SMPTE Journal

Blue-Max High-Power Blue Flux Projector for Large Scale Bluescreen Composite Photography

By Jonathan Erland

Reprinted from the *SMPTE Journal*
November 1985 Issue, Volume 94, Number 11

Blue-Max High-Power Blue Flux Projector for Large Scale Bluescreen Composite Photography

By Jonathan Erland

In the eight years that have elapsed since the release of the motion picture Star Wars, *the compositing technique known as "bluescreen" has enjoyed a phenomenal growth. Greater sophistication in the application of this technique has, in turn, led to greater demand for it. One of those demands, heretofore difficult to meet, has now been satisfied: bluescreen on a large scale — 50×150 ft or larger.*

The compositing process known as bluescreen had its beginnings in the work of Messrs. Dunning, Pomeroy, and Oliver in the late 1920s and early 1930s. From Dunning's use of a colored backing to distinguish the foreground from the background, through Pomeroy's five separate compositing processes, to Oliver's insightful application of the lithographic color separating process, these pioneering efforts produced a system of travelling matte photography that was to blossom into a rich tapestry of technical wizardry.

While travelling matte photography has been in the arsenal of motion-picture technology for many years, the refinements that occurred in the years since *Star Wars* have catapulted it into one of the most important motion-picture processes extant. It has been estimated that from *Star Wars* through the present, motion pictures incorporating travelling matte photography have accounted for approximately $10 billion in revenues. The Academy of Motion Picture Arts and Sciences has acknowledged the importance of this aspect of film technology by granting several technical awards in connection with travelling matte processes, including a Technical Achievement Award for the subject of this paper.

In its most elementary form, the steps involved in the bluescreen travelling matte process are as follows: a foreground scene containing actors or other moving articles is set before a colored backing, such as blue, and filmed. The resulting negative is then separated into positives representing the three primary photographic colors (red, green, and blue) on black-and-white stock. It is then possible to bipack the blue separation with the original negative and print it with a red light to a high-contrast black-and-white stock. This yields a burn-in matte which can be reversed to produce a hold-out matte.

Reconstructing the image consists of printing the red separation through the burn-in matte, followed by the green separation (which is used to print both green and blue). The hold-out matte is now employed to protect the image just deposited and to permit the printing of the selected background scene. This is a much simplified version of the process, and there are several ways to go about it, all dependent on the images to be composited and the equipment available. For a comprehensive discussion, the reader is referred to the excellent tutorial paper by Walter Beyer which appeared in the *SMPTE Journal* of March 1965[1] and the article by Petro Vlahos on travelling matte photography which appeared in the *A.S.C. Manual*.[2]

Of course, there were problems involved in acquiring a clean blue field for the background. A painted blue backing seems simple enough, but it is asking a great deal of an absorptive medium such as paint to absorb the large amounts of red, yellow, and green light and reflect the relatively small amount of blue light that is emitted from the standard tungsten stage light. In addition, the backing frequently has to be illuminated to the same level that the actors appearing before it will be, and that requires that the blue paint not be so saturated as to be too dark in comparison.

Then if that hurdle is surmounted, the problem remains of unwanted shadows being cast upon the blue backing by the actors or other foreground subjects, thus lowering the blue exposure below the critical threshold required for matte formation. It was with profound relief that in 1964 the visual effects community greeted the arrival of the Stewart travelling matte transmission screen, a rear-lit seamless filter of ingenious construction that at one stroke improved the quality of the blue color and eliminated the problems of shadows.

In ensuing years, further improvement was brought about by two factors: first, the use of fluorescent tubes with their inherently higher blue content to illuminate the Stewart screen; and then the introduction by Apogee of fluorescent tubes containing a specific phosphor which provided an emission almost exclusively at the wavelengths required for bluescreen (Fig. 1). Coupled with a modified dye formula for the Stewart screen, this provided an exceptionally pure blue.

The reason for this fanatical pursuit of an ever purer blue can be appreciated by referring to the spectral sensitivity chart for the Eastman color negative film 5247 shown in Fig. 1. In this chart, it is readily apparent that instead of the three color records being neatly separated, they overlap considerably. They especially overlap in the green-to-blue transition, in which the green sensitivity manages to dip to a low point at about 435 to 440 nm before actually rising again as it proceeds towards the ultraviolet region.

As color negative has evolved over the years, it has gained in speed, but it has done so at the expense of progressively less separation between the color records, so that the crosstalk between the blue and green records has become steadily more pronounced. This drive for speed led to the development of 5294 film, in which the blue and green records overlap to the extent that it is essentially impossible to practice the bluescreen process.

Presented at the 126th SMPTE Technical Conference in New York (paper No. 126-91) on November 2, 1984. Jonathan Erland is affiliated with Apogee, Inc., Van Nuys, Calif. This article was received May 24, 1985.

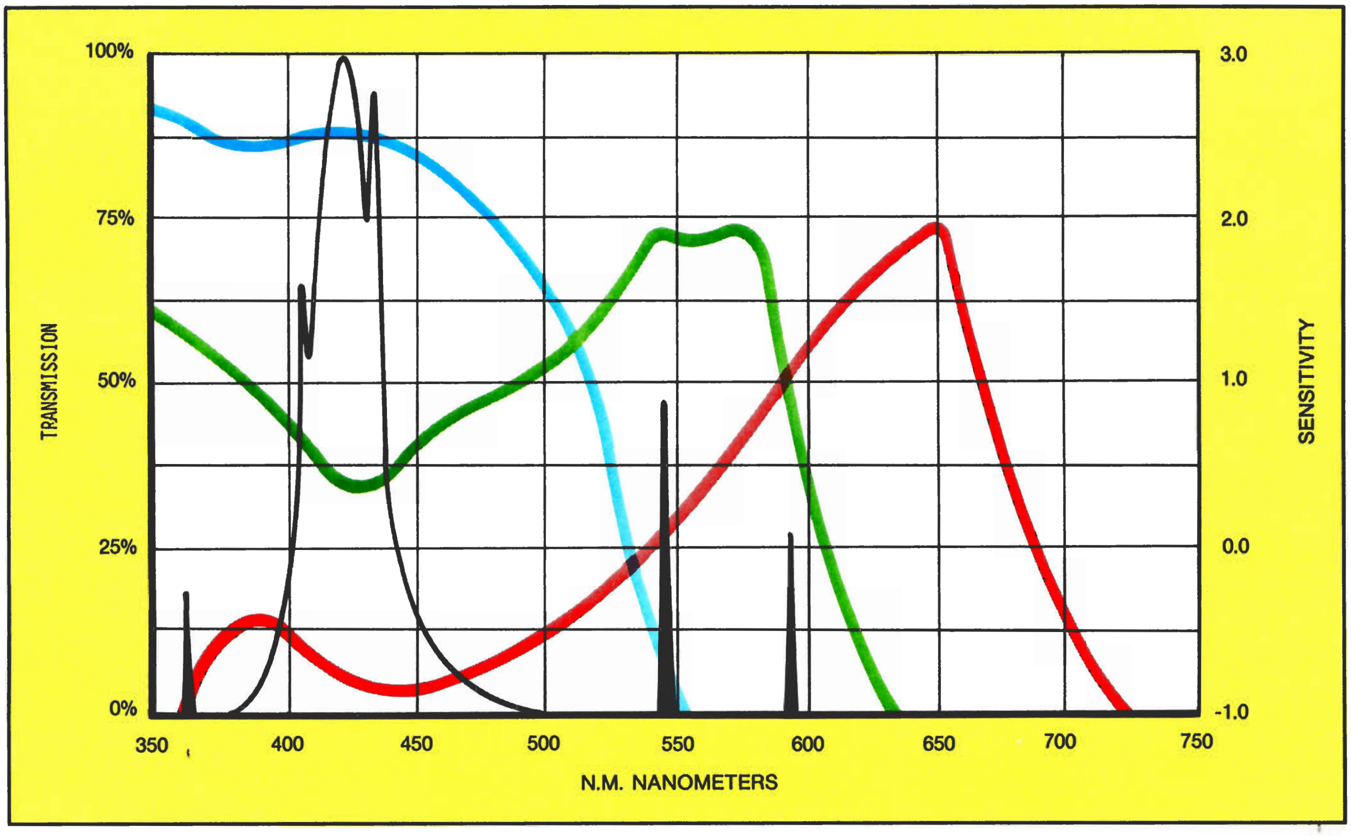

Figure 1. Emission line for Apogee lamps. Spectral emission line for Apogee bluescreen lamps superimposed over spectral sensitivity curves for Eastman color negative 5247.

While this is the subject of intense study by both Kodak and industry engineers, in the meantime, 5247 is the only viable bluescreen process filmstock available.

With the dice apparently loaded against it, it seemed that an effort of sheer genius was needed to take advantage of this densitometric quirk. The genius in this case was Petro Vlahos.[2] Vlahos reasoned that if one bipacked the black-and-white green color separation positive together with the original negative, the result would be the difference between the two, thus obtaining a synthetic blue record without exposure in the bluescreen area. In a sense, this would produce a four-record film (Fig. 2).

While Vlahos' improved technique allowed greater latitude in terms of the range of color that could be reproduced as well as the ability to incorporate features such as smoke and glass objects, the problem of blue spill remained to plague those attempting the bluescreen process. Any system that depends upon a backing of diffuse and incoherent light is fraught with problems of reflection of the backing by the foreground subject, and this includes the phenomena of thin objects such as latticework, railings, antennae, etc., being "wrapped" by the backing light and dropping out of the matte. To some degree the effect of spill can be offset by the careful application of fill lighting onto the foreground subject, but this is of no avail in situations that produce a specular reflection of the screen (Figs. 3–5).

This classic bluescreen situation required the invention of an entirely new travelling matte process, applicable only to a motion control system, and known as the "Reverse or Nega-

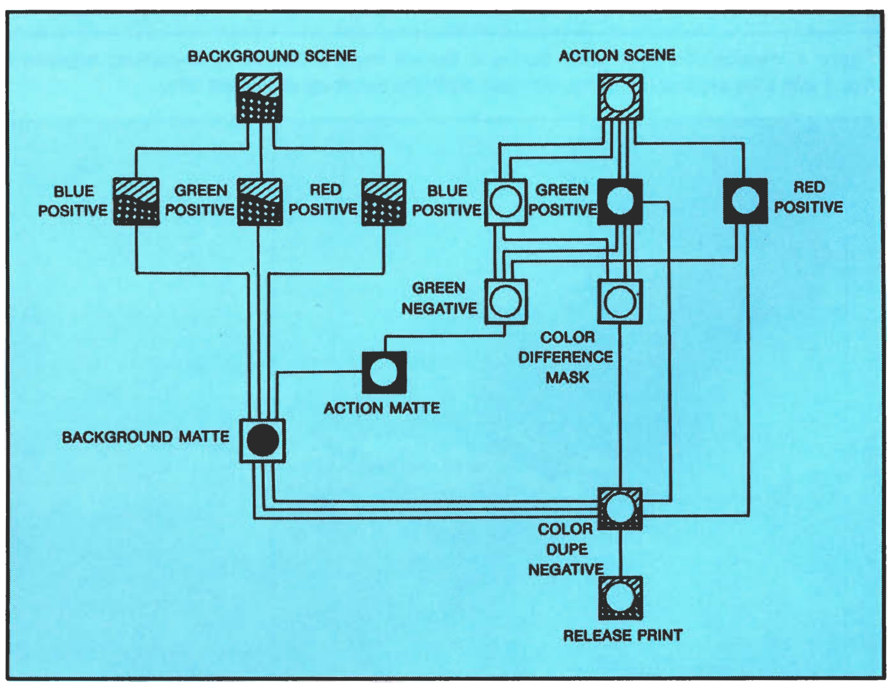

Figure 2. Petro Vlahos' flow chart for Color Difference Bluescreen Process. The extraction of the synthetic blue record produces, in effect, a four-record film.

Figure 3. Firefox Blue Spill Matte Series 1, original shot. Note blue reflected on wing surfaces from bluescreen — undesirable, but unavoidable on such surfaces.

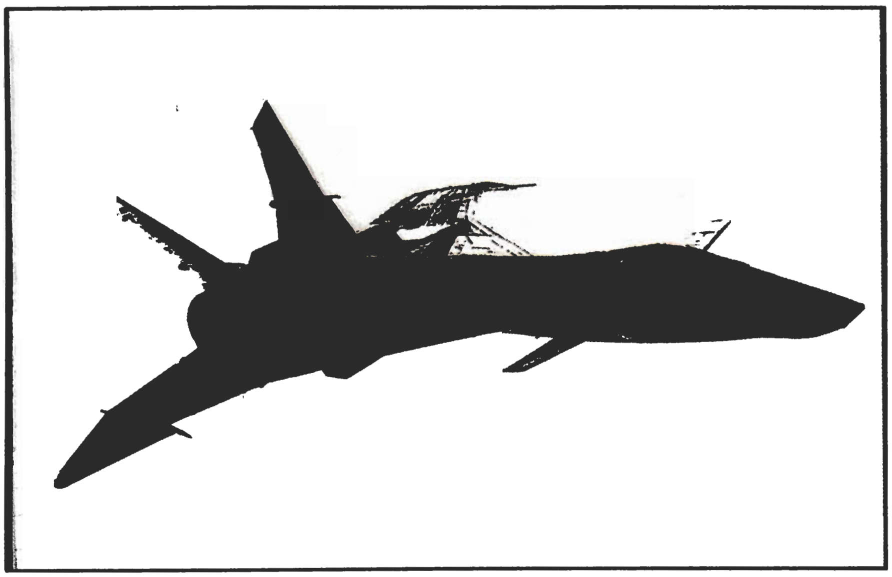

Figure 4. Firefox Blue Spill Matte Series 2. Burn-in matte produced by bi-packing negative of No. 1 with blue separation, using red filter. Note the break-up of the left wing.

Figure 5. Firefox Blue Spill Matte Series 3. Final composite, complete with holes in the foreground subject, an unacceptable result.

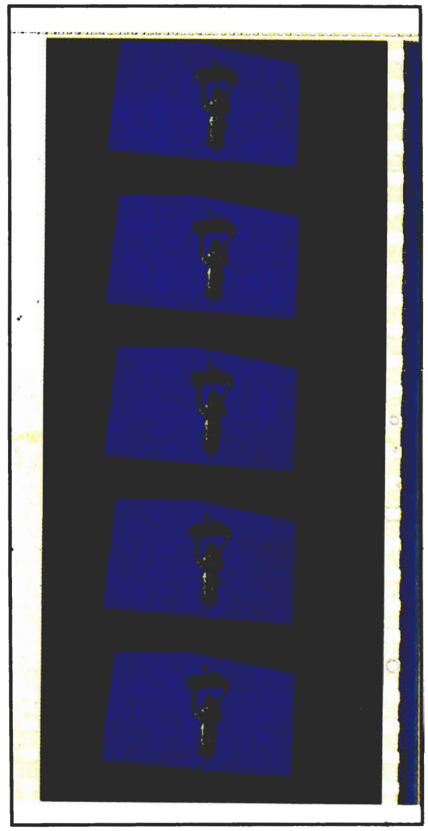

Figure 6. A bluescreen element from 2010 made with Apogee's Blue-Max. (Photo courtesy Boss Film Corp.)

tive Bluescreen Travelling Matte Process." This process, which won an Academy Scientific and Engineering Award in 1984, was described in the March 1983 *Journal.*[3]

Another problem encountered in high-quality bluescreen work is the limitation of the size of the backing. For a painted backing, of course, there is no size limitation. But as already discussed, painted backings are the least capable of yielding high-quality mattes. Until now, the bluescreen of choice has been the seamless transmission type, mentioned earlier, that won a Technical Achievement Award for Stewart Filmscreen in 1964. That screen, however, is limited by its manufacturing process to a maximum size of 40×90 ft — a considerable size, especially in view of the phenomenal quantity of lighting required for a screen of those proportions. Despite the impressive size of the largest Stewart screens, recent productions such as *Dune* and *2010* (Figs. 6 and 7) have required screens of even larger proportions. To obtain these large screen sizes, it was necessary to resort to front projection.

Although front projection bluescreen is alluded to in the Beyer paper

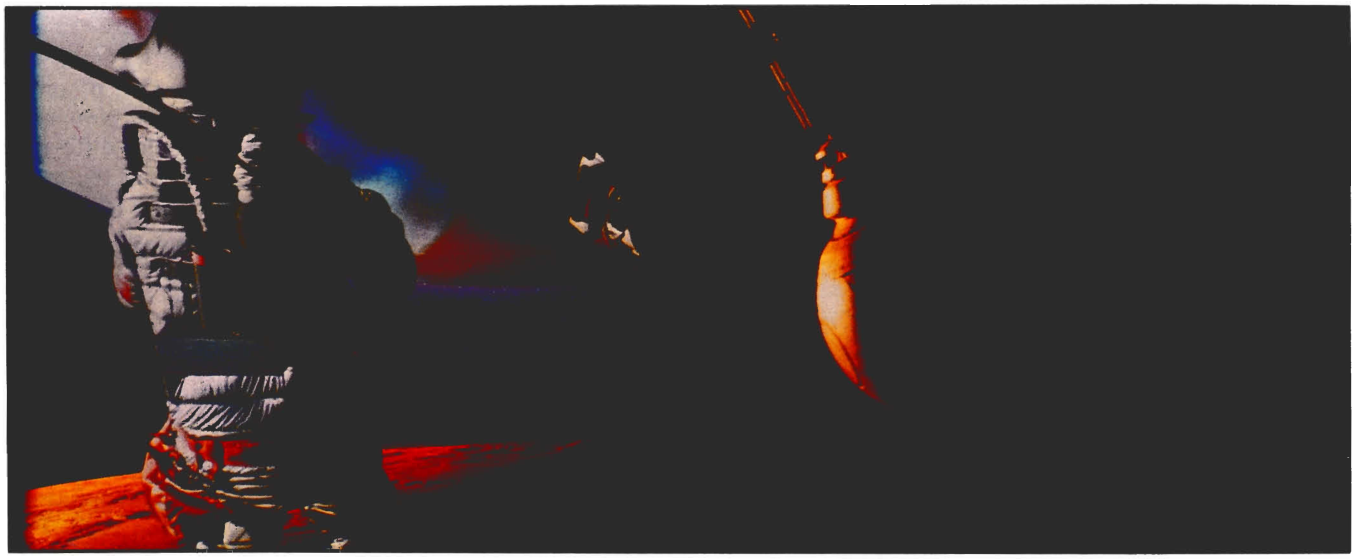

Figure 7. Mark Vargo composite from 2010. *(Photo courtesy Boss Film Corp.)*

referred to earlier, the first application of this technique appears to have been made by L. B. Abbott on the motion picture *Tora! Tora! Tora!*, and came about because of an inadequate front projection plate. Rather than cancel an expensive shooting day, Abbott opted to go ahead with the scheduled shoot. He substituted blue light for the plate, planning to composite the plate into the scene at a later date.[4]

But before we get into the details, let us take a closer look at the material that has made possible so much of what we take for granted in visual effects compositing — the Scotchlite retroreflective front projection screen (Fig. 8). Scotchlite is the invention of Philip V. Palmquist, who was attempting to increase the efficiency of road signs and the like, with a view to saving the lives of motorists and the dollars of taxpayers. He based his work on the already established catadioptric principles embodied in glass beaded reflectors, with improvements that yielded superior optical qualities and efficiencies.

This was not the only approach to this problem, as a survey of the patent literature quickly reveals. However, most of the alternative retroreflective designs are based on the cube corner prism principle, which is limited in the degree to which it can return an off-axis light to its source. Scotchlite, which is based on a spherical lens, can in effect rotate with the source and consequently remain effective up to 30° off axis.

Rohm and Haas developed a retroreflective sheet material using calendered plastic and with very similar properties to Scotchlite (Fig. 9). This was an attempt to produce a true catadioptric plastic sheet composite screen that promised uniformity and economy. However, they abandoned development of this material and sold the patent to 3M.

With the possible exception of the Rohm and Haas entry, none of the alternative approaches offer the optical properties of Scotchlite. In a photomicrograph of Scotchlite (Fig. 10), one can see the individual glass spheres, which vary slightly in size from the nominal 2.5 mils, and include occasional aberrations such as opaque white spheres and marbled "aggies." A human hair, lying across the Scotchlite, provides a scale reference for the magnification, which is about 40×.

Returning to Bill Abbott and *Tora!*

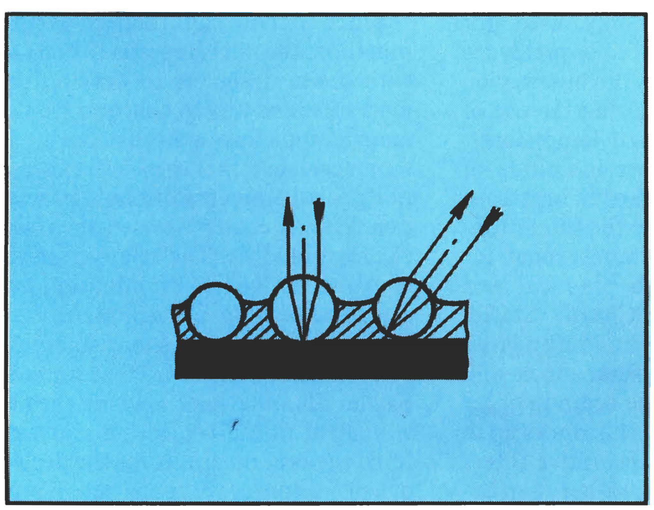

Figure 8. Illustration from Scotchlite patent, indicating how light rays impinging on the surface from various angles are retroreflected along the same axis.

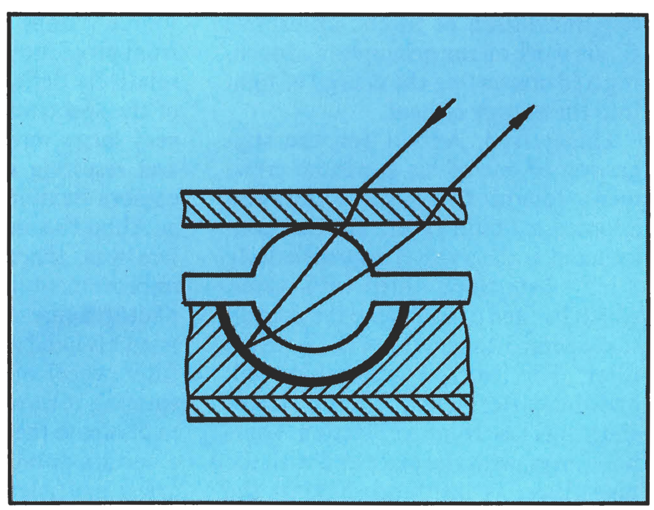

Figure 9. Rohm and Haas catadioptric. Illustration from Rohm and Haas patent showing a proposed calendered plastic laminated sheet retroreflector. This approach offered economy and uniformity.

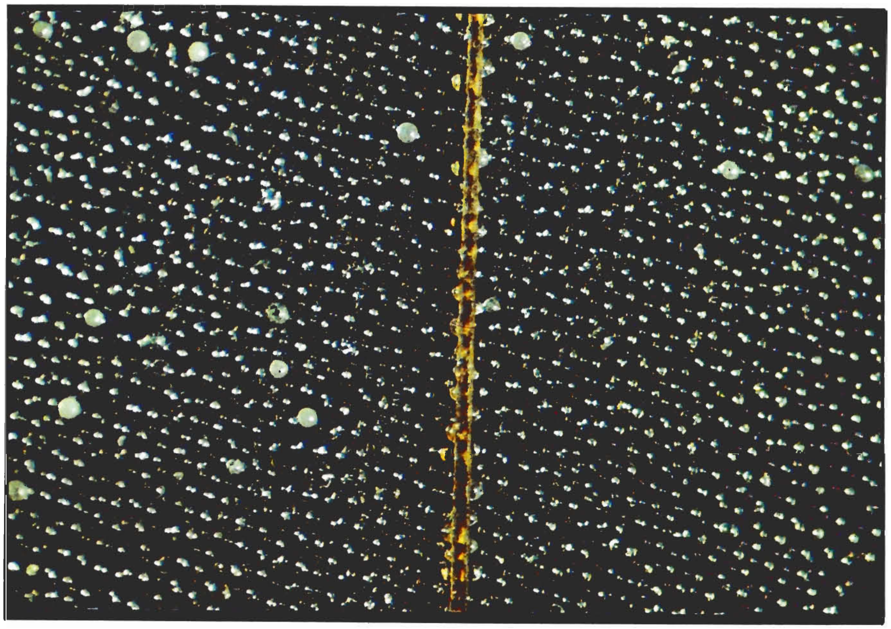

Figure 10. Photomicrograph of Scotchlite showing its individual glass spheres (averaging 2.5 mils) which include occasional white spheres and marbled "aggies." A human hair provides a scale reference for the magnification, about 40×.

Tora!Tora!, among the many sequences slated to be shot via front projection was a large section of a Japanese submarine. Unfortunately, the plate that had been prepared for this particular shot turned out to have been improperly balanced to the extent that it was unusable. In what can only be described as a moment of pure inspiration, Abbott decided to convert it to a bluescreen shot by the (apparently) simple expedient of projecting blue light to the Scotchlite screen. He then sent for some 47B Wratten filters (the standard blue separation filter). These were thrust into the light beam of his very powerful front projector, whereupon they promptly incinerated in a puff of smoke. This was the first lesson of filters: absorptive filters work on the principle of absorbing and converting the energy of light into the energy of heat.

Undeterred, Abbott (on the suggestion of one of his Japanese crewmen) fought fire with water and adopted a liquid filter. He had constructed a glass vessel approximately 8 in.^{2}×2 in. thick, filled with water, which he then dyed blue to the density that seemed to equal a 47B Wratten filter. This worked admirably well, and thereafter he made a practice of shooting his front projection shots both ways, with the plate and with the blue filter, as insurance against the vagaries of the front-projection process.

Abbott also noted a serendipitous benefit of great importance obtained by this method of carrying out the bluescreen process. Blue spill, the bane of bluescreen compositing, is largely eliminated by virtue of the fact that the projected blue light is of necessity a coherent beam. This is further enhanced by the retroreflective screen's faculty for returning the beam strictly along its own axis. Essentially no scattered blue light remains to fall upon foreground subject matter where it could be reflected back to the camera with the consequent degradation of the matte image.

A problem that confronted Abbott and subsequent practitioners of this technique is that the white light source lamps commonly used for front projection of full color plates are relatively deficient in the blue region of the spectrum, requiring the use of very large wattage and lamphouses, and resulting in severe inhibition of camera flexibility. Also, as ingenious as Abbott's solution to the filter problem was, there was much room for improvement in both practical and photographic areas. Charlie Staffel tried his hand at it by building a large filter wheel of 47B filter stock and rotating it through the beam in order to dissipate the heat. This works up to a certain point, but absorptive filters are so inefficient that, rather than being transparent to their selected color, they consume almost as much of their selected wavelength as they pass.

Blue-Max

The obvious solution was to design a dedicated luminous flux projector capable of producing the pure spectral lines needed for color difference matte compositing. Under the direction of Apogee's senior design engineer, Don Trumbull, a design team was marshalled which included Jonathan Erland, Research and Development Dept.; Stephen Fog, Engineering Dept.; Dr. Paul Burk, consulting optical engineer; and Bill Shourt, Dick Alexander, and Steve Sass, Machine Shop and Electrical Depts.

The first element in the design of a lamphouse specific to this application was, of course, the lamp itself. Past experience with bluescreen work dictated a gas discharge lamp of some kind. Mercury, we knew, provided spectral lines so appropriate it seemed as though it had been designed for matting (Fig. 11.) Mercury peaks at 436 nm, precisely in the valley the green record's sensitivity, and 545 nm, essentially the optimum position for maximum green exposure. However, a pure mercury short arc lamp isn't a practical reality yet, so the next candidate was a mercury-xenon, which can be produced as a high-power, short-arc lamp, and which still retains sufficient red emission beyond 650 nm to provide for effective red matting. In order to have sufficient power available to fill very large screens with a narrow spectral line, we selected a 5000-W lamp from Optical Radiation Corp. The lamp we received was so impressive that Roger Dorney, Apogee's Optical Dept. head, was inspired to dub it "Blue-Max." The name was instantly adopted and is now official.

Since we now had a source of illumination, the next step was to consult with optics designers to develop the most effective way to concentrate the lamp output into a usable beam. It soon developed that there were essentially two distinct traditions in projection systems, each possessed of its own virtues and vices. The relative merits of Abbe vs. Kohler illumination are discussed in *Optical Engineering.*[5]

For our purposes, the gist of the distinction could be stated as follows: Kohler illumination (in which the arc is imaged in the projection lens) offered the best prospects for the design of a projector for front projection process photography, especially in view of the requirements for maintaining nodal point alignment between pro-

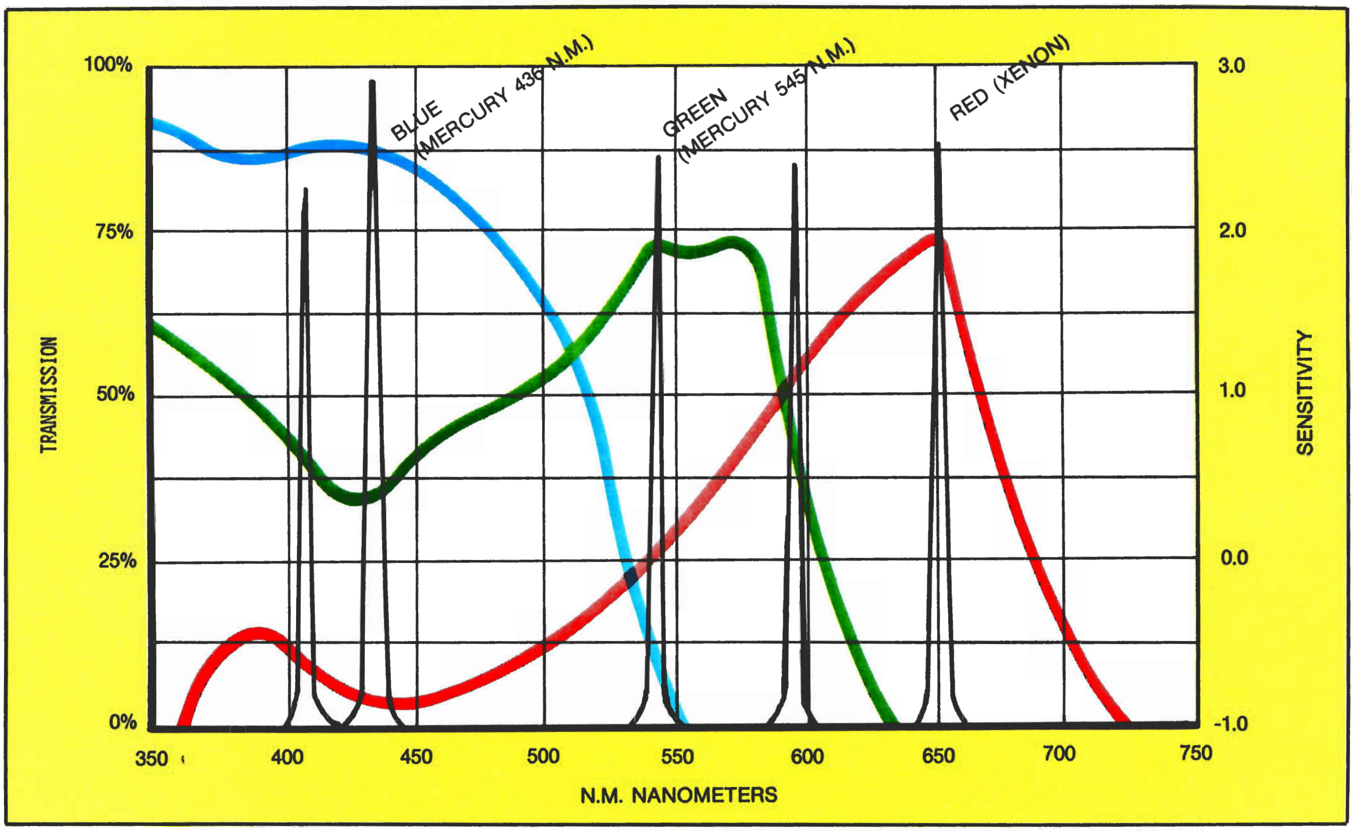

Figure 11. Spectral emission of a mercury-xenon arc lamp, superimposed over 5247 sensitivity curves, showing the relationships that make this lamp especially suitable for matting.

jector and camera lenses. On the other hand, Abbe illumination (in which a reflection of the arc is imaged at the film plane) offered significantly better efficiency in terms of the collection and delivery of light, which is why it forms the basis for nearly all film projection applications. However, our circumstance differed from both of the conditions addressed by Abbe and Kohler. We were not projecting images — only light (although the light had to behave as though it was emanating from the camera lens).

The issue was resolved by the adoption of an optical design produced for us by Dr. Paul Burk. This design, which dispensed with both projection lens and film plane, utilized a relatively new optical device known as an "integrator" whose function is to integrate and homogenize the relatively uneven distribution of flux obtained from a collector mirror and to become itself the apparent source of illumination. This system, with its supplementary lenses, provided the most efficient collection of lamp output while allowing for effective methods of filtering and attenuation, as well as the ability to tune the delivery of the lamphouse in order to optimize it for various film formats and lenses (Fig. 12).

It then remained to design the filters that would isolate the required spectral line in the most efficient manner possible. Abbott had resorted to a liquid cell approach in order to avoid having his gelatin filters burn up. We turned to dichroic coatings, both reflective and transmissive, to reduce the losses experienced with absorptive filters such as Abbott and Staffel had used (Fig. 13). Dichroic, or interference filters, unlike absorption filters, do not absorb the unwanted spectral energy. Instead they either transmit or reflect the radiant energy of interest. With appropriately designed dichroic filters, it is possible to isolate a desired spectral region with a minimum of loss and with considerable accuracy.

The next issue to be addressed was the beamsplitter itself, with particular reference to the fact that, by their nature, beamsplitters pass only about half of the light that strikes them. In conventional front projection, it is taken for granted that it will be necessary to light the foreground scene one whole stop or more hotter than it would otherwise be. This situation can be alleviated somewhat, if the lamphouse power is available, by using off-ratio beamsplitters (Table 1). As we can see from this table, a beamsplitter comprising nothing but a sheet of glass, with one side anti-reflection coated, will reduce exposure from the foreground scene by only $2/10$ of a stop while requiring only 3 stops more projected light than a 50/50 beamsplitter. This is the result, obviously, of the fact that while the reflection is reduced on the beamsplitter, the transmission is increased.

However, we also have another avenue to pursue. When front-projecting blue light, it is necessary to beamsplit only the blue light, allowing the rest of the spectrum to pass unhindered through the glass. What is described here is a narrowband 50/50 interference filter effective for the matting spectral line in use, that also has the serendipitous side effect of reducing by 50% the projected blue light falling on the foreground subject (Fig. 14).

Of great interest to the creators of Blue-Max is the potential to perform sodium vapor compositing via front projection. The sodium vapor process developed by Petro Vlahos is demonstrably superb, hampered only by the complexity of the requisite camera and the problems of a diffuse background screen. The former is irremediable, but the latter is something we can change.

So far, we have defined a variety of beamsplitters comprising various ratios and operating at various wavelengths. Having resolved that issue, we now turn our attention to the fact that, unlike conventional front projection of plates, front-projected blue (for simplicity's sake we will continue to refer to bluescreen regardless of the actual color used) permits the camera to move about a great deal. This cannot be done while projecting a motion-picture plate, for the obvious reason that the image on the screen will move about also, keystoning and upsetting the stomachs of the audience. We are talking here of movements beyond merely nodal point moves for the

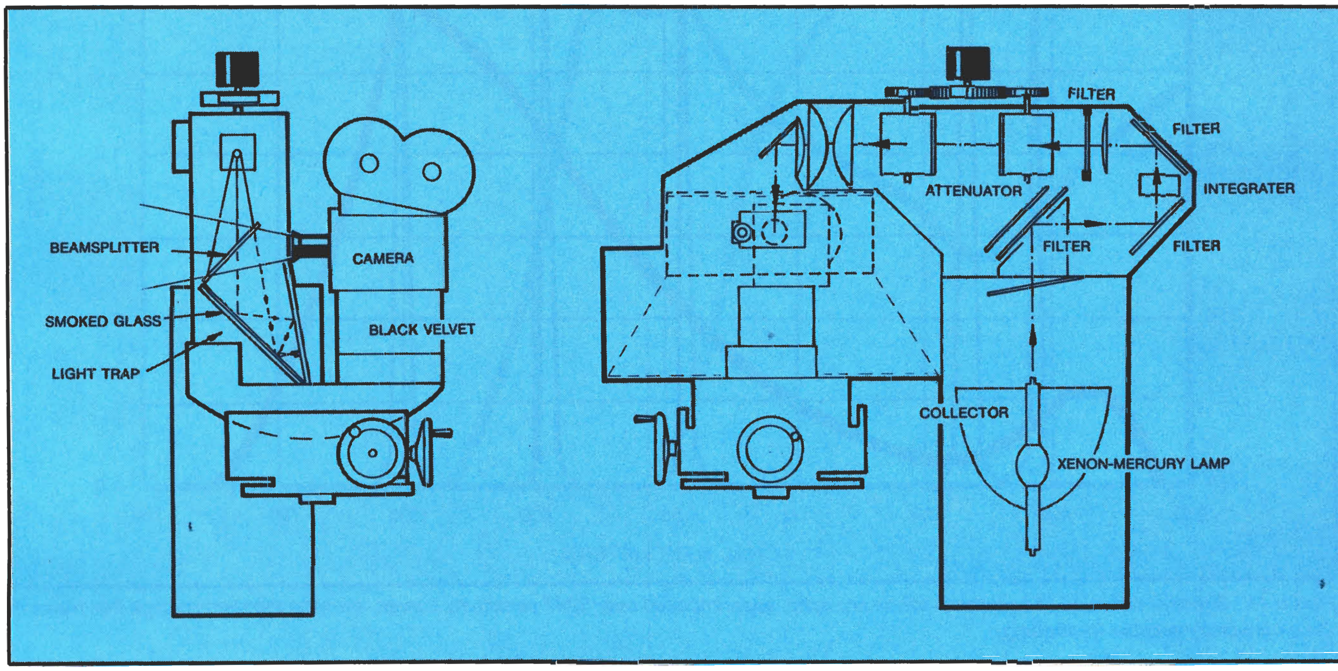

Figure 12. Patent illustration 2, the Blue-Max. Two views indicating how the light beam is controlled, filtered, and delivered coincident with the camera's view.

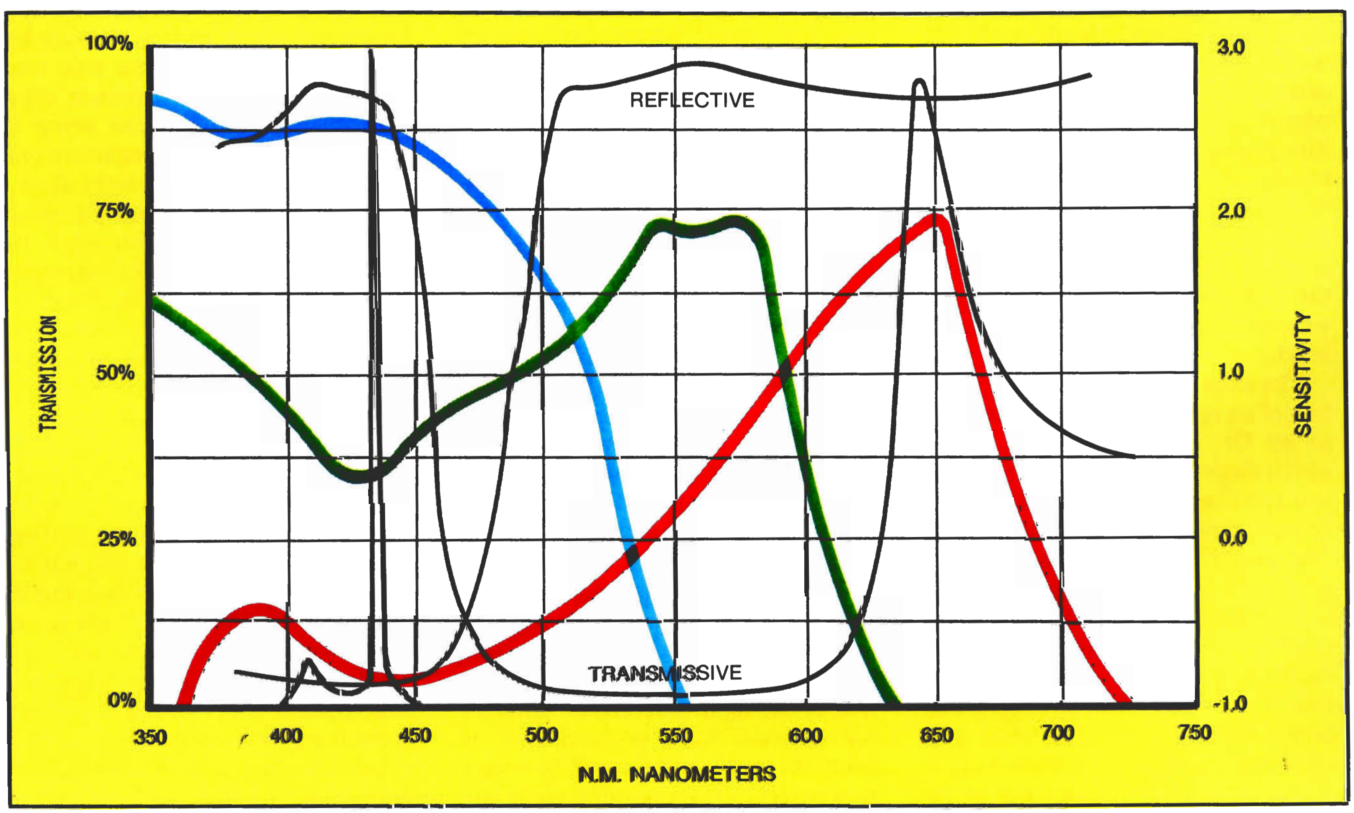

Figure 13. Transmission curve for filters. Superimposed over the 5247 sensitivity curves are the reflection/transmission curves for the Blue-Max dichroic filters. Such filters do not absorb the unwanted spectral energy. Instead, they transmit or reflect the radiant energy of interest with great efficiency.

Table 1 — Reflection/Transmission Values for Various Beamsplitter Ratios

Nominal Ratio R/T	Actual Ratio R/T	% Projected Light Passed to Camera	% Foreground Light Passed to Camera
50/50	48/48	23.04	48
45/55	43/53	22.79	53
40/60	38/58	22.04	58
35/65	33/63[b]	20.79[f]	63
30/70	28/68	19.04	68
25/75	23/73[c]	16.79[g]	73
20/80	18/78	14.04	78
15/85	13/83[d]	10.79	83
10/90	8/88	7.04	88
5/95[a]	3/93[e]	2.79	93

[a] Plain glass, one side AR-coated.
[b] One-quarter stop reduction.
[c] Half-stop reduction.
[d] One-stop reduction.
[e] Three-stop reduction.
[f] One-quarter stop reduction.
[g] One-half stop increase.

The expense of foreground lighting in front projection can be reduced, where lamphouse power is available, by the use of off-ratio beamsplitters. At a ratio of 30/70, for example, a loss of 4% of projected light yields a saving of 20% of foreground lighting.

camera, which are permitted for conventional front projection. With bluescreen projection, we can make gross moves with the camera and projector.

While it is necessary to keep the foreground action contained within the bluescreen, it is not necessary to fill the frame with blue, as a garbage matte can be employed to complete the frame. The ability to garbage matte also permits the inclusion in the frame of other apparatus necessary to filming; for example, rigging for flying objects. Should it be necessary for foreground action to occur in front of such rigging, then Scotchlite flags can be employed to "clean up" the acting area. (These flags, being closer to the camera than the main screen, produce a higher gain than the screen, and this is compensated for by the addition of a light scrim of nylon net applied to the surface of the flag.) Such multi-planing can be designed so as to interrupt the foreground subject and thus accomplish the same effects as are achieved via the techniques developed by Schuftan, Jenkins, and Eppolito in multi-planar photography and front projection.* By simply projecting a clip out to a middle or foreground layer of Scotchlite and trimming the screen to the desired contour, one can place the actor in front of or behind the plate at will. Moreover, unlike the Jenkins method, this can be performed at any number of planes from the camera.

With front projection, one should not get more than 30° incident to the screen to avoid falloff, and when trucking towards or from the screen, it is necessary to adjust the output of the projector to maintain the exposure value at the screen. This is done

*Details of these techniques are given in a second paper by the same author presented at the 126th SMPTE Technical Conference (paper No. 126-90) entitled "Front Projection — Tessellating the Screen." This article will appear in a forthcoming issue of the *Journal*.

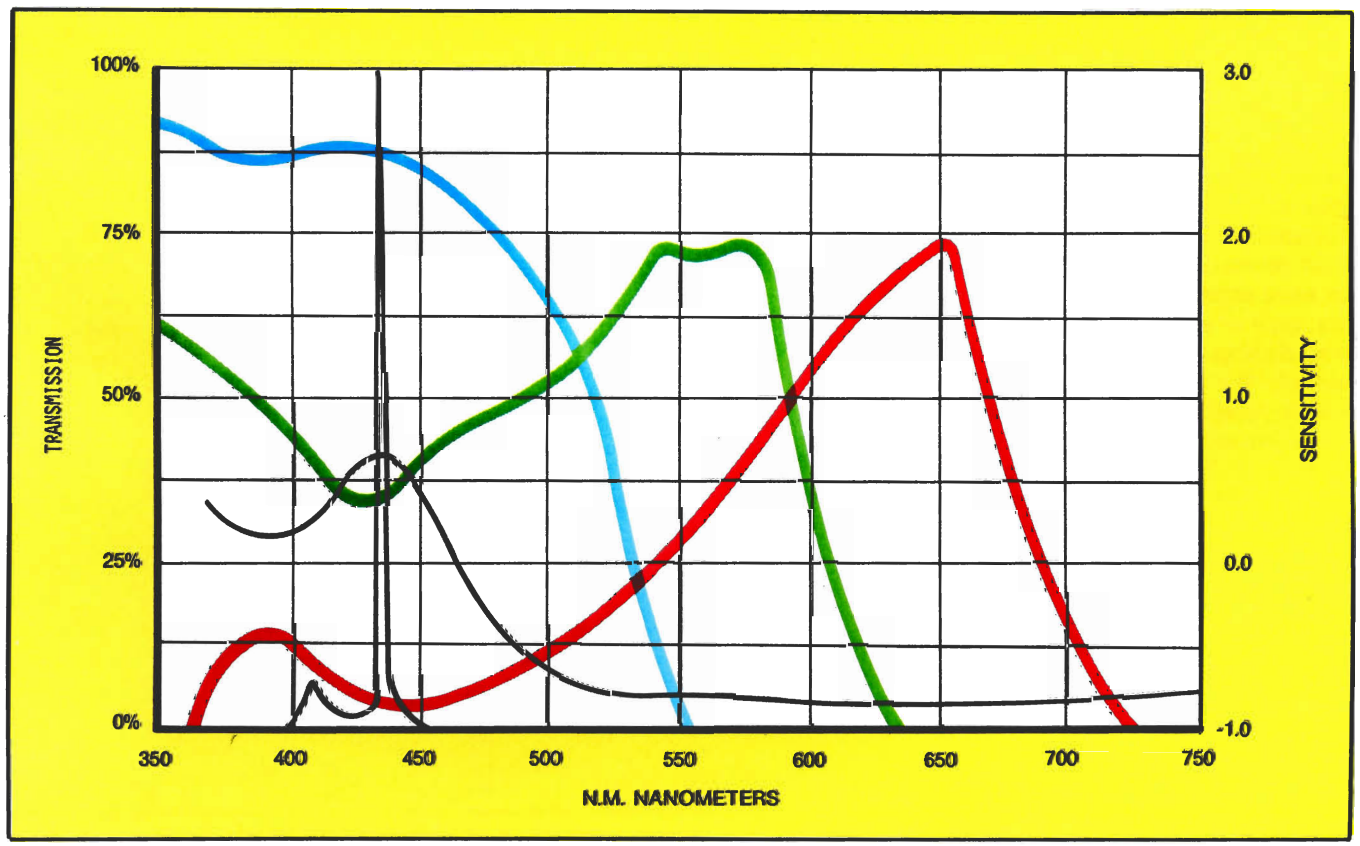

Figure 14. Curve for narrowband beamsplitter. Shown here in conjunction with the Blue-Max emission trace is the narrowband beamsplitter effective only for the matting line of 436 nm.

with attenuators governed by a servomechanism in the projector.

The attenuation is accomplished by taking advantage of yet another unique attribute of dichroic coatings. Such coatings, which are comprised of various elements deposited as a vapor to a finite thickness, will alter their characteristics as the angle of the incident light beam changes. The tendency is for a cut-off filter to shift to the left in the spectrum as the angle is increased, hence the relative thickness of the coating, so that if a zero degree blue cut-off filter is introduced into a white light beam it will yield an essentially blue light at zero degrees. But, if the same filter is then tilted so as to increase the angle of incidence, the result will be a shift further towards the blue end of the spectrum, progressing to violet and ultraviolet. However, if the light consists, as it does in our case, of one narrow spike, then the effect produced by this maneuver is simply to reduce the quantity of transmitted light. In actual practice, since there is a cone angle and the light is not perfectly collimated, it is necessary to have two such filters which are tilted at opposing angles so as to equalize the attenuation effect and make it uniform across the projected field.

The attenuator thus having provided the ability to move the camera/projector apparatus about, it became necessary to create a new solution to the problem of "spent" light; that is, the light that has passed through the beamsplitter and is now useless. Various methods have been employed for accomplishing this in conventional front projection, but most have relied on some object remote from the camera, such as a black flat or cone. This is all right as long as the camera is not moved. We needed a solution that would permit the camera to move, and so we settled on the design shown in Fig. 1. The spent light passing through the beamsplitter strikes a piece of smoked glass at about 45°. The light that has not been absorbed by the glass is reflected to a black velvet which will absorb most of it, and what survives that will be reflected back to the glass, and so forth. In short, virtually nothing survives to return to the camera.

Close-ups

In both front projection and transmission bluescreen compositing, extreme close-ups have presented various problems. Obviously, if a subject approaches very close to the camera/projector apparatus, the projected light will record on the subject in spite of the vast difference in gain between the subject and the Scotchlite screen. Furthermore, certain rules have long been applied in front projection technique regarding the spatial relationships between the camera, the subject, and the screen.[6,7,8] These rules are directed at preventing fringing of the subject that results from having a soft shadow rendered at the screen, which is the consequence of having a relatively short subject-to-camera distance versus a relatively long subject-to-screen distance. Additional problems are introduced if the subject includes highly reflective surfaces, i.e., silver lamé clothing or space helmets; and all these problems are exacerbated if the subject is to be backlit. In close-up photography via transmission blue, blue spill is the principal villain encountered.

In Blue-Max compositing, these difficulties can be resolved by the adoption of Reverse Front Projection™ (Fig. 15.) This process involves a somewhat radical rearrangement of the basic elements of front projection, which is best understood if the Scotchlite screen material is thought of, in optical terms, as a set of condensers. If the camera is removed from the projector and the beamsplitter is replaced with a 100% front surface mirror, we have now a simple projector. This projector throws a beam to a Scotchlite screen. Situated at right angles to this screen is another of black velvet; disposed between these screens at 45° is a beamsplitter, which may be made up of plain glass. The effect of this arrangement is to take the diverging projected cone of light from the projector and deliver it as a converging cone of light, having turned it 90°. We then position the camera so that the nodal point of its lens coincides with the focal point at which the projected cone of light converges.

What we have done is to acquire all the advantages of front-projected blue, in terms of the purity of color and the absence of blue spill, without having had to project the blue onto the foreground subject. We have also eliminated fringing resulting from poor alignment of projector and camera nodal points, as there is no shadow at all cast upon the screen by the foreground subject. In addition, we have eliminated the haloing resulting from the backscattered light that occurs when the subject is backlit. This occurs because of the "diode effect" produced by this arrangement of Re-

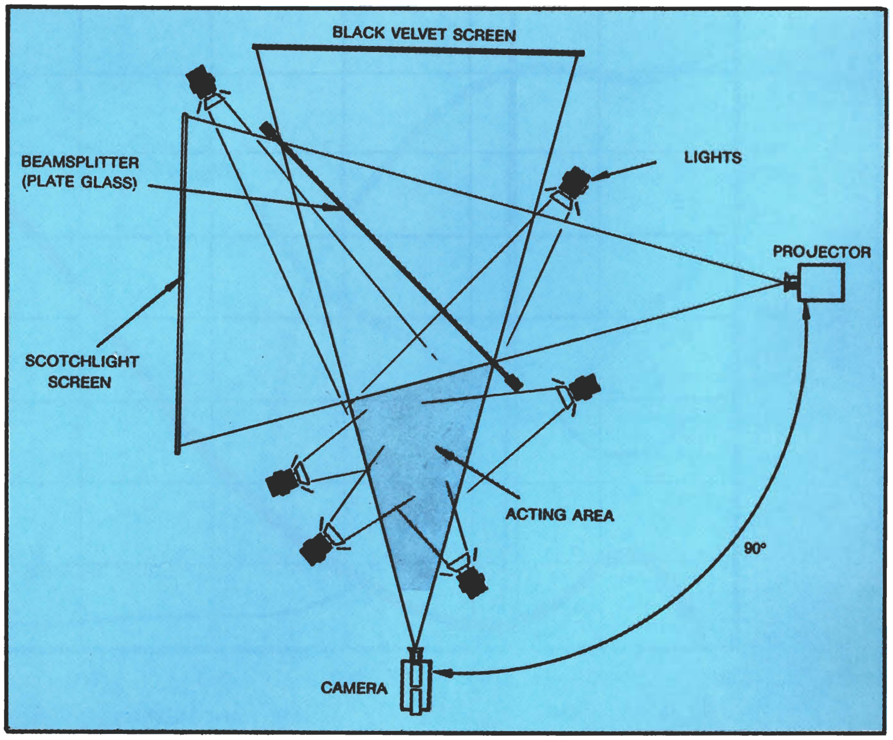

Figure 15. Reverse Front Projection. A solution to front projection close-up photography, whether plate or bluescreen. This arrangement eliminates the front-projected blue contamination, as well as fringing and halo problems.

verse Front Projection. In normal front projection practice, a ray of light striking the back surface of a foreground subject will be reflected back to the Scotchlite screen and then return again along the same axis, plus or minus some 2%. Some of the light will restrike the subject, while some of the light will pass the subject and make its way to the camera, producing the objectionable halo.

In contrast, the "diode effect beamsplitter" handles that situation in the following manner: the ray of light striking the back of the foreground subject is reflected back towards the beamsplitter where approximately 8% is redirected towards the Scotchlite screen. The remaining 92% is passed through the beamsplitter to the black velvet screen, where it is absorbed and dies. The 8% that was reflected to the Scotchlite screen returns from there to the beamsplitter, where again 92% is passed on through, while 8% is reflected towards the foreground subject. Thus, only 8% of 8%, or .64%, is made available to the camera to record as halo. (To be sure, only 8% of our projected blue light is being made available to the camera also, but that is not a serious problem to the Blue-Max because of its massive output.) It should also be borne in mind that in conventional front projection, only a theoretical 25% of the projected light survives the journey to the camera, so we are, in fact, sacrificing approximately 1½ stops.

Some degree of camera flexibility is also sacrificed in using Reverse Front Projection, as the camera cannot move from the nodal point defined by the projector. Of course, for gross moves, provision can be made to move both the camera and projector in synchrony, but in most cases it would seem that it would be easier to move the subject in relation to the camera. Zooming is certainly possible, as are all nodal point moves for the camera, and these should cover most requirements for close-ups. Apogee has applied for patent protection on Reverse Front Projection as well as for the Blue-Max, and both are available to the industry under license.

No catalog of the advantages of compositing via bluescreen versus front projection would be complete without reference to the issue of generations. It is quite well known that successive duplications of a photographic image bring about a rapid degradation of that image. Similarly, most of us know that the reproduction of a color image from color separations offers the best prospects for faithful reproduction. Eastman Kodak has gone to great lengths to design color masked interpositive stock to increase the fidelity of regenerated color images. It stands to reason that an optimum result cannot be expected from the rephotographing of a projected image that is of necessity unmasked. There is currently a move towards a color print stock designed specifically for this purpose, but even with such a stock in hand, the problem remains of mismatched generations: that is, that the foreground and the background are of different generations from each other.

Figure 16. John Dykstra, director of special effects, setting up a Blue-Max shot for Alice in Wonderland.

In bluescreen compositing, the process is such that the foreground will be a second-generation image made from separations, and thus of a high degree of fidelity. The background will either be also from separations or from a masked interpositive, in any case providing for superior reproduction, and of the same generation one to the other. There is quite simply more control over the composite image via bluescreen than via front projection in-camera compositing.

Conclusion

In summary, what we have produced is an efficient, sophisticated, dedicated luminous flux projector for color difference compositing (Fig. 16). Blue-Max has not had an idle moment, having worked on three major feature films: *Dune, 2010,* and *Life Force*. Ongoing development of the Blue-Max is aimed at increasing its efficiency as well as reducing still further both the size and weight of the unit.

References

1. W. Beyer, "Traveling-Matte Photography and the Blue-Screen System — A Tutorial Paper," *J. SMPTE*, vol. 74, No. 3, March 1965, pp. 217-239.
2. P. Vlahos, "Travelling Matte Composite Photography," *A.S.C. Manual*, 5th and 6th eds.
3. J. Erland, "Reverse or Travelling Matte Process," *SMPTE J.*, vol. 92, No. 3, March 1983, pp. 268-275.
4. L. B. Abbott, "Special Effects: Wire, Tape and Rubber Band Style," *A.S.C. Manual*, p. 177.
5. *Optical Engineering*, vol. 2, pp. 222-226 and vol. 5, pp. 338-339.
6. P. Vlahos, Motion Picture Research Council Report R-053.
7. P. Vlahos, "Front Projection," *A.S.C. Manual*, 5th ed.
8. P. Vlahos, "The Front-Projection Process of Composite Photography," *J. SMPTE*, vol. 80, No. 9, September 1971, pp. 685-691.