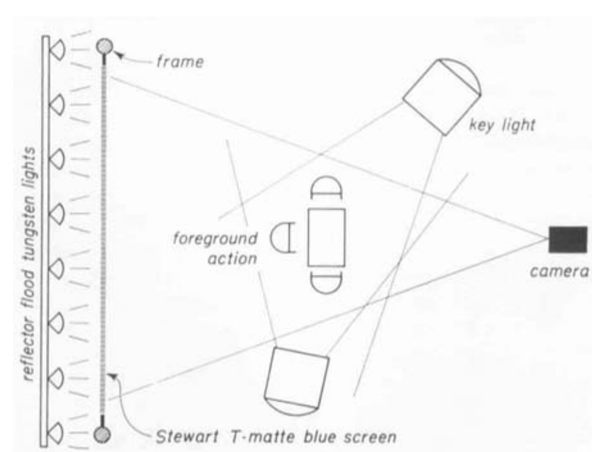


Fig. 6. Basic arrangement of camera, lights, foreground action, and the blue screen.

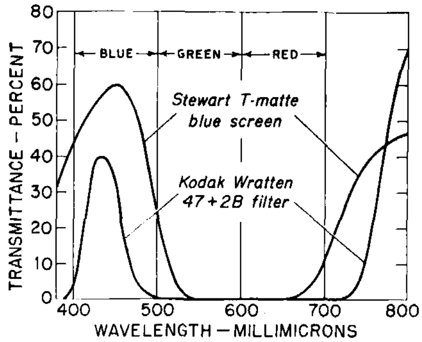


Fig. 7. Light transmission and filter curve of a Stewart blue screen together with filter characteristics of the 47+2B filter.

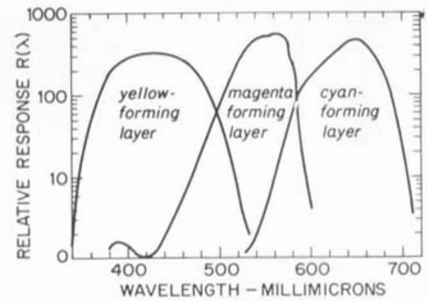


Fig. 8. Spectral sensitivity response of Eastman Color Negative Type 5251.

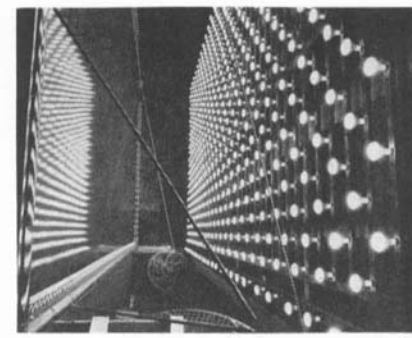


Fig. 9. Rear view of blue screen (left) mounted on aluminum framework and bank of individual incandescent lamps used to illuminate it. Fan used for cooling lamps may be seen in background.

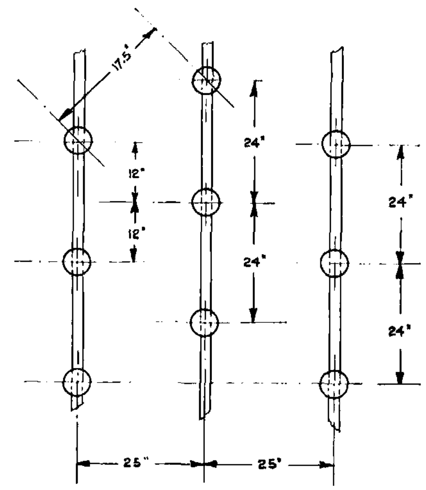


Fig. 10. Dimensions for placement of the reflector flood tungsten lamps on framework shown in Fig. 9.

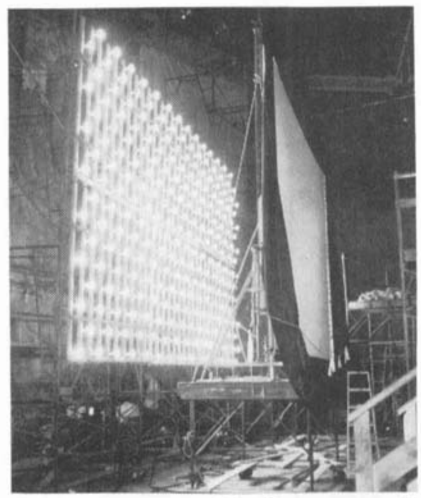


Fig. 11. Small portable blue screen in place on set with light bank placed 7 ft 6 in. behind it.

Fig. 12. View of framework carrying 600 tungsten lamps used to illuminate blue screen.

For reference, the spectral sensitive response of the presently used Eastman Color Negative Film, Type 5251, is shown in a graph reproduced from the Eastman data sheet for this multilayer color rawstock (Fig. 8).

The blue region of the visible spectrum is, in technical terms, that between 400 and 500 millimicrons. The peak transmittance of the blue screen lies at 450 millimicrons. For practical purposes this color is usually referred to as ultramarine blue.

The advantage of a transparent blue screen over a painted backing with front illumination is that it permits perfectly controlled blue content at all light levels and distances by merely regulating the voltage and intensity of the light sources which illuminate it from the rear. Stewart T-Matte blue screens show very good uniformity in pigmentation. Even where areas of density variation may be visible when the screen is illuminated, they are of no consequence in matte work on the reduced, exposed film frames. The light distribution pattern of such a screen is almost the same as for ordinary transparent screens. However, the use of "extended" banks of multiple lights as opposed to a single illumination source, as in background projection, affords more freedom of camera movement, such as tracking, tilting, panning, etc. The Stewart screens are seamless and are available in any size up to 88 by 46 ft. They can be rolled up for transportation without damage to the surface or color. When used, they are suspended and drawn tight — laced to a collapsible aluminum frame mounted on rollers. This permits their use almost anywhere, and only about 10 ft of space is required behind the screen for the banks of lights.

An off-screen picture of a 50 x 24 ft Stewart T-Matte blue screen mounted in an aluminum frame is shown on Fig. 9. Since these screens are used with the matte side toward the camera, an image of the lights appears reflected in the rear, glossy surface of the screen.

Lighting Behind the Blue Screen

Lighting the blue screen from behind is presently done with 300-w (110-v) reflector-flood bulbs (not photofloods). In order to avoid any possible fall-off of light from bulb to bulb, the lamps are mounted in a diamond-shaped pattern. The framework is made of sections of wire-molding welded to angle-iron standards, with the light sockets spaced as shown in Fig. 10.

The sections of wire molding are 25 in. apart and the bulb sockets are placed every 24 in. In this manner, the diagonal distance from bulb to bulb is 17.5 in. (and, as can be seen, four bulbs form a square with an additional bulb directly in the center). Basic sections or units are 8 x 10 ft with 40 bulbs each.

A screen 25 by 15 ft with light banks placed outside the set area can be seen on Fig. 11. There are six light banks, carrying about 240 bulbs, equaling 72,000 w or 600 amp, all remote-controlled from one dimmer.

Another arrangement of light banks carrying a total of 600 bulbs equaling 180,000 w or 1,500 amp, is shown from backstage in Fig. 12. This required the distribution of the load between two dimmers and the additional use of powerful blowers (Figs. 9 and 12) to cool the lamps and ventilate the area during line-up time.

The light banks exceed the total surface area of the screen by about two rows o bulbs to prevent fall-off of illuminat toward the edges. When the situatio lemands, the excess lights are goboed so as to shield them from the camera.

The accepted working distance between the surface of the light bulb and the rear surface of the screen (Fig. 11) is generally 7 ft 6 in. This distance is determined by the overall density of the screen, which is about 0.17 to 0.24 (60–65% transmission). It has been found that at this distance the bulbs will not create an objectionable light pattern on the screen which might tend to disturb uniformity of the blue-screen area registered on the film. Where the light banks are placed closer to the screen, the use of silks or nets may be required between lights and screen to induce a measure of diffusion and nullify any light pattern effect.

For reasons of economy, lights placed at the distance from the screen specified above are operated at substantially less than their rated voltage, thus reducing heat and increasing lamp life. It is, of course, possible to rear-illuminate such a screen with blue fluorescent tubes, since their output of blue radiation is higher. However, this output is only about 40 w per tube, the tubes require elaborate equipment for voltage regulation, and they are substantially more expensive than reflector-flood lamps.

Before discussing camera and action, it will be helpful to consider lights and the screen together as one major component of the blue-screen traveling-matte system.

Lights and Screen as One Component

Since it is essential to vary the intensity of the blue level of the backing in accordance with different key light conditions on the foreground action, we must establish a dependable measuring system which we can repeat for any desired setting.

The first test consists, therefore, of varying the line voltage up or down in 5-v steps, while measuring the blue illumination coming through the screen in terms of foot-candles. The light banks are placed 7 ft 6 in. behind the screen and carefully aligned to be parallel from side-to-side and center-to-corner. A precision voltmeter is connected to the output of the dimmer (or dimmers, where lights are controlled by more than one). The illumination can be read by using an exposure meter calibrated in foot-candles. If an incident light meter is used, the light-integrating hemisphere should be removed and the flat white disc placed in front of the meter cell. The readings, which will range between 5 and 70 ft-c, are, of course, relative; but if the same meter is used again for setting the blue level illumination during production, this procedure may be used as a yardstick.

For ease of reading and repeatability, it is simplest to hold the meter directly against the front or "matte" surface of the blue screen. There is nothing gained by taking readings at a distance in front of it.

The following data apply only to the specific screen measured at a particular time and are not to be taken as factual for any other screens. The figures below were obtained through a series of meter readings on two different screens — one 50 by 24 ft (Screen A) and the other, 25 by 15 ft (Screen B). All data are mean values from four series of readings given in Table I and plotted in Fig. 15.

Since the densities of the two screens differed, as can be seen, we are aware later in production that a higher voltage will be required for Screen B to establish the same "blue" level as for A.

Experimentation has shown that it is possible to repeat any voltage-vs.-foot-candle or foot-candle-vs.-voltage setting within good accuracy, providing careful line-up procedures are followed and identical meters are used.

This test also permits checking screens for defects, evenness, etc. At the same time, it may instruct personnel from the electrical, grip, and camera departments in the basic procedure of the blue-screen operation.

The Camera

The camera used in traveling-matte photography must be equipped with registration pins and be rock-steady in performance. The major studios sometimes use special matte cameras that are tied down during shooting, especially for shots where matte paintings are used as plates for the background. Generally speaking, however, for the majority of production shots there is appreciable freedom from painstaking preparations and restrictions in blue-screen photography.

As stated in the general description, any single-film camera can be used for blue-screen matte photography, be it 16mm or 35mm standard or anamorphic double-frame Vista-Vision, Technirama, Techniscope or 65mm flat or anamorphic as used in Todd AO and Super- and Ultra-Panavision productions.

There is one rule that must be observed: blue-screen traveling-matte shots of the foreground action must be done in the same screen format as the production itself: that is, don't shoot the blue-screen foreground action in the double-frame VistaVision system if the rest of the production is being shot, say, in 35mm 1.85-1 wide-screen format. There is, of course, no restriction on the background plates, other than quality considerations, if it comes to making blow-ups. However, it it wise to consult with the laboratory prior to commencing production to insure that the required facilities will be available when formats other than the 35mm standards are to be used.

The foreground action is generally staged and played about 25 ft in front of the blue screen. Minor deviations from the distance in the direction of the screen are not critical. However, some undesirable "blue haloing" of certain specific subject matter will cause difficulties on the matte if one operates closer to the screen than recommended.

Basic Concept of Blue-Screen Photography

The fundamental requirement for photography in front of the blue screen can be explained as follows:

The density of the blue-screen area in the blue-sensitive layer of the color negative after development must be a specific amount above the density

Table I

Screen A Voltage	Screen A Foot-candles	Screen B Voltage	Screen B Foot-candles
65	7.85	65	5.0
70	11.62	70	7.75
75	17.2	75	11.5
80	22.1	80	14.75
85	27.75	85	18.0
90	33.12	90	23.25
95	40.3	95	29.5
100	46.85	100	35.0
105	54.2	105	41.4
110	61.6	110	44.0
Max. 117	64.66	Max. 117	52.5

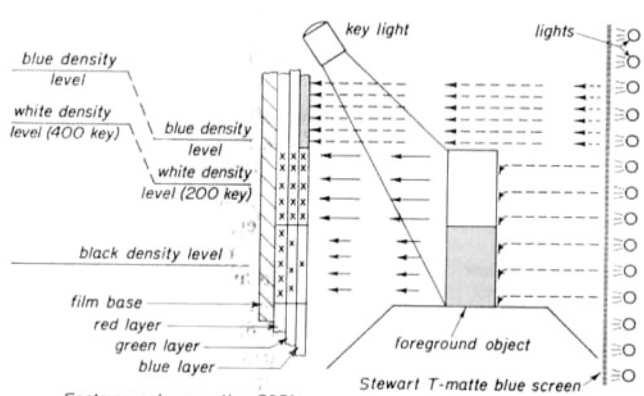
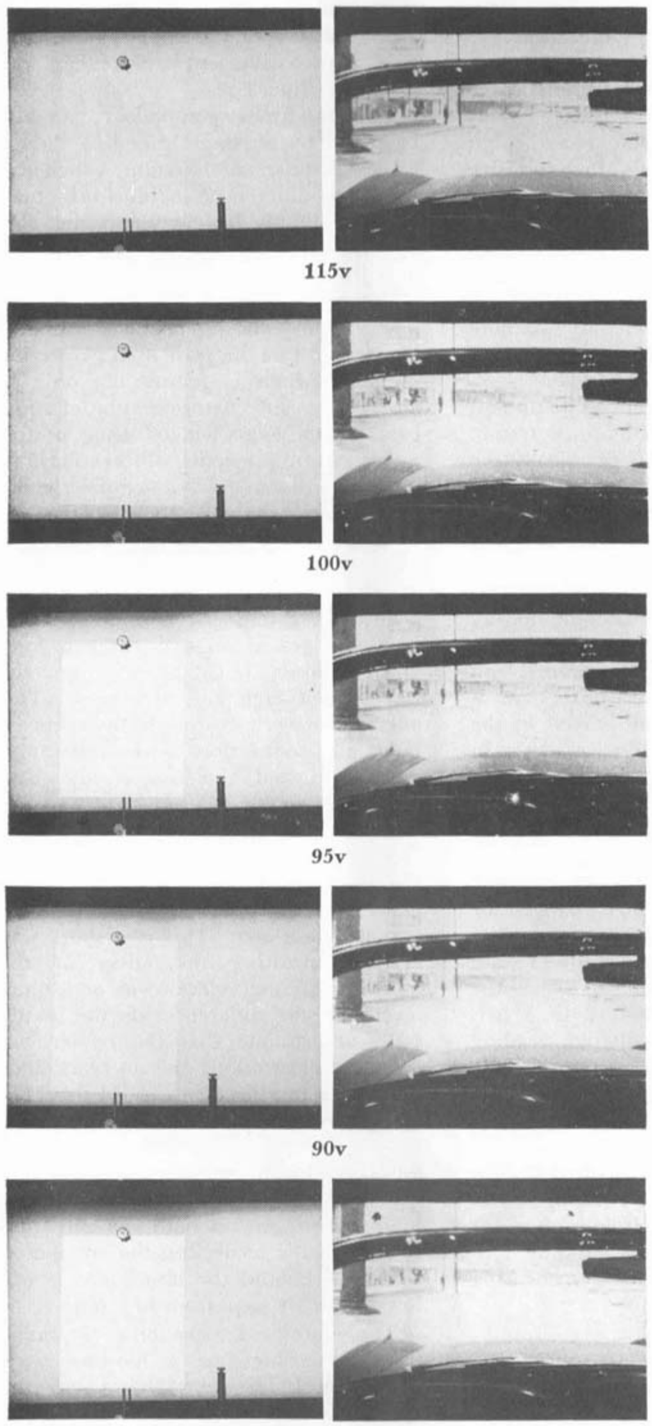


Fig. 13. Effect of blue-screen illumination on color negative in camera. Light emerging from blue screen at right (broken arrows) proceeds directly toward the film and registers on the film's blue layer. Where this light strikes impenetrable foreground object, it proceeds no further as indicated by deflected arrows at right of object. Keylight illuminates subject for desired registration of image on the film.



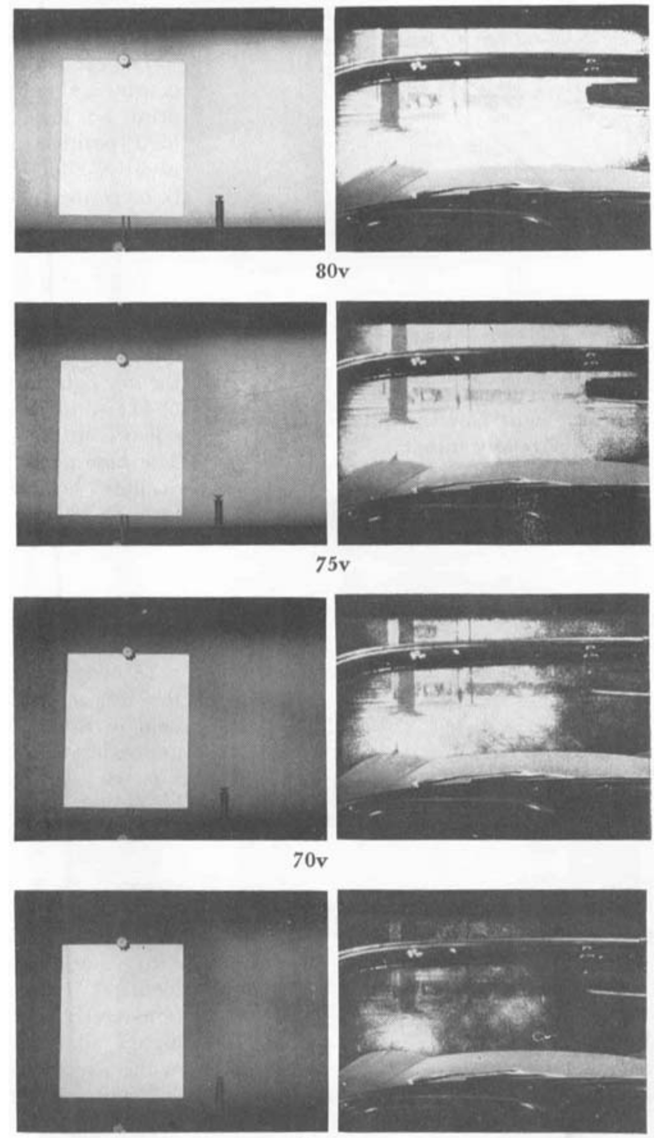


Fig. 14. Series of photos of blue-screen tests with white card in direct comparison with actual foreground object and plate; illumination was decreased in 5-volt steps. Matte deterioration sets in below 90-v exposures.

derived from any black object in the foreground scene.

A minimum allowable difference between blue-level density and black-level density must be maintained in order to achieve a perfect, clean matte.

In photography in front of a blue screen we are exposing on the color negative (a) foreground action and (b) blue-screen area — each having its own illumination independent of the other.

The foreground can be varied in key light level with respective *f*-stop changes according to action and story requirements.

The blue-screen brightness can be varied independently by voltage regulation and is photographed simultaneously with the foreground action which determines the exposure for both.

The director of photography should establish the foreground action key light and *f*/stop first then set the blue screen illumination level, preferably just before shooting is to begin. He should beware of making last-minute changes in key or *f*/stop without also readjusting the blue screen illumination which would otherwise remain at the incorrect setting.

These fundamental rules and the basic concept are shown schematically in Fig. 13.

In the middle is a black-and-white object representing the gray scale range of the foreground action illuminated by white light (key). On the left is a magnified cross-section showing, in a simplified manner, the Eastman color negative film of the multi-layer type (5251). (Camera and lens are not shown since we are only concerned with the light as it reaches the film for exposure.)

The ultramarine blue light from the blue screen will expose only the blue sensitive layer of the color negative, leaving the red and green layers unexposed, and will establish after development the blue density level. This blue-screen light is, of course, completely shielded by the foreground action and does not reach the film in that area.

The reflected key light from the black-

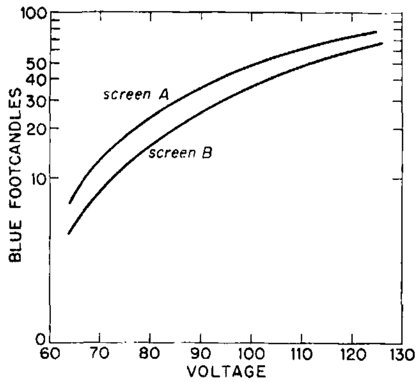


Fig. 15. Transmission ratio of "blue foot-candles" and power voltage for two screens tested by author.

Fig. 16. White card reading of the illumination on the set prior to shooting in order to establish the "blue brightness level."

and-white foreground object will expose all three color layers in proportion to their respective brightness. The light from the black object will thus give, after development, the black density level, and, of course, the white object will be above that level practically at the other end of a complete gray scale representing the total brightness and/or density range of the foreground scene.

The relationship between negative density and color content in the positive print is: low negative density equals high positive color content and high negative density equals low positive color content.

The relationship of the density levels to the left of the color negative cross-section can be explained pictorially as follows:

The black density level is the absolute minimum level of exposure, regardless of the key light intensity.

The white density level will go up and down with the key light at equal *f*/stop. The blue density level is practically the "ceiling" which must be raised and/or lowered in order to keep the key-light-controlled white always below it. In so doing, the foreground scene virtually always hangs, exposure-wise, with its gray scale range below the blue density level.

In order to achieve this properly on the set, a perfect matte-white card is held in front of the blue screen in the approximate key light area, as shown in Fig. 16. To establish the blue-screen brightness level, a Photo Research Spectra spot meter, with the filter selector set at "blue," is pointed alternately at the white card and the blue screen area and the voltage changed for the blue-screen lights until both the white card and blue-screen readings are identical. It is advisable to adjust the blue-screen reading about 2 to 5 ft-L higher than the blue-filtered reading of the white card to be on the safe side for sufficient blue density in the developed negative. This also compensates for differences in readings that will result if the white card is tilted during the course of taking readings. The Spectra Spot Meter is a brightness meter for reflected light and is calibrated in foot-Lamberts, which has no bearing on our readings since we use it merely as a yardstick for "leveling" the brightness of two adjacent surfaces as seen from the camera.

This brightness comparison can also be made by looking through a "blue" 47 + 2B filter combination, which will show the differences in blue brightness between the white card and the blue screen area. When the voltage is changed, a point will be reached at which the white card blends with equal brightness into its blue screen background. I like to call this the poor man's metering method, which is permissible only in emergency, since determination of equal brightness will vary widely, being, as it is, arrived at by subjective observations.

The problem is, of course, more complicated than is shown here. In aiming for balance between foreground objects and adjacent blue backing areas, edge characteristics due to exposure level must be considered; that is, the edges of an over-exposed foreground must not "grow" into the blue screen area and vice versa. This effect of image growth will be discussed later in connection with laboratory techniques and the use of the blue separation record.

Let us now illustrate the "blue" level setting vs. key light consideration for the foreground action on a test chart and compare the chart with an actual action shot. This is a short way of demonstrating the effect of the above-mentioned black-level and blue-level exposure differences on the matte. It is unfortunate that the reader can see these illustrations only in black-and-white as reproduced in Fig. 14 from 8 x 10 glossy photos. These show nine exposure tests, arranged side-by-side for comparison. When photographed, the foreground key illumination remained constant on both the card and the car in the scene, but the voltage on the lights behind the blue backing was lowered in 5-v steps from 115 to 65 v.

The white card series shows the range from a too-high to a too-low blue-density level. The scene photos show the effect of such exposure range on an actual matte at each 5-v step, corresponding to each white card photograph to its left. There is one pair of photos showing the exposure relationship between white card and backing at which the blue backing and the blue component of the white card are equal. Readings made on the set during the tests with the Spectra Spot Meter indicated equality at approximately 90 v. This frame is indicated by an arrow. Table II shows the blue readings from the white card and blue backing areas at different voltages (as they were made from the original negative).

(The 15-v jump was taken at top of the scale since we knew that above 100-V the blue area was already too high.)

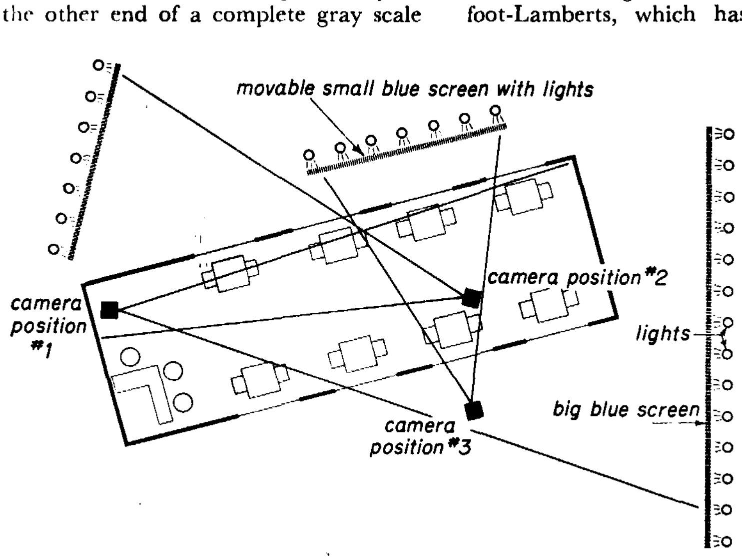


Fig. 17. Dining car set on the sound stage showing the fixed large blue screen and lights at right, and the smaller, movable blue screen in two different positions to accommodate camera changes.

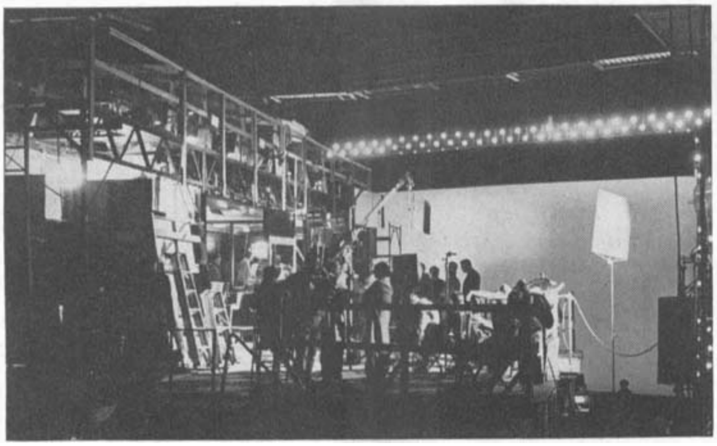


Fig. 18. Large blue screen lined up on dining car set for camera position No. 1, indicated in Fig. 17.

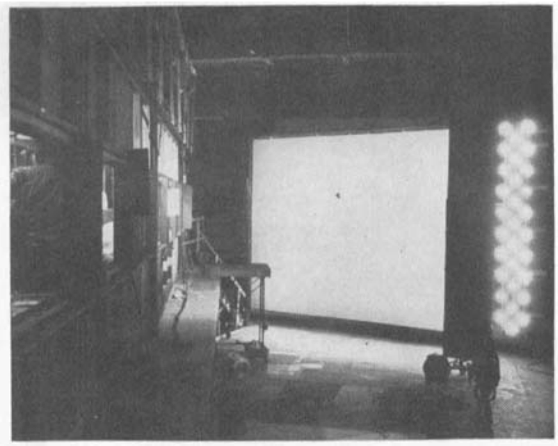


Fig. 19. Smaller, movable blue screen and lighting unit in position for photography of dining car interior from camera position No. 2.

The photographs at the right in Fig. 14 show the effect of matte deterioration as it occurs progressively. The first signs of "pepper and salt" grains occur in that area of the matte where the blue backing "shines" through the windshield, which reduces the exposure about 12% or so as compared to the area above it.

It is therefore essential to make the spot-meter readings always through the area or in the area of possibly lowest transmission on the set — which in this case was through the windshield of the car. Table III serves as a guide for voltage settings for the screen lights.

Data given were derived from sample screens and equipment specifications as described above and using Eastman Color Negative Film Type 5251.

The figures in Table III verify the basic concept that at equal exposure as prevailing between *f*-stop and key light, we must raise the blue density level by increasing voltage as the blue component of the white card (when reading as per Fig. 16) goes up with the key light.

Table II

Voltage	Blue component white card	Blue backing area behind white card
115	1.96	2.08
100	1.95	2.03
95	1.95	1.98
→ 90	1.94 ←	1.93 ←
85	1.94	1.87
80	1.93	1.80
75	1.94	1.68
70	1.93	1.61
65	1.93	1.56

Table III

f-stop	Key light level in foot-candles	Voltage for blue backing
2.3	150	80
2.8	200	85
3.5	300	85–90
4.0	400	90
4.5	600	95
5.6	800	110

One other conclusion can be drawn from both the tests shown in Fig. 14, together with the above table: There is not much latitude in exposure toward the low-voltage end of the scale but quite some reserve on the upper end. In other words the point where matte deterioration begins cannot be precisely defined on the set, but we can definitely stay above and avoid it.

Background Density

The last three scene photographs in Fig. 14 illustrate the importance of the density of the background scene. If, for instance, the car were being driven at night through a pitch black forest, the pepper-and-salt effect in the corner of the windshield area would be negligible down to the 80-v setting. Good traveling-matte photography, however, calls for perfection and one must not count on situations which one can "get away with." If the production office changes its mind and switches to a bright day plate, costly hand work would be required to animate a painted hold-back cover matte to repair such annoying spots.

There is no substitute for experience in this type of work and it is, of course, impossible to set down fool-proof instructions. It is hoped, however, that the above outline of the fundamentals and theory will be enough to provide some guidance in the undertaking of this blue-screen process.

The practical aspects of the blue-screen system may be seen in an example involving a big screen, semi-permanently installed at the end of a sound stage, and a second "flying" screen used simultaneously for versatility and economy.

Figure 17 shows the floor plan of a set involving a dining car in front of a large blue screen, with an additional smaller and readily movable screen to satisfy three different camera angles, as indicated.

Figure 18 shows the outside of the set with the large blue screen behind it, and Fig. 20 displays the camera angle for position No. 1 with the blue screen covering all windows to the right.

Often corrective measures can be taken on the set to avoid unnecessary difficulties in making the matte (Figs. 20 and 21). Originally the set dresser had placed the flower vase on the table between the cream pitcher and sugar tray and it extended into the blue screen area (Fig. 20). To correct this, the vase was moved to the left, placing the flowers in front of the wall between the windows. The composite shot (Fig. 21) shows the result. Figure 19 shows a smaller blue screen with light bank properly set for camera position No. 2 (Fig. 17), which may also be seen from inside the set in Fig. 22. The camera angle here, of course, includes only the two windows in the rear and avoids the area not covered by the blue screen in this shot.

In Fig. 23, the smaller screen is placed further around, and is seen from the side angle for camera position No. 3 as indicated on the floor plan (Fig. 17). Figure 24 shows the final composite shot for camera position No. 3.

Both Figs. 23 and 24 are frame enlargements from daily and composite film clippings. These are reproduced here to illustrate what we call temporaries, or "temps" for short, in which a minute halo shows around foreground objects. After the dailies when the background plates become available, Technicolor can provide a temporary composite. This is an optical print using the male and female mattes without any refinements of color-difference matte. Such composites are usually delivered within a few days and are used for judging the action and action-to-background timing only. The halos and/or matte lines in such "temps" are unobjectionable for the purpose for which they are used. After creative talent has accepted the

Fig. 20. Blue-screen set-up as seen from camera position No. 1.

Fig. 21. The resulting composite shot with background printed-in, as filmed from camera position No. 1.

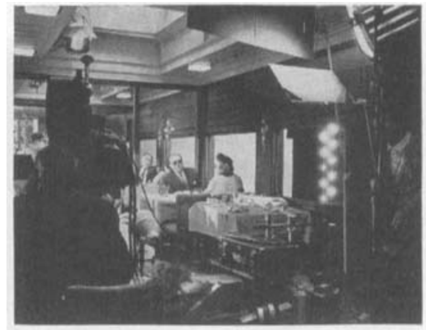


Fig. 22. Interior of dining car set showing camera in shooting position No. 2.

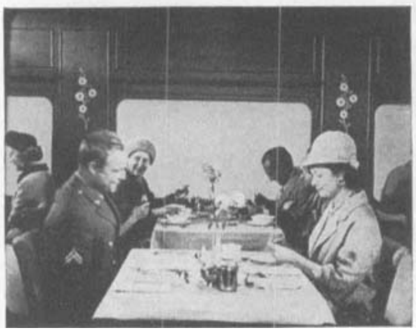


Fig. 23. Dining car interior with the blue screen visible through windows, camera position No. 3.

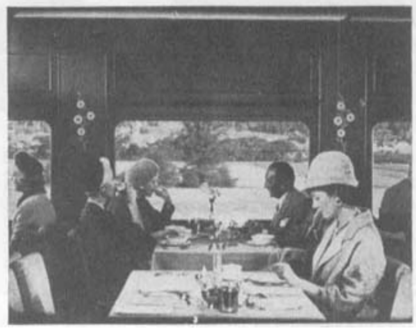


Fig. 24. The composite shot showing the scene through windows resulting from blue-screen use.

shot, the making of the "finals" is undertaken.

Painted Blue Screens

Before concluding discussion of the transparent blue screen, I would like to describe painted blue screens with front illumination, as used through the years.

A painted blue screen is made by first applying a coating of white fire retardant product, to the raw muslin used as screen material. Then a Kriegrocine binder is prepared. In order to obtain even distribution of the blue pigmentation, a wetting agent, Kriegromine, is used (10 grams of Kriegromine to 5 gallons of water). For blue pigmentation we use a DCU-Blue No. 107-1 with about 4 to 8 pounds of DCU-Blue to each gallon of Kreigrocine binder. This solution is thinned to brushing consistency and then applied to the muslin screen, already prepared with the white fire retardant. (Kriegromine and Kriegrocine are technical terms for products of Krieger Color Industries, Inc., in Hollywood who prepared these materials in accordance with the formula of the Motion Picture Research Council.)

First-surface blue screens nowadays have only two advantages. One is their comparatively quick availability in areas and under circumstances where production may call for blue-screen traveling-matte shots photographed away from studio facilities. The other is when composite photography demands actors or objects to dangle in midair. This may require them during production to walk on or work over a blue screen floor surface. The screen, therefore, must extend under the action to be filmed.

One of the major disadvantages, however, is the imperfection inherent in a painted surface, as it affects the entire scope of matte making and follow-through of composite shots.

The purpose of the blue backing is to provide an exposure of the blue record on the color negative without exposing the green or red records. Actually, however, there is always a small exposure of the green record with either type of backing. In the case of the translucent backing, however, green exposure is relatively low and it is therefore possible to employ the color-difference principle to its full extent.

The painted backing causes a considerably greater exposure of the green record, and it therefore becomes necessary to use a cover matte of greater density. The blue pigment as a paint not only reflects blue light but because of the binder and first surface effects there is a substantial reflection in both green and red. These reflections increase as the backing accumulates a dust layer. Also, the use of the denser cover matte makes the optical effects work more difficult, particularly in regard to partially transparent and rapidly moving objects.

It is well, therefore, to exercise some caution with respect to the type of foreground material used in front of the blue painted backing. Numerous pigments have been investigated to improve the blue paint for this purpose. While these pigments differ somewhat in total reflectivity, the ratio of blue to green reflectance is surprisingly constant.

A solution to this basic problem would be to investigate the possibility of reducing the green exposure by selective rejection of the blue-green cross-over region of the color negative film with the aid of a special filter. I recall that such a project was underway at the Research Council but was, to the best of my knowledge, not completed and would require re-evaluation of the characteristics of the presently used Type 5251 color emulsion.

There are, of course, other disadvantages in the use of painted blue screens, such as the cumbersome and time-consuming procedure required to obtain even illumination with arc light, especially without interference from the action lighting. Delays will occur when foreground action photography requires changes in the blue-backing illumination. This, in fact, can be so troublesome that in many cases photography continues under different key light conditions with no readjustment of the brightness and light distribution on the blue screen. Then inferior work results which cannot be compensated satisfactorily in the laboratory.

Pits for Permanent Blue Screens

A major requirement for a more or less permanent installation of a large blue screen, whether it is of the painted or translucent type, is a pit in the stage floor (Fig. 25). This is recommended, of course, in order to allow the camera to operate close to center screen for maximum use of the available screen area. If the screen is placed with its frame on the stage floor, sets must be erected on raised parallels. Such set construction is expensive, and time-consuming, poses problems in obtaining rigidity for the camera during shooting, and interferes with the otherwise prevailing economies of the blue-screen traveling-matte system.

By providing a pit, as shown schematically in Fig. 25, it is possible to employ blue-backing traveling-matte photography on the original stage floor with all the flexibility and speed of ordinary production. There will, of course, occasionally be a need to work at higher levels in front of a blue screen in order to accommodate, for instance, action in an airport control tower or in a special set requiring extreme down-angles, such as a mock-up of a large airliner, etc.

From the basic concept and from practical experience in using the blue-screen traveling-matte process on many pictures, the following condensation is offered for general guidance:

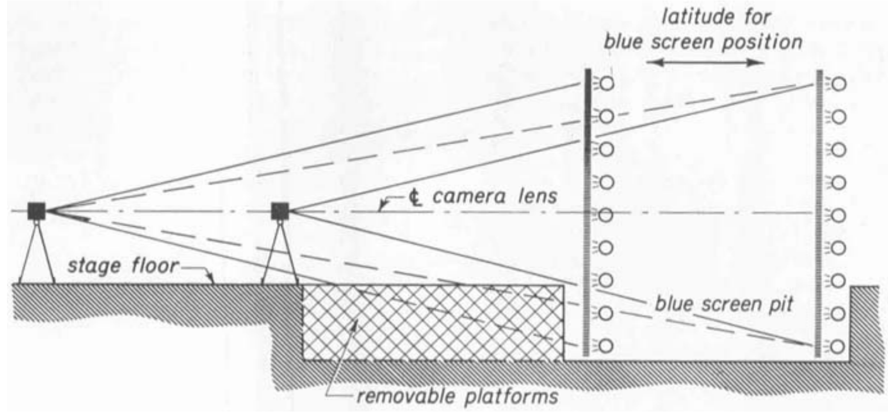


Fig. 25. Cross-section of sound stage with pit to accommodate blue screen and light banks and enabling camera to work at floor level. Alternate positions of screen, lights and camera are shown.

Foreground Photography

There are no short-cuts by way of guess work or rule-of-thumb formulas that will produce good results in final blue-screen composite photography. For instance, one cannot make a rule that a painted blue backing should be illuminated with ⅓ or ½ of the key light.

In general, action can be photographed in front of a blue screen as if the blue screen virtually did not exist, although any unwanted light falling on a front-illuminated painted blue screen will upset the evenness of illumination of the screen, later affecting the matte. It is, of course, advisable to prevent *excessive* stray light from reaching a transparent blue screen, but some stray light is not at all serious.

One of the major concerns of the director of photography in making a blue-screen shot should be the depth of field, since contrary to process-photography procedure, the background plate is later clear and needle sharp from foreground to background. Take, for example, a train compartment scene. It will look displeasing if an actor in the background appears blurred while a sign indicating the name of the station appearing behind him in the composite shot is crisp, sharp, and readable. Therefore, lighting and *f*-stop considerations should carry the far limit of depth of field as close to the edge of the set as required for the composite shot. This is, of course, not a strict rule: low-key automobile interiors or the like often show fuzziness and fall-off in crispness on upholstery in the rear seats. This is permissible and causes no trouble, especially in night scenes where dark plates are used. Too much out-of-focus condition of foreground action or set adjacent to or extending into the blue screen area should, however, be avoided since soft edge characteristics tend to cause fringe difficulties in the matte.

For shots that have to be made with long focal length lenses having shallower depth of field, it is possible to print the plate slightly diffused — which can be done while preparing the separations optically.

Careful consideration must be given to lighting objects distant from the camera and near the blue-screen area. They should be lit as if the scene were "live," in order to incorporate the effect already determined for plate photography. Direction of the lighting source must be the same in both the plate and the foreground action. In other words, if the shadows of objects move from left to right in the plate, they should move in the same direction in the foreground action.

Correcting Reflections

The blue screen must not be reflected in shiny areas on foreground objects such as automobile hoods, glass panels, highly polished table surfaces, etc. These areas are especially critical if the camera is moving to imitate, for instance, acceleration and deceleration in a straight backward angle on an automobile shot. The man responsible for the blue-screen operation should check all possible camera positions beforehand and correct any such reflections should they exist.

One of the most interesting personal experiences that I had along this line was when shooting rain in front of a blue screen which increased to a cloudburst. After some tests, the rain was lit at a steep angle, almost directly down from the top of the blue screen. The shot could only be made once, since all three stars of the picture were riding in an open buggy. It worked exactly the way it was planned — with one exception, and that was the gradual formation of a puddle of water from the rain next to the coachman's seat which reflected the screen in the full beauty of its blue color but could not be foreseen since there was no rehearsal. Fortunately this was outside the composition area and did not at all spoil the shot which is now a part of the completed picture.

When reflections do occur in the actual composition area, they can be corrected with a hand-painted hold-back matte to reinforce the original matte in this area as required. This technique is described in Part 3.

Other Problems

Other problems to watch out for are small gaps between vertical or horizontal window portions, door gaps, venetian blinds, matchstick curtains, small fringe-like patterns at the end of curtains, etc.

Extremely narrow gaps or holes on the set in front of the blue screen become in the particular area the equivalent of an *f*-stop for the blue screen, as exposed in the camera on the negative film. In so under-exposing the blue area, the negative will not reach the required density in that spot and a hole or crawling pattern may appear in the matte.

The color-difference matte system, makes it possible to use glass panels, clear liquids, whirling ropes, cigar smoke and flying hair in the wind, veils, etc., in scenes. What one really has to watch out for is that glass panels, when set at certain angles, do not turn blue because of internal reflection, since these will later be areas of breakdown in the matte. Any straight clean glass panel free of imperfections, dust and air bubbles can be used in front of a blue screen. Reflected images of the action will even enhance the realistic look in the composite shot.

Curved windshields pose a substantial problem since there is always one angular position in the curve which will cause internal reflection and result in under-exposure in that area of the blue backing. A tinted windshield, of course, should be avoided because of the possible color similarity to the blue backing.

In selecting colors and textures for wardrobe and other set dressing needs, it is essential to avoid ultramarine blue and colors very close to it. Rich purples and violet also are taboo. However, the level of illumination and the surface characteristics of materials also so strongly influence the effect that it is virtually impossible to outline do's and don'ts all along the line.

Foreground and Plate Coordination

All efforts made to obtain good clean composite shots in blue backing, successful as they may be, are entirely spoiled if there is no proper coordination and record keeping between foreground photography and the shooting of the so-called plates or background action. Amazingly little tolerance exists between the positioning and movement of a plate camera and the camera shooting the foreground action.

If, for instance, an actor sits down on a bench in front of the blue screen and the action camera is titled to follow him, and if the plate camera shot is straight back, the composite shot will show the foreground and bench moving up relative to the actor in front of the fixed background.

In shots of vehicles (for instance, of automobiles), if the foreground-action camera is not set up in the exact position of the plate camera, in the composite the car will seem to travel sideways or go up hill or down.

Making Dolly Shots

It is permissible to make dolly shots in the foreground action, for example, inside an airport tower, even though the background plate camera did not move while shooting. If the action visible through the tower window on the plate is in excess of 50 ft and practically at infinity, a shot moving several feet back and forth has no severe effect on the perspective in the composite photography. If the plate, however, displays background material shot at closer range, then the dollying distance of the action camera represents a large percentage of the distance at which the plate camera was set and the perspective is severely affected.

Similar considerations have to be taken into account when panning on and off the blue screen, as may be the case where an actor walks across a room to look out a window and then walks back, with the plate being shot straight in a fixed position. Panning shots of this type require a most careful brightness meter reading for the blue screen setting under the steepest angle of view of the camera as it changes or leaves the perpendicular position to go off screen.

There is latitude for argument on the subject of perspective for this type of traveling-matte photography, which exceeds the scope of this article.

Where a print of the plate is already available for line-up purposes, it is helpful to inset a cut-frame in the camera viewing tube. An even better system is to place a projection screen behind the foreground action and project the background scene from an elevated platform on that screen, with projector and camera lens closely in line. In spite of a few obstructions or shadows from the foreground set and lighting equipment, the camera operator will see a good "composite" for correcting the camera position to satisfy proper perspective.

Similar projection arrangements in other directions, not interfering with the field of view of the camera, can be used for timing action of the actors or movements of props as required in a scene.

A very flexible method for timing action during filming of the foreground is the use of an editing machine, modified with a closed-circuit industrial television camera and corresponding monitor. The editing machine with the background plate runs in sync with the action camera. The TV monitor shows the plate during the take and can be used by the director to cue action or it can be so placed that the actor has a direct glimpse of the background plate. This is a handy procedure providing the TV monitor can be hidden sufficiently in the foreground action as, for instance, in an airplane cockpit, where timing a landing sequence is of greatest importance. This matter is treated in more detail in Part 5.

If the plates are shot after the action photography is completed, it is helpful to a certain degree to have cut-frames from foreground action handy for camera line-up.

Plates shot full screen not only affect scope but also provide quite some latitude to shift the background horizontally and vertically. Thus objects of major importance on the plate may be brought into preferred positions within the foreground scene.

However, it is best not to count on this type of flexibility. It is: (a) more expensive, and (b) interferes with quality if, for instance, the vertical shift brings the frame line of the plate into the foreground action, requiring double printing of masters, etc.

One cannot be careful enough in thoroughly surveying the scene through the camera finder and applying all possible corrections that will help but not restrict the full artistic scope of the scene. Some sets can be stripped to the bare minimum to avoid hardships in matte making. Others may be left unaltered for authenticity and realism, but require expert know-how to become masterpieces of blue-screen traveling-matte photography.

I could report further on other little pitfalls encountered in blue-screen photography, but the improved color-difference blue-screen system has worked so satisfactorily that even the tips of palm tree leaves shaking wildly in the wind, flying blond hair and other critical objects such as rain are no longer problems.

There is no doubt that well-informed and educated personnel will do a better job on the set and in the laboratory to achieve both perfection and economy to the benefit of the blue-screen traveling-matte system.

Part 3. Special Photographic Phase

In this, Part 3 of our discussion, there are set forth in detail methods of follow-through for normal blue-screen shots and the color-difference matte principle as a completely new concept of blue-screen traveling-matte photography.

The major problems encountered in general traveling-matte photography can be classified as follows:

Separation: A portion of a scene after it is photographed, must be "lifted out" and separated from those areas into which other portions are to be inserted. There must be sufficient density contrast between the exposures of the foreground action and of the backing against which it is photographed to build up adequate density contrast in the matte silhouettes.

Registration (including "fit" and matte-edge characteristics): Each matte silhouette must match the corresponding action silhouette in all details within a few thousandths of an inch, and must have density and edge characteristics such that the edges of the matted portions will not appear in the assembled composite. Here it should be noted that *present-day requirements for wide-screen presentations are much more severe than for those of standard aspect ratio.*

Color Balance: As many as six different color records—separate pieces of film—must be accurately balanced and matched for printing on a single composite internegative. This obviously requires precision color and density control in each of the components, and most careful control of density in the mattes.

The Normal Blue-Screen Process

Bearing in mind the basic concept of the blue-screen system and the procedures for action photography as set forth in Part 2 of this series, we will now describe the procedure of making a blue-screen traveling-matte shot, from negative to composite. Before discussing this procedure, which is graphically outlined in the accompanying illustrations, first we quote what is considered a "classical" description of normal blue-screen shots written by L. B. Abbott and Ray Kellogg of 20th Century-Fox Studios.* Abbott is rated one of the leading experts in this field and is head of that studio's special Photographic Department:

"The problem confronted in making a matte without handwork is to be able to separate photographically the whites and blacks of the foreground from the background. This is accomplished in

* "Special photographic effects in motion pictures," L. B. Abbott and Ray Kellogg, *Am. Cinemat., 38:* No. 10, Oct. 1957, republished from the *Jour. SMPTE, 64:* 57–66, Feb. 1955.

color photography in the following manner:

"Figure 29-A shows the foreground photographed against a blue backing. A blue backing is chosen because it will expose the blue-sensitive layer of Eastman Color Negative, but not expose the red-sensitive layer. This selectivity of color sensitivity is the key to the process. Any color which will expose one of the three—red, blue or green—layers without exposing one of the others may be used for the backing. Blue is favored because, when lighting the action, face quality is more easily judged than it would be against yellow or green or red; also, should there be any matte fringing in the final scene the blue edge-effect is more apt to be harmonious with the sky or water that often constitutes the background than would a red or green fringe.

"Figure 29-B is the black-and-white separation positive from the blue-sensitive color negative. The darks of the foreground are well separated from the light background.

"Figure 29-C is a dupe negative from the black-and-white separation positive of the red-sensitive color negative. The lighter areas of the foreground, which are now dense because this is a negative, are well separated from the clear background.

"Figure 29-D represents a print obtained through a bi-pack of 29-B and 29-C. Since there is now density in both the white and black areas of the foreground object it is opaque on the 29-B plus 29-C combination and the resulting print yields, therefore, a clear foreground with an opaque background [the female matte].

"Figure 29-E is a print from Fig. 29-D with densities reversed, being clear in the background area with a perfect opaque foreground silhouette [the male matte].

"Figure 29-F represents a background scene viewed through the silhouette foreground matte.

"Figure 29-G shows the foreground

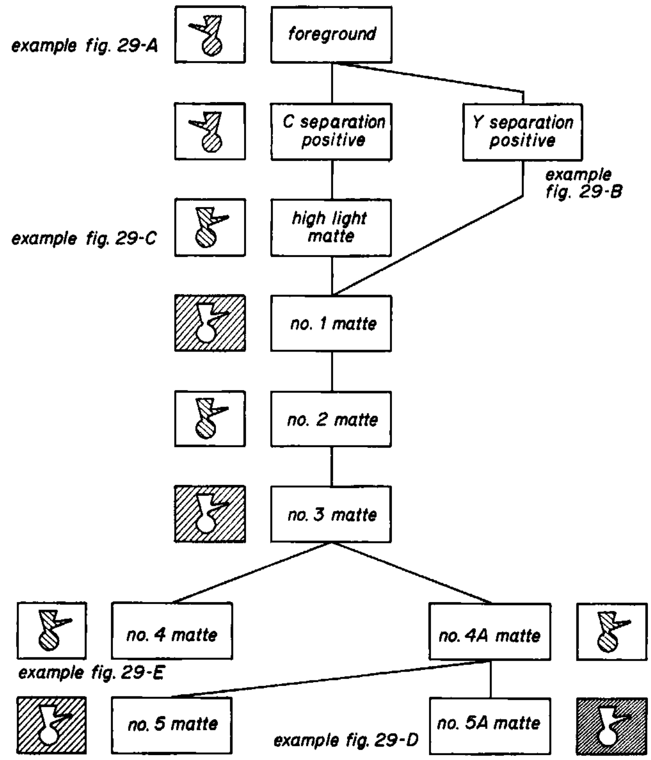


Fig. 26. Successive steps in the production of mattes in an early blue-screen traveling-matte process. The examples correspond to the photographic reproductions in Fig. 29.

viewed through the clear-area foreground matte.

"Since the blacks of Figs. 29-F and 29-G represent no exposure in the negative, it is readily seen that each part may be exposed separately on the same negative, producing the final composite (Fig. 29-H).

"This explanation of the traveling-matte process has been condensed as much as possible to make its function most easily understood. In doing so, the physical and mechanical problems encountered have not been mentioned."

In order to build up the proper densities in the opaque areas of the female and male mattes without affecting "size" and "fit" and at the same time clear up the transparent areas of these mattes, it was not uncommon in the old blue-screen method to find matte-making procedures as elaborate as those shown on the flow chart (Fig. 26). Figures 26, 27 and 28 show how these mattes were used in the earlier system to print background and foreground onto the internegative for the composite print. Indicated on the charts (Figs. 27 and 28) are figures corresponding to the illustrations in Fig. 29, A–H, to orient the reader as to where the different steps represented by the pictures would appear within the chain of printing procedure. All unmarked in-between-steps are, of course, the necessary density "build-up" operations.

Following is the step-by-step procedure for this process:

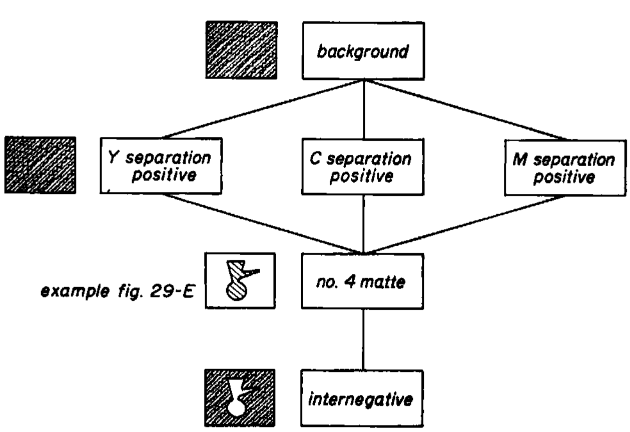


Fig. 27. Progressive steps in printing the background onto the internegative, using the male matte.

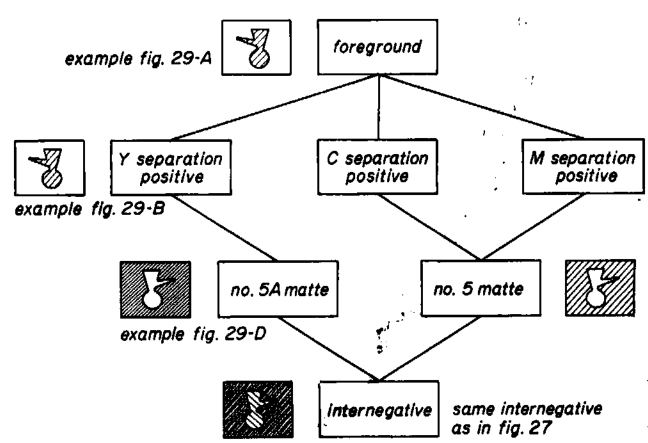


Fig. 28. Progressive steps in printing the foreground action onto the internegative, using the female matte.

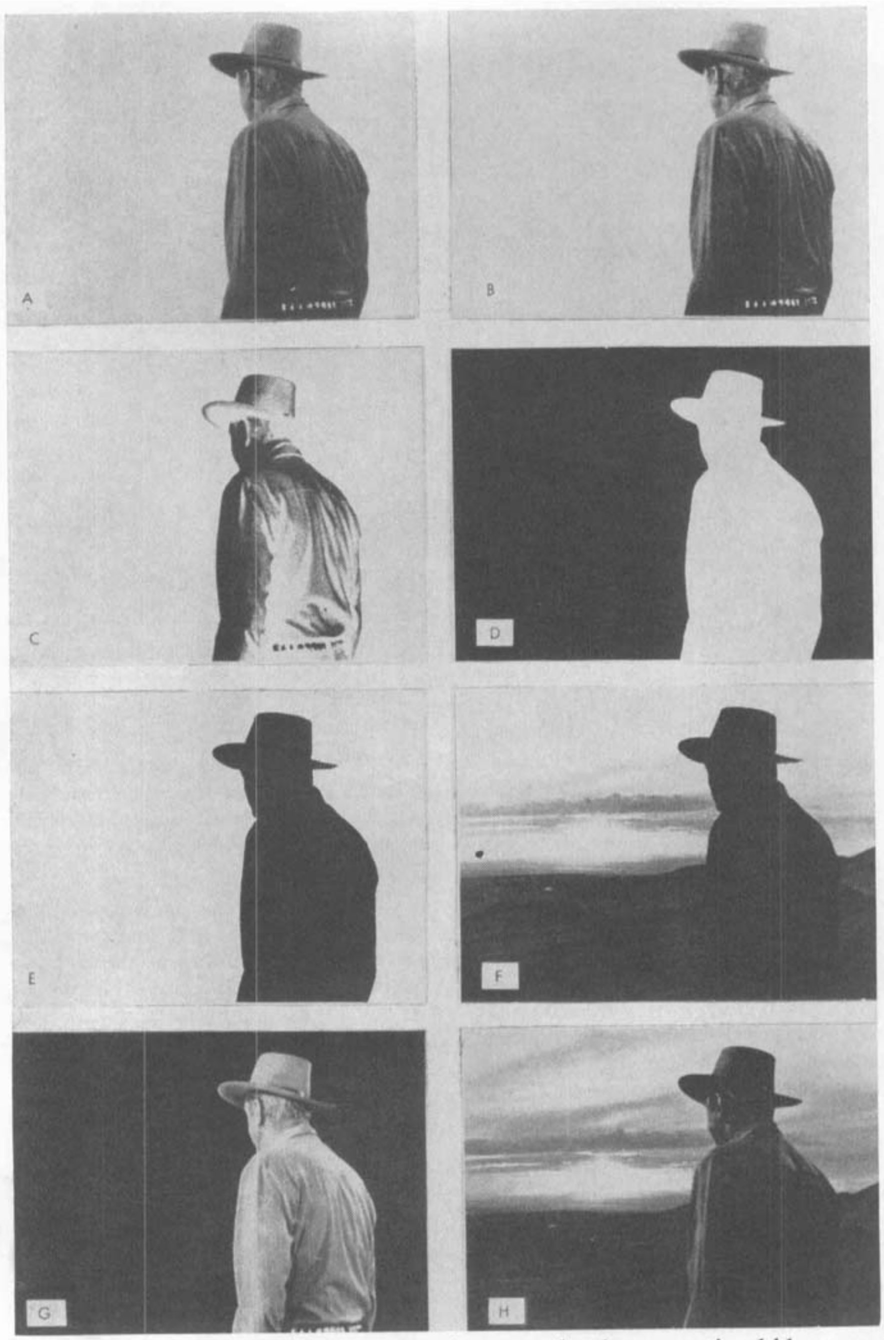


Fig. 29. Successive steps in making a traveling matte by the conventional blue-screen method. Reproduced are film clips of the various elements of the composite in various stages of its production. "Female" and "male" mattes described in the text are exemplified by D and E respectively.

Table IV. Description of Eastman Kodak 35mm motion picture films.

Type No.	General Description
5251	A multilayer color negative suitable for both exterior and interior photography. Balanced for 3200 K tungsten lamps but may be used outdoors with No. 85 filter.
5302	Fine-grain release positive film for general black-and-white production release printing. Also useful for making negative and positive titles, dubbing prints for sound.
5365	A slow, yellow-dyed master positive material of extremely low granularity. Used as a companion to Type 5234.
5235	A very fine-grain panchromatic film intended for making black-and-white separation positives from color negatives, such as those made on Color Negative Film, Type 5251.
5253	A multilayer color film suitable for use in preparing both color master positives and color duplicate negatives from originals on Color Negative Film, Type 5251. Eliminates need for making black-and-white separation positives except where protection of the original against fading is desired. May also be used for making color duplicate negatives from black-and-white separation positives.
5375	A fine-grain film designed for variable area sound recording using a tungsten light source.
5362	A high-contrast positive film for making negative and positive titles, silhouette mattes for process work, and traveling-mattes for printer light control.
1134	A special order film used for making traveling-mattes.
1145	A special order film often used in place of Type 5375 or Type 5362 for making traveling-mattes.

(1) Expose foreground action—blue-screen shot—on Eastman Color Negative.

(2) Expose three Pan. separation positives from foreground color negative by step contact.

(3) Expose highlight matte optically from cyan separation of foreground action.

(4) Expose No. 1 matte from yellow separation positive by optical printing through highlight matte.

(5) Expose No. 2 matte from No. 1 matte by step contact.

(6) Expose No. 3 matte from No. 2 matte by step contact.

(7) Expose No. 4-A matte from No. 3 matte by step contact. (No. 4-A is an auxiliary matte used in making the final foreground matte No. 5.)

(8) Expose No. 5 matte from No. 3 by step contact. (No. 4 is the final background matte used to prevent exposure in the foreground area while printing the background.)

(9) Expose No. 5 matte from No. 4-A matte by step contact. (No. 5 matte is used with the cyan and magenta separation positives when printing the foreground action onto the internegative.)

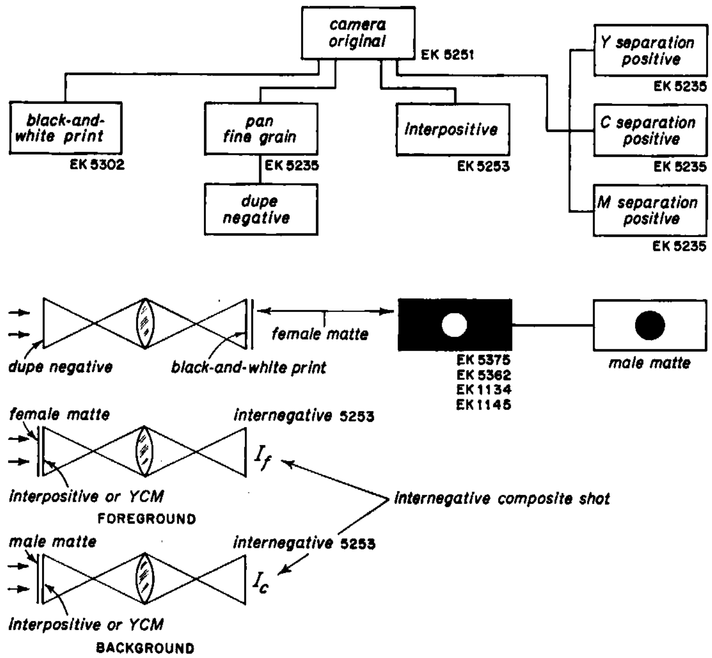
(10) Expose No. 5-A matte from No. 4-A matte by step contact. (No. 5-A matte is used with the yellow separation positive when printing the foreground action onto the internegative.)

(11) Expose background scenery or action onto the internegative by optical printing through the No. 4 matte in contact with the internegative stock. (The Y, C, and M separations are printed individually.)

(12) Expose C and M separation positives of foreground action separately onto the internegative optically through No. 5 matte in contact with the internegative stock.

(13) Same as Step 12 except using No. 5-A matte and optically printing the yellow separation positive of the foreground action onto the internegative stock.

Thanks to recent improvements in the emulsions of films used in the above method, it is now possible to avoid certain steps in the procedure, depending on the scene content and the equipment used.



I_f = Internegative foreground exposure
I_o = Internegative foreground and background exposure = composite
I_f = I_o Same piece of rawstock going through printer twice

Fig. 30. Progressive steps of an abbreviated method for producing a normal blue-screen composite shot, developed by Ross Hoffman of Universal Pictures Corp. The various Eastman Kodak film stocks employed are indicated by the film type numbers.

Ross Hoffman, head of the Special Photographic Department of Universal Pictures Corp. has proposed a shortcut method that has proved workable and is described as follows:

The camera original (top, Fig. 30) is the negative of the blue-screen foreground action, which is photographed on Eastman Color Negative, Type 5251. From this negative three to six prints are obtained: one black-and-white print on Type 5302 EK positive film, using blue light (47 + 2B filters); one panchromatic fine-grain print on EK Type 5235 film, using red light (29F filter); also red, green and blue positive separation masters on Type 5253 stock, plus an interpositive on Type 5235 stock. From the panchromatic fine-grain a dupe negative is made on Type 5235 stock. This concludes the printing procedure represented in the flow diagram, top of Fig. 30. The various film stocks mentioned here are described in Table IV.

The middle diagrams in Fig. 30 indicate the procedure by which a female matte is made, utilizing the dupe negative and the black-and-white print in an optical step-printer and using any one of the following film stock: Eastman Type 5375, Type 5362, Type 1134, or Type 1145. By direct contact printing, a male matte is then made from the female matte.

The diagram in the lower left of Fig. 30 shows how the female matte is paired with the interpositive of the foreground to print the foreground action through the female matte onto the internegative for the composite shot. This internegative, for reasons of clarity, is indicated at I_f in the diagram. Below it is indicated how the male matte is paired with the interpositive of the background in order to print the background through the male matte again onto the internegative of the composite shot. This internegative is indicated at I_o in the diagram. I_f and I_o represent the same piece of raw stock going through the printer twice, while merely the pairing on the projector side in the printer (in one running pass) consists of the female matte and the interpositive of the foreground. The second running consists of the male matte and the interpositive of the background.

After development (of I_f/I_o) the internegative of the composite final shot is obtained, which then, through contact printing, becomes the final composite photography for projection.

It should be pointed out that on the last two printing operations the interpositive of the foreground and/or background may be replaced by substituting the Y, C, M masters, resulting in a substantial reduction in graininess. Also, it should be borne in mind that strict attention to close tolerances and the use of modern equipment is essential to the attainment of perfect registration throughout the process.

Part 4. Common Problems in Making Traveling Mattes

The importance of "fit" between the male and female mattes employed in the traveling-matte process can best be emphasized by analogy to certain mechanical engineering considerations. In mechanical engineering, the fit between a shaft and a hole, or bore, is said to be accurate when the two components are machined to size so that the shaft fits the hole without play. This is also true of the male and female mattes prepared for a traveling-matte shot (Fig. 31). The mechanical determination of fit between shaft and hole is shown in the series of drawings on the left; the drawings on the right show similar situations in the production of male and female mattes, with particular emphasis on their photographic edge characteristics.

Figures 31-A, 31-B and 31-C illustrate three conditions of "fit" between a shaft and bore. Figure 31-A illustrates no "fit" with the diameters of both components having both plus and minus zero allowance or, in other words, no tolerance at all. In mechanical engineering, such a shaft machined to that tolerance cannot fit into a bore having a similar tolerance. Conversely, where tolerances are excessive there is needless play between the two. In analogy, the identical situation in male and female mattes is illustrated at Fig. 31-X. Here male and female mattes—both printed on high-contrast raw stock, such as Eastman's Type 5362 or Type 5375—have very steep edge characteristics. Male and female mattes having high-contrast sharp edges, as illustrated here, will either overlap minutely or be undersize, causing a matte line or, if optically fitted into each other, a variation of the matte line between the two images will occur.

Figure 31-B shows a shaft having a plus-minus zero tolerance and a bore having a tolerance of minus-zero but plus 0.004. In other words, the bore has been machined or enlarged slightly to accommodate the shaft in a smooth fit. In our matte-making procedure, this is analogous to a male matte made on high-contrast stock coupled with a female matte printed on fine-grain, low-contrast stock, such as Eastman's Type 5365, which produces a soft edge characteristic. Thus we see that male and female mattes having these characteristics will produce a much better "fit", or can be made to fit with virtually no matte line, especially when, during printing, optical magnification and/or reduction to proper

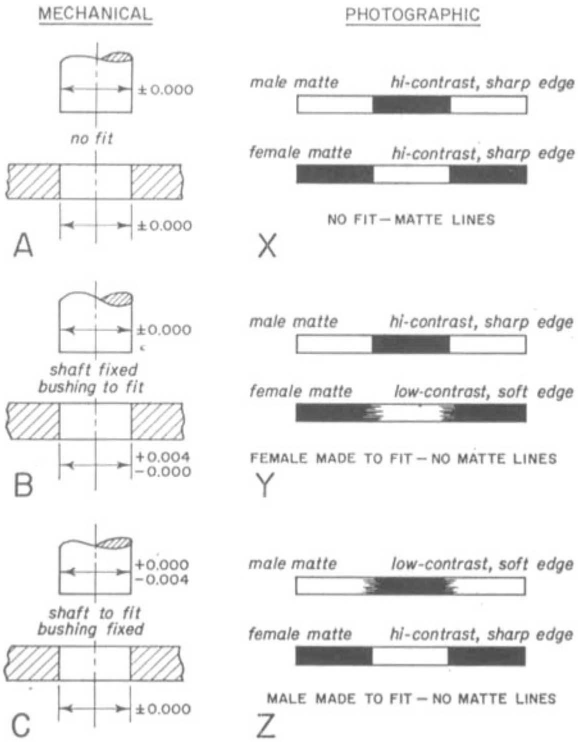


Fig. 31. Proper fitting of mattes is essential to a successful traveling-matte shot. Diagrams above illustrate analogy between mechanical and photographic achievement of "fit" and "edge characteristics" in traveling matte and engineering design.

size is employed. This optical operation is depicted in Fig. 31-Y and can be compared to using a reamer in a bore to open it up sufficiently so that a smooth fit between shaft and bore is obtained.

Figures 31-C and 31-Z repeat the previously described situation except that now the bore has no tolerance. The outside diameter of the shaft has been machined down to a tolerance of + 0.000/ − 0.004 to permit a smooth fit into the bore below. Here, again, this compares to the photographic procedure illustrated in Fig. 31-Z, which shows the male matte with a low-contrast soft edge and the female matte with a sharp edge.

The last two situations depicted in Figs. 31-Y and 31-Z are similar and produce like results, i.e., it is feasible to combine and print either a male or female matte having a soft edge characteristic with a female or male matte having a sharp edge characteristic. Since it is not desirable to have soft edge characteristics in both the male and female mattes, the analogy has not been carried out to that extent.

It is in this area of composite photographic work that Wadsworth Pohl of Technicolor Corp. has made most valuable inventive contributions toward perfection of matte fitting procedures, resulting in "no matte line" composite shots.

It is beyond the scope of this presentation to describe matte-making and composite printing procedures as they can be performed on optical printers of different manufacturers. Special traveling-matte printers, bench-type printers, and also multiple-head printers demand different sequential arrangements of foregrounds, backgrounds and mattes during the followthrough of the complete composite procedure. Sequential arrangement means, depending upon the equipment and procedures chosen, the order in which specific pieces of film may be threaded either in the projection head or in the camera head of the optical printer used.

As the composite master is being printed, the various scenic elements must be held in perfect register and tolerances must be those allowed by the limits of resolution of the photographic process.

For example, if the film-plus-lens system will give a limit of resolution of 30 lines/mm, the tolerance of error in the position of the matte edge at any point must be at least in the order of 0.001 in. For an overall system of, say, 60 lines/mm this figure becomes 0.0005 in., which is in the tolerance classification of the raw stock perforations. It should be pointed out that raw stock tolerances and printer performance are not the only factors contributing image jiggling and movement of matte lines. Practice has shown that more often than expected a matte line or, in an extended scene, portions thereof gives apparent symptoms of misregistration while in fact the phenomenon stems from poor contact in the bi-pack of the two films. The Newton rings that occur in ordinary film printing are proof of this. In traveling-matte work, poor contact in bi-packing affects edge characteristics as they are transferred from two pieces of film onto one, and it occurs more often when bi-packing film in the camera than when threading film in the projector side of the optical printer.

On the other hand, multiple-head printers make it possible to project images optically in an appropriate manner from single films in separate gates onto the final internegative. Most modern optical printers can maintain registration-of-frame position within a few ten-thousandths of an inch. Nevertheless, various forms of optical distortion may also give rise to matte lines in portions of a scene, especially when films are changed from the camera to the projector of the optical printer during certain printing stages.

Image distortion also arises from the need for and use of beam-splitting prisms, especially if they are used in exposing the negatives from which the mattes are to be made. Careful design of printer optics tends to keep such distortion within tolerable limits. Halation and, of course, film shrinkage belong in the category of troublesome effects. Halation can be reduced by using special films and by avoiding its cause during the original photography on the set. Also, film shrinkage will take place between the time the matte is made from the camera original and the time the final composite is made. Careful control of processing techniques and the use of recently developed film materials give promise of making this problem one of minor importance.

Color-Difference Matte System

The basic concept of the color-difference matte system should not be considered an extension or adjunct to the conventional blue-screen process, but rather as a completely new scientific approach to color traveling-matte composite photography. It was invented by Petro Vlahos during his association with the Motion Picture Research Council and subsequently followed through on feature film production, proving its value and workability. With the aid of the flow chart, Fig. 33, the basic principle is described as follows:

Let us first consider what happens when we photograph a white figurine so illuminated that there are light and dark areas representative of a gray-scale reproduction on color negative film.

The figurine appears identical in gray-scale value on the blue, green, and red positive separations since the object is merely black and white. If the figurine is placed before an ultramarine backing, as in the blue-screen system, the gray-scale values on all three separations are

Fig. 32A. "Blue positive separation"; blue backing registers clear.

Fig. 32B. "Green positive separation"; blue backing registers dark.

Fig. 32C. "Red positive separation"; blue backing registers black.

again the same, but the blue backing now appears black on the green and red separations and clear on the blue separation.

If the figurine is replaced by a person with normal flesh tones and dress, the blue separation will show more density than the green record, for all colors except the blues. The backing again appears clear on the blue separation and black on both the green and red separations. One set of such separations is shown in Figs. 32 A, B and C.

Were it possible to increase the density of the green separation in those areas where density is less than in the blue separation, the green separation would become identical in density to the blue separation except for the backing area, which is already black in the green separation.

There is a technique that creates just the additional density required for comparing the densities of the green and blue records; the recording of this difference on a separate film, called the color-difference record, gives this system its name.

A drawing in the left lower corner of Fig. 33 shows how the color difference record is produced by bi-packing the original negative with the green positive separation and printing with blue (47 + 2B) light.

If that difference record is later paired with the green separation, the net density of the bi-pack is identical to that found on the blue separation for all areas except the blue backing. This pairing (Fig. 34) therefore is equivalent to a "synthetic" blue separation usable for the final composite printing operation, since it is a faithful duplicate of the blue separation for all colors except the blue of the backing.

These three printing separations (normal red and green plus "synthetic" blue) are all dense in the blue backing area, thus, in a sense, converting the blue backing to a black backing.

If the foreground alone should now be printed in this manner and projected, it would appear in normal full color against a black backing. Two examples of this are shown in black and white in Figs. 35 and 36.

Because the blue backing now repro-

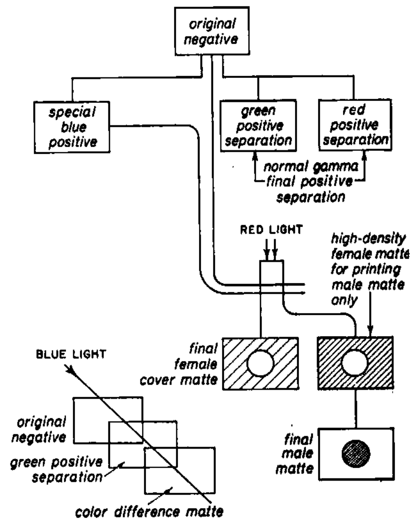


Fig. 33. Basic concept of procedure for the Color Difference Blue Screen Process. Note absence of normal blue positive separation and the printing process for the color difference matte.

duces as a black backing, the following advantages have been achieved:

(1) Blue fringes cannot appear.

(2) All objects formerly difficult or impossible to reproduce, such as smoke, clear liquids, glassware, blurred objects, fast motion, etc., now photograph normally and realistically.

Theoretically no mattes are required in printing the foreground scene to the dupe negative. In practice, however, a very faint cover matte (Fig. 33) is employed for the reason that the blue backing is never perfectly blue; invariably there are traces of green present and also the dyes in the multilayer color negative are not as perfect as desirable for this purpose.

For printing in the background scene one must cover the foreground action; for this a male matte is made and used in the printing procedure shown in Fig. 33.

The special blue positive separation for printing the male matte is printed at a somewhat lower density so as to reproduce a clear backing area and in order not to lose density in the foreground. This male silhouette must be transparent in the same degree that the original foreground scene was transparent.

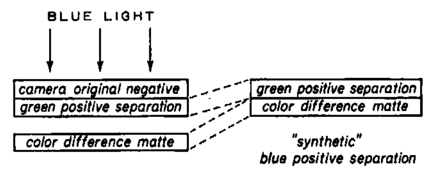


Fig. 34. Cross-section of bi-pack pattern employed in printing the color difference matte and how latter is bi-packed with green positive separation to form the synthetic blue positive separation.

Fig. 35. Example of result obtained when printing foreground action, using red, green and synthetic blue separations without female matte. Note that blue backing area is now black.

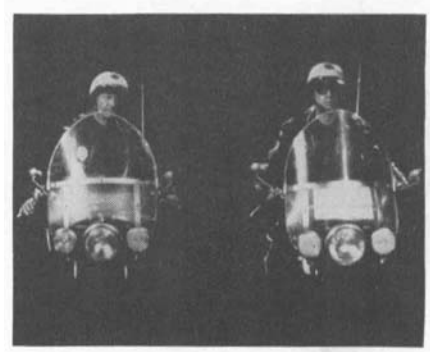


Fig. 36. Another example of results obtained in printing foreground action having transparent objects and fine pictorial detail, using red, green and synthetic blue separations. The blue backing area becomes black.

This allows the background scene to appear through transparent objects, blurred edges, glassware, etc., without any blue fringes or halos whatsoever, just as it would appear in normal photography. Briefly, this is the basic concept of the color-difference system.

Summary

The process begins after a perfectly exposed color negative is obtained. With normal gamma, blue, green, and red positive separations are made. The green and red separations will be the final positive separations for the entire process. The normal blue positive separation is used to double check fine pictorial detail as an indication for proper exposure on the set.

A special blue separation must be made which is later used for one purpose *only—to bi-pack* with the original negative and to print with red and/or green light two female mattes, one with lower density and the other with a higher density. The black-and-white panchromatic film used for printing the female matte can be Eastman Type 5235 and developed according to Eastman's specifications.

Two female mattes are required, as follows:

(a) a light female matte having a gamma of 0.7 or 1.0 which is governed by the green content of the blue backing as well as by the "background to be" if rich blacks are in it. (This matte is used for printing the foreground and will prevent veiling of background.); and

(b) a heavy female matte having a gamma of 2.0 to 2.8 which is used to print a male silhouette of the foreground which is used to cover the foreground area when printing the background scene.

For the light female matte, negative developer is used, whereas the heavy matte should be processed in positive developer. In achieving the light and heavy female mattes, and also the final male matte, one should determine the need for . . .

(c) a color-difference record. This is determined by pairing the original negative with the green positive separation and looking at both before a strong white light through a blue filter. (If a uniform gray picture is seen, no color-difference record is required. If bright spots show up, a color-difference record is required.)

These bright spots will become density areas on the color-difference record in the amount that blue was less than green. The raw stock used in making the color-difference record should be the same as for making normal separations and should also have the same gamma. *The system will not reproduce rich purple.*

After obtaining the color-difference record, one has achieved the basic element in the color-difference matte process which results in the "synthetic blue" separation that completely replaces the normal blue separation.

In cases of complete failure to obtain good results, it is always advisable to make a normal blue positive separation and project it to check whether fine pictorial detail in the foreground scene has marginal density due to over- or under-exposure, which will invariably spoil the final composite shot. (Fish-nets, small cast-iron railings, mesh wire patterns, etc., can be troublesome!)

If blue reflections should have occurred on objects such as the hood of a car, etc., in the foreground action, thus causing undesirable transparency in matte areas, it is recommended that a black-and-white registration print be made that can be used in an animation camera for painting a hold-back matte to reinforce the male matte in that area that would cause print-through of the background plate. Such a "handwork" hold-back matte is originally a female from which a print is made under perfectly controlled conditions, to match in density the already existing mattes in use.

Part 5. Conclusion: Problems and Future Requirements for Traveling-Matte Photography

As stated earlier, the blue-screen process is not the only way to achieve successful composite photography, but it is presently the most effective way of achieving it by way of a single-film system. Other methods, which utilize infrared, ultraviolet, and sodium illumination, also have their place in traveling-matte photography, and so does transparency photography. The various methods, therefore, call for intelligent selection by production management and for using the process chosen within the limitations for which it was designed.

Difficulties With Present Traveling-Matte Processes

(*1*) *Registration:* There is general agreement that difficulty in holding the various components in precise register is the most serious problem in commercial traveling-matte applications. Tolerances must be held to not over two ten-thousandths of an inch. From the standpoint of the film, the most serious troubles arise from instability of the film itself, and from inequality or lack of sufficient precision in the perforations.

(*2*) *Image Spread:* Images in the different layers have differing areas. Some of this is caused by the inevitable spreading of the light as it passes through the successive layers. The fact that lenses cannot be perfectly chromatically corrected may also account for some of the trouble. Differences in characteristics between the layers, and, as a result, of the processing, may also contribute.

(*3*) *Density Separation:* Use of colored (blue) backing is now almost universal in color traveling-matte work. The blue record is then processed with one of the others to give the matte. From the standpoint of image spread and registration, the better second record is the green. However, because of color difficulties, it is very common to have to go to the red record in order to obtain reliable separation. Even so, there is enough trouble to cause all operators to hope that eventually separation can be obtained with nonvisible light.

An ideal color negative would have:

(a) a perfectly stable base and emulsion, unaffected by changes in temperature and relative humidity;

(b) precise, accurately aligned Dubray-Howell type perforations, guided from the perforation edge rather than from the film edge;

(c) very thin emulsion layers, with characteristics of these carefully designed to keep scattering of transmitted light (during exposure) very low, and to keep image spread during processing to a minimum;

(d) an interchange of position of the red and green sensitive layers so that a sharper image can be obtained on the red record, and so that the green record —which is the most important one in the composite result—will have the greatest image spread; and

(e) a matte that could be incorporated in the negative and exposed with nonvisible light, and that, following processing, could be stripped off or washed away, leaving the negative in more or less "normal" form.

The matte films should have:

(a) high contrast and high resolution; microfile-type emulsion, which is very satisfactory for some steps;

(b) Dubray-Howell perforations, guided from the perforation edge rather than from the film edge;

(c) a thin, stable, and optically clear base, since some of the operations require exposure or printing through the base; and

(d) a separating agent to prevent matte film sticking to other films when used emulsion-to-emulsion.

There has been some talk of the advantages of having all matte films and negatives "toeless." Of greater advantage would be to have them all carefully designated and matched for use with a specific color of backing, a specified light exposure, and with specified processing so that results would be uniform and accurate.

The amount of such film used per year for travelling-matte work may not make investment in its development very attractive to film manufacturers. However if it were perfected, total use of such special film would be many times the present rate.

Advantages and Disadvantages of Various Separation Systems

Advantages	*Disadvantages*
I. Intensity Separation	
(1) Requires no special equipment other than black (velvet) backing. (2) Cameras and techniques are those used in ordinary photography. *Note:* This system has been thoroughly tried and found desirable.	(1) Dark areas in foreground disappear into backing. Thus hand work is needed, generally to the extent that the silhouettes are best drawn largely by hand. (2) Since there is only a single negative available, there is no opportunity to remove "holes" by double-negative method.
II. Color Separation (General)	
(1) Provides "white" backing. By making this intense enough, separation may be possible on a single negative. (2) Use of separate negative for matte silhouette is possible, allowing same light levels on foreground as for ordinary photography. *Note:* Techniques have already been tried and are more or less perfected for some types of color separation.	(1) High-intensity lighting required for backing often "kicks" from edges of foreground objects, obliterating matte line. (2) High, uniform intensity required for backing illumination is often difficult to achieve. (3) There is always possibility of interference with or from foreground color. (4) Generally, special lighting equipment, filters, and sometimes film, are required.
IIA. Ultraviolet Light	
(1) Only slight interference with foreground color. (2) Provides sharpest matte edges of any color method. (3) Gives best promise for obtaining matte from single negative record.	(1) Requires filtering of foreground lighting, or of action camera. (2) The very narrow band of wavelengths available between cut-off of glass optics and useful blue or violet color makes source of ultraviolet a real problem. Expensive, accurate filters are required. (3) Ultraviolet light is uncomfortable to some eyes. (4) Matte produced in camera requires correction in size due to lens performance in ultraviolet region. (Not corrected for ultraviolet, matte too small.)
IIB. Infrared Light	
(1) Ordinary film acts as its own filter because it is insensitive to infrared. (2) Incandescent lamps provide excellent sources of infrared. (3) Wide wavelength band gives good exposure with minimum of trouble. (4) No interference at all with foreground color. (5) No discomfort to actors.	(1) Spill light, especially from foreground, is hard to control, making double-negative method necessary. (2) Matte edge is not as sharp as for ultraviolet, although well within tolerable limits. (3) Focusing may give some difficulty, especially where single lens is used for visible and infrared light. (4) Matte produced in camera requires correction due to lens performance in infrared region. (Not corrected for infrared, matte too big.)
IIC. Mercury Green Line or Yellow Backing	
(1) Requires less filtering than ultraviolet. (2) Techniques now perfected permit use of ordinary Technicolor camera, whereas other methods require either an additional camera, a special camera, or special film.	(1) Interferes with foreground color, limiting to some extent colors and intensities which can be used. (2) Gives more trouble than invisible light would from "kicks" around edges of foreground objects. (3) Intense source of monochromatic light is difficult to obtain and to control with necessary uniformity over large backing areas. (4) Yellow color is disconcerting to actors and director.
III. Use of Polarized Light	
(1) No possibility of interference with foreground color. (2) No special lighting equipment required. Only backing needs filtered light. (3) Does not require high illumination of backing, reducing trouble from "kicks." (4) Uses same light level on foreground as in ordinary photography. (5) Offers possibility of using standard camera and single film for matte photography.	(1) Provides a "black" backing which will usually necessitate use of "double negative" matte preparation. (Most color systems must use this same method.) (2) At present, requires use of two cameras, a two-strip camera, or special film. (The same limitations apply to color methods.)

(See next page for Advantages and Disadvantages of Different Types of Backing.)

Proposals for Improving Traveling-Matte Processes

I. Ultraviolet Single-Film System

(*1*) *Film:* Film should be the same as present Eastman color negative with a filter such as the Wrattan 1B, which would not pass ultraviolet light to the color negative layer. Over this would be a layer of ultraviolet and blue-sensitive reversible emulsion.

(*2*) *Exposure:* Backing area should be illuminated with filtered ultraviolet light. Foreground should be lighted normally, with no necessity of removing ultraviolet from the foreground light. Light levels and exposure should be the same as now required with a camera having a 1B filter in front of the lens.

(*3*) *Development and Processing:* The following should be the processing procedure: Develop both layers but before fixing, dissolve the developed silver in the upper layer only, then expose to ultraviolet light to reverse the image. Develop reversed image and fix the entire film. This should give a reversal layer on the top having a positive layer, with the regular negative image in the color layer. The backing area of the double layer should be clear, the action or foreground should consist of a positive and negative image overlaid, so should be completely opaque. With proper film emulsion balance, this record should be directly usable as a "holdout" matte against the background.

(*4*) *Matte Procedure:* The following should be the matte procedure: (1) Using developed double-layer film as a hold-out matte, expose dupe negative to background positives. (2) Make foreground matte directly from developed double-layer film. (3) Bleach or strip off reversal layer from double-layer film, leaving only original color negative. (4) Using this and foreground matte, print-in foreground on dupe negative.

(*5*) *Advantages:* Single-film system, requiring only standard camera; no need to filter set lights.

II. Infrared Single-Film System

This would be exactly like the ultraviolet system except that the top layer would be sensitive to blue and infrared. No filter between layers would be required, since color negative is not sensitive to infrared.

The advantage would be greater ease in lighting, and less color trouble since no visible light at all would be cut off. The problem would be to find lenses which would give sharp imaging in the infrared. Definition might not be as good as for the ultraviolet method, but with proper lenses it should be very acceptable.

III. Polarized Light

(*1*) *Film:* Two films would be used in a beam-splitting camera. One would

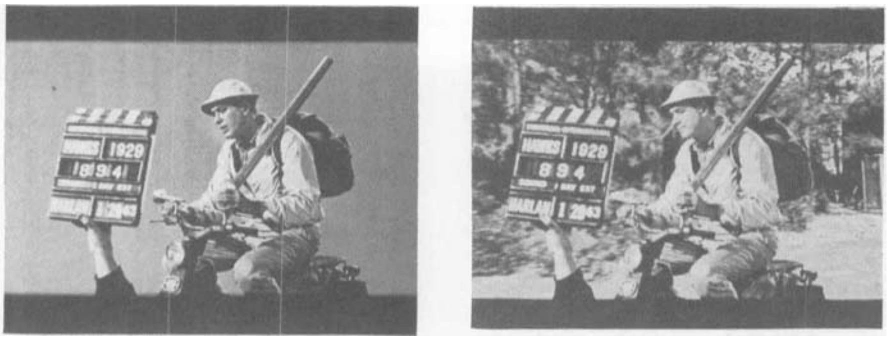


Fig. 37. Two frame enlargements of excellent example of a fringeless composite shot achieved with blue-screen traveling-matte photography; at left, the foreground action is photographed in front of a blue screen on the sound stage where the motor scooter has been properly mounted to permit stage hands to impart a natural jiggle to its movement. The result of compositing the blue-screen shot with the background shot is shown at right. (Photos by the author.)

Advantages and Disadvantages of Different Types of Backing

Advantages	*Disadvantages*
I. Cloth	
Black velvet (for intensity separation). Aluminum painted cloth (for polarized light). Colored cloth (for color separation).	(1) Backing lighting must be from the front, i.e. from the same general direction as foreground lighting.
(1) Comparatively easy to manipulate.	(2) Reflective efficiency is generally low thus requiring for color and polarized light work a relatively high level of incident light.
(2) Allows full matte of front action, i.e. it can even be put under actor's feet, if required.	
(3) Can be draped to cover parts of objects, and is otherwise more flexible in application than other types of backing.	
II. Translucent Screens	
(Useful for either color or polarized-light separation methods.)	(1) Generally inflexible in application and limited in scope.
(1) High efficiency makes it relatively easy to obtain necessary high intensity, uniform illumination required by color methods. Also, since translucent screens transmit polarized light without depolarization, they are ideal for this method.	(2) Illumination requires either large distance behind screen or elaborate grid of lights.
(2) Backing lighting can be from the rear and therefore completely separate from foreground lighting.	(3) Impossible to obtain matte line near floor or to matte entire foreground action as can be done with cloth backing.
(3) Background scene can be projected during matte photography of foreground.	
(4) Usually are readily available on the sets.	
III. Scotchlite (Reflexive-Reflector) Screens	
(1) Very high brightness levels possible with very small lighting units at camera position.	(1) Small but intense light source at camera.
(2) Possibility of "kicks" from backing practically eliminated.	(2) Shadows cast by light source may be visible to camera lens and may produce difficulties.
(3) Uniformity of illumination inherent in process.	(3) Beam splitters or other arrangements tend to cause flare in camera.
	Note: If problem of suitable illumination from camera position can be solved, Scotchlite screens may well be one of simplest and most effective methods to manipulate.

be standard color negative, the other, a fine-grain black-and-white negative.

(*2*) *Exposure:* The backing area would be lighted with polarized white light of such intensity that a density of about 2.0 would be given on the color (action) negative. The black-and-white negative would be exposed through a polaroid filter, crossed so that the backing area would appear dark. Light loss for the background record would be that diverted by the beam splitter (of the order of ½ stop) to the black-and-white film.

(*3*) *Development:* Each record would be developed in a normal manner.

(*4*) *Matte Procedure:* A print would be made from the color negative and used with the black-and-white to give a "hold-out" matte. From this point on, matte procedure would be very similar to that now used with color film.

(*5*) *Advantages:* The advantage of this method over the present "blue-screen" system would be that there would be no interference with color, and that it would present no color problems.

(*6*) *Disadvantages:* Requires two films and involves loss of light in beam splitter.

IV. Polarized Light Single-Film System

This would use a film similar to that described in Sec. I above except that instead of a 1B filter, a polarized layer would be used over the color negative. The upper layer would be a very slow black-and-white emulsion.

Exposure of the color negative would have to take the absorption loss of the polarizing layer which would be at least 50%, and probably more of the order of 60%. Procedure would be the same as in I.

Notes on the Use of Polarized Light

It has been found that the Vectograph system produces regions of varying polarization in proportion to the intensity of incident light. Is it therefore possible to produce similar regions only where the incident light is polarized?

The idea is roughly as follows: The backing screen would transmit to the camera only polarized light, while the foreground action would be illuminated by unpolarized light. Now, assuming that the region on the negative which images the backing area would be so affected that it would polarize light, it no longer would be necessary to use a filter in front of the camera or to use more than the one negative film. Let us assume that we can obtain this negative record with the backing area capable of polarizing light, while the foreground action area can remain a normal record in every respect. A print made with polarized light would then have the backing area perfectly clear. Then, by double exposing another print first through the negative under polarized light and then through the first print under ordinary light, a second print could be obtained in which the backing area is still clear and the background area completely exposed. It is assumed, of course, that the polarized light used in printing would have a plane of polarization at right angles to that of the polarizing material in the backing area.

As may be seen, the success of this scheme depends upon obtaining a polarized region in the negative corresponding to that area of the backing which receives polarized light for photography. Unfortunately, no literature on the process indicates that this is possible.

Acknowledgments

For the above compilation, I should like to give due credit to Armin Hill, Herbert Meyer and Petro Vlahos who were associated with me at the Motion Picture Research Council, and whose comments guided this presentation.

Part 6. How Electronics May Simplify This System in Near Future

A Look into the Future

Since this section concerns methods and procedures for traveling-matte photography never before undertaken in feature film production, I shall first describe briefly another procedure utilizing generally available transparency background projection equipment as a means of illuminating the backing. The procedure, first suggested by the transparency department of Paramount Studios in Hollywood, is applicable to both the conventional blue-screen and the color-difference methods of traveling-matte production.

A standard transparency screen is used in conjunction with process projectors equipped with long-life, high-efficiency dichroic filters which provide the required blue illumination. The dichroic filters render pure blue light with virtually no green or red contamination, resulting in better separations.

Adaptor lenses permit shortening of the projector throw, and the projectors do not clutter up the stage area at rear of the process screen; thus there is no obstruction to the projection of the background plate. The latter may be projected during the process take, following the standard procedure of the transparency process for motion pictures wherein synchronization of shutters is established at 180° out of sync. An advantage is the fact that the projected picture may be viewed through spectacles with yellow-colored lenses, which eliminate the blue illumination and permit viewing the background picture in full detail and contrast.

Advantages and Disadvantages

There are advantages and disadvantages in this system, and the more important are described below:

(1) In none of the previously proposed systems of traveling-matte photography has projection of the background scene been incorporated. Presentation of the background scene simplifies determination of perspective, direction of shadows, and timing of the foreground action with that in the background. The creation of a "composite" image on the set is, of course, a most desirable feature.

(2) Transparency screens and projectors are within the scope of studio operations and are considered relatively portable items of production equipment.

(3) At least three or four projectors are required to illuminate the backing in this system.

(4) In spite of the fact that a relatively short projection throw can be used, more space must still be provided behind the screen to accommodate the projectors than when the screen is illuminated by a bank of incandescent lamps, as pictured and described in Part 2.

Another Approach

Another and more advanced approach to making composites utilizes important components of television in combination with the film camera. It is called the "Shoot-and-Tape" production method and became feasible with the introduction of low-priced, portable video-tape recorders.

What is meant by the "Shoot-and-Tape" method? In the photographic set-up, a 35mm reflex motion picture camera is augmented by a vidicon TV camera and a portable video-tape recorder to form a unified motion picture production tool. Its purpose is to streamline conventional production procedures and introduce production economies, while increasing the quality of the ultimate film product both technically and artistically.

In Fig. 38, a professional reflex-type motion-picture camera, such as shown in Fig. 39, is combined with a small vidicon camera in such a manner that the latter "sees" a parallax-free image of the scene through the taking lens of the film camera. The electronic output of this camera combination may be viewed in the finder, and also on monitors set up as required on the sound stage. At the same time, the video signal is being fed to the portable video-tape recorder. A simplified diagram of this arrangement of components is shown in Fig. 38.

Some Advantages of the Photo-Electronic Combination

(1) The photo-electronic combination has all the features of a video finder system and provides viewing on a remote monitor screen the scene and action as "seen" by the camera lens. The remote monitor viewing is especially advantageous to the production staff on an extremely narrow set, when making a dolly shot, or when shooting from a highly

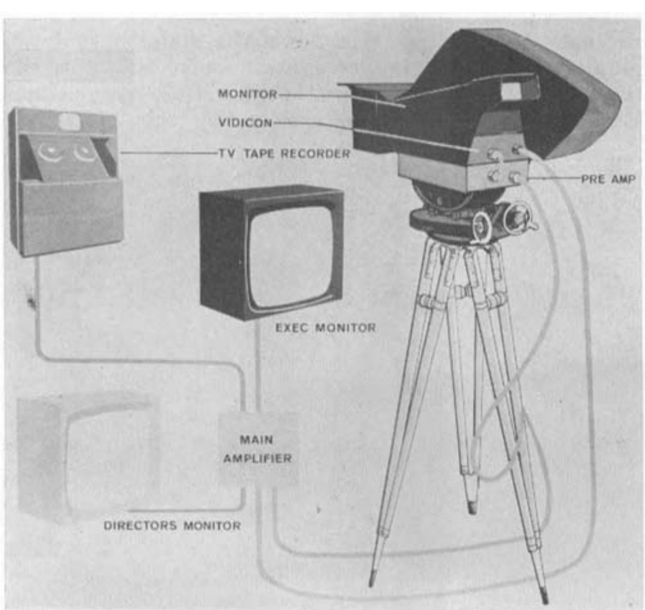


Fig. 38. Artist's conception of a Mitchell Reflex camera coupled with vidicon camera and other electronic components for use in film production system.

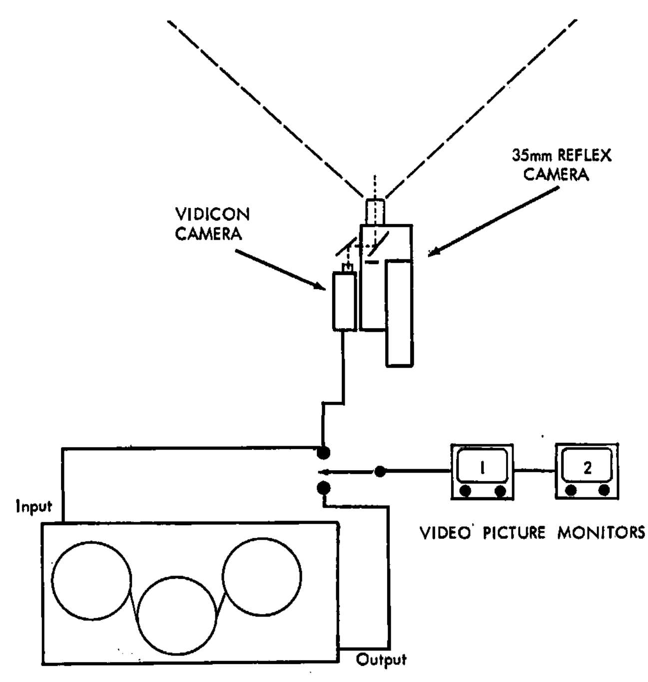


Fig. 39. Schematic of the electrical wiring hook-up between cameras and components pictured in Fig. 38.

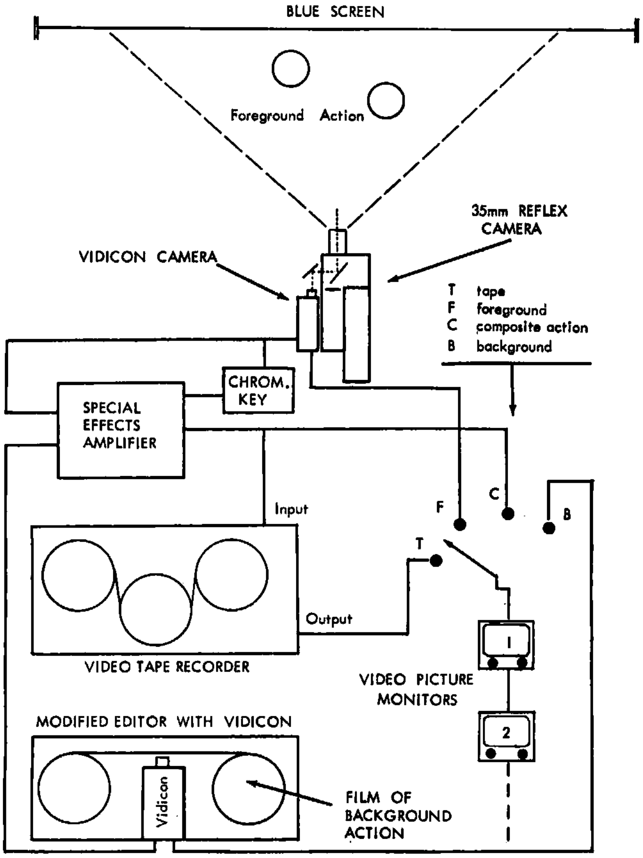


Fig. 40. Schematic of various components and the interconnecting wiring for a combination electronic-film camera proposed for the production of blue screen traveling mattes. System provides electronic viewfinder for camera, viewing of action on remote monitors, video-tape recording of action, and integration of pretaped background and action filmed before the blue screen.

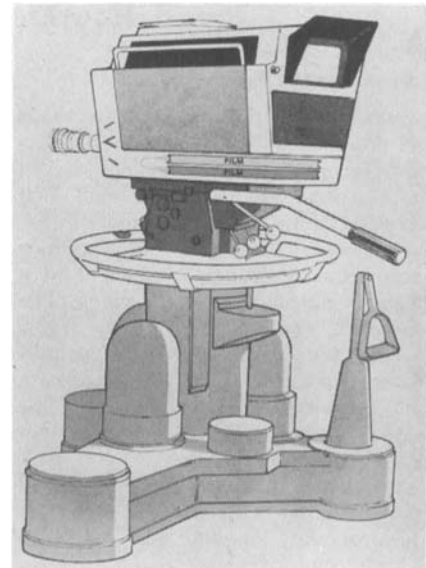


Fig. 41. Artist's conception of combination Mitchell photoelectronic camera use in proposed film production system of the future.

elevated boom. There is never a parallax problem and no restrictions as to focal length of the lens on the camera.

(2) It is possible to view each take immediately after shooting by playing back the video-tape record of it. Where several takes of the same action are recorded, playing back the tape enables the director to make a choice, thus reducing the necessity for shooting numerous takes in order "to get it right." The tape record gives him the answer that he would normally have to wait for until the dailies were screened the following day.

(3) Rehearsals may be taped with the film camera inactive, the tape played back and a choice made; or the playback may be for the benefit of the players, enabling the director to show them how they look in action, and to point out any necessary changes in routine.

(4) By means of a second video-tape recorder, the selected takes can be transferred in proper order, permitting the study of a finished sequence in its entirety.

What has all this got to do with blue-screen traveling-matte photography? Following extensive studies of the "Shoot-and-Tape" method described here, it was found that it also could be used to considerable advantage in the production of composite photography.

For recording and viewing composite shots on the sound stage, the "Shoot-and-Tape" set-up diagrammed in Fig. 38 would have to be expanded, as shown in Fig. 40. In Fig. 40 are shown, from top to bottom, the following basic components: Stewart T-Matte blue screen with foreground action before it; the reflex-film-camera vidicon-camera combination; chroma-key unit; special ef-

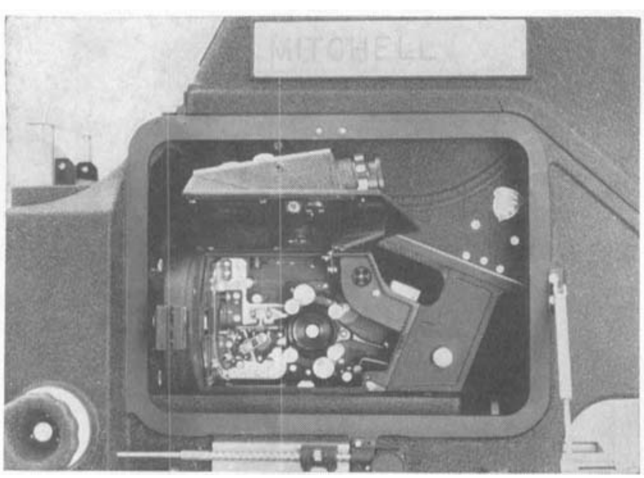


Fig. 42. Mitchell Mark II Reflex 35mm camera in blimp (door open) before addition of vidicon camera and other electronic components proposed by author for traveling-matte work.

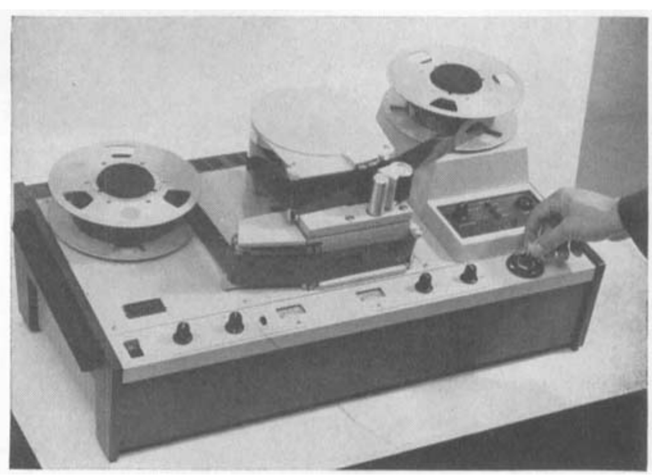


Fig. 43. Ampex VR1500 portable video-tape recorder as an ideal component for the "shoot-and-tape" set-up for traveling-matte and feature production.

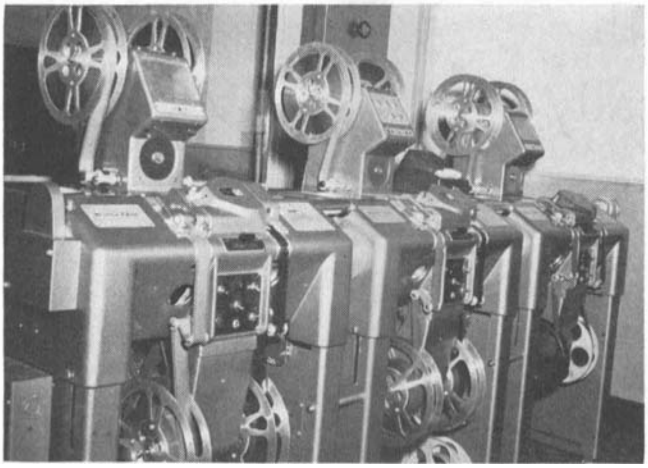


Fig. 44. A special Westrex 35mm film editor modified by RCA for vidicon image pickup or used for background plate display in traveling-matte photography.

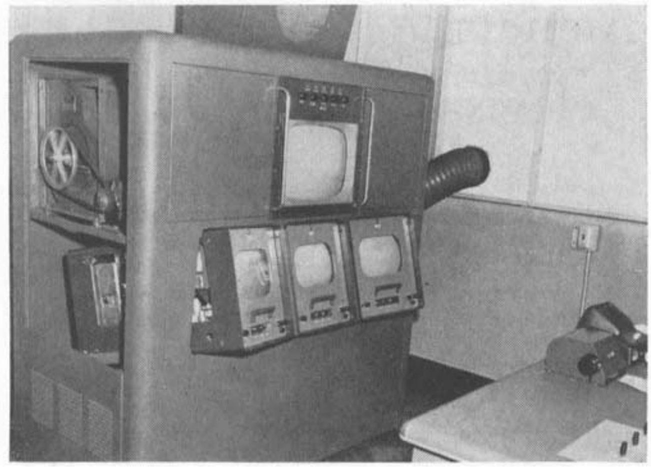


Fig. 45. Rack having several TV picture monitors in an arrangement ideally suited for use in electronic editing of video images in photoelectronic production of traveling mattes.

fects amplifier; video-tape recorder; selector switch; picture monitors; and modified editor with vidicon. (Some of this equipment and its use was previously described in Part 2.)

Visualizations of typical vidicon film camera combinations, such as suggested in Fig. 38, are presented in Figs. 41 and 42. The portable Ampex video-tape recorder is pictured in Fig. 43, and a version of the Westrex 35mm film editor modified to permit viewing of the film images on video monitors is shown in Fig. 44. The video monitors are pictured in Fig. 45. The type of equipment illustrated here may shortly be put to new uses in traveling-matte photography.

The basic concept of the proposed photo-electronic traveling-matte process, diagrammed in Fig. 40, is as follows:

Photo-Video Traveling-Matte Process

The combination vidicon film-camera records the action normally as it is played before the blue screen. The vidicon camera pickup is channeled simultaneously to the chroma-key unit, to the special effects amplifier and to the tape recorder, as shown in Fig. 40. The previously filmed background action is threaded in the modified Westrex film editor. The film camera and editor operate simultaneously and in sync during a take. Thus, by electronic means—i.e., the chroma-key and the special effects amplifier—the foreground and the background are integrated and become a finished composite picture.

It would exceed the scope of this article to go into full detail regarding the electronics involved. However, a brief explanation is in order: the various units in the system provide an electronic means for suppressing the blue area of the background behind the action, and replacing it with the "plate" action in that area only—thus creating a composite image that can be viewed on the monitor or recorded on video tape.

The chroma-key unit may be described as a color matrix system which is able to suppress all luminance information; it can be adjusted to provide a narrow-band selection in the chromatic color scale.

The same electronic components that are used regularly by most television stations to achieve traveling-matte effects are utilized in this proposed photo-electronic traveling-matte process.

It should be pointed out however, that a single black-and-white vidicon camera cannot be combined with the film camera to produce the desired results: a two-color or preferably a three-color camera must be used.

What the Monitors Show

The switch "TFCB" in Fig. 40 enables the production director to quickly channel to monitors M1 and M2 important information he wishes to see as the show is being rehearsed or photographed. Throwing the switch to position "F" will bring into view on the monitors the foreground action only, as "seen" by the camera. Switching to position "B" will show the background action, either from the film itself or from a static substitute, such as an artist's drawing, etc. Switching to position "C" will show the composite shot that results from integrating the images from the camera and the film editor. Switching to position "T" provides an immediate playback of the images recorded on the video tape; this may be action only, the background plate only, or the final composite of both—just as it will appear on motion-picture film sometime later, following laboratory processing and printing. The big advantage this set-up provides, however, is that the director can preview a scene before filming it, to study the overall effect or individual performances, and to make decisions on the set regarding foreground or background.

Those who are familiar with the inherent difficulties encountered in traveling-matte photography will no doubt agree that, with proper calibration between the electronic and photographic components, a system such as outlined here can lead to absolute trouble-proof accomplishment of the photographic phase of the traveling-matte process, especially since the electronic phase can reveal instantly all the areas that can be corrected prior to or during actual photography.

Some may argue that this photo/electronic method of traveling-matte photography could add considerable extra cost to a production; on the contrary, the method can be expected to quickly pay for itself as a result of its faster and more efficient production of composite shots. Incidentally, the method is similar to that for an "Electronic Traveling-Matte Printer," once under serious consideration by motion-picture engineers.

This system has not yet been put together as physical hardware and made to work on a feature film, and is described here only as a "look into the future." That there is validity in its concept is borne out by the many positive and encouraging remarks that have been made to me by experts in both the electronics and photographic fields with whom I have discussed it.