INTERNATIONAL PROJECTIONIST

VOLUME XXVI OCTOBER 1951 NUMBER 10

Is Lenticulated Color-Film Practical?

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THE proclivity of Hollywood brass to clamp restrictions on all technological progress in the motion picture field is paralleled only by the eagerness with which certain producers pursue any *fata morgana* flaunting the Lorelei promise of by-passing a few pennies of production.

The so-called lenticulated-film process of photographing and projecting movies in natural color is by no means of recent vintage. Eastman Kodak abandoned a variant of the process (known as "Kodacolor") in 1932 in favor of the totally different and immeasurably superior Kodachrome process for 16-mm filming.

Said Thomas E. Hargrave, president of Kodak:

"At least two American motion picture producers and a large European manufacturer have done a great deal of work in this [lenticular film] field over a considerable period of time. So far as we are aware, none of these efforts has yet met with commercial success."*

Industry Interest Revived

Readers of IP will recall that the lenticulated color-film process was described briefly and summarily dismissed on page 34, July 1951 issue of IP. But the recent settlement of the Keller-Dorian patent suit, in which Eastman and Technicolor were co-defendants, has refocused industry attention on the dejected color cadaver which certain production bigwigs are attempting to vivify—in the fond hope that the cost of color footage can be cut by a penny or fractional part thereof.

Should success attend this attempted vivification, however, Mr. Exhibitor would soon find himself hanging shirtless from a very high limb; while Mr. Producer pockets (he hopes) a trickle of pennies from inexpensive color-film processing. In our humble opinion, the exhibition industry would be best served by *improving* the movies, not by undermining the high degree of quality they already possess.

The theory of the lenticulated-film color process is indeed intriguing (from an academic point of view), and it works just fine and dandy on paper—providing that some mighty important factors are left out of account. So let's go over the whole thing once again with utter frankness, meanwhile offering a fervent prayer that lenticulated film will never be substituted for Technicolor.

Human Color Vision

As far as human color vision is concerned, the entire visible spectrum consists of only three overlapping bands of colors. Three primary colors, no more, no less. These are *Vermilion* (deep orange-red); *Emeraude* (slightly yellowish green); and *Indigo* (deep violet-blue). All other colors are merely combinations, in various proportions, of two or all three of these primaries.

The visual sensation called "white" is nothing more than the result of combining the three primaries in equivalent proportions. This may be demonstrated by a simple experiment.

If we cut strips from vermilion, emeraude, and indigo gelatine (called separation filters by photographers) and place one strip of each color over a camera lens so that no light can get through the lens without passing through the three filters placed side by side, it will be found that the performance of the lens is not seriously impaired as to image formation or its ability to image colored objects. Only the "speed" of the lens will have been impaired, since comparatively little light is transmitted by the filters.

Color-Filter Action

A distant white building focused upon a white card by the "color-filtered" lens furnishes ample proof that equivalent amounts of V, E, and I light form a white image when they recombine. A red object will give a red image, a yellow object a yellow image, *etc.*

All that happens is that the filters covering the lens split up the light into its V, E, and I components. The image-forming power of the lens recombines these three components into the original colored scene which is focused upon the card.

Another experiment shows what happens when one primary color is missing. Cover up the emeraude filter-strip, and the image of the white building will be colored *magenta*, which is the result of combining equivalent proportions of vermilion and indigo alone. With the vermilion strip covered up, the image will be *cyan*, which is emeraude plus indigo. And with the indigo strip masked off, the image of the white building will be *yellow*—vermilion plus emeraude.

Anatomy of Lenticular Film

Now, an ordinary black-and-white motion picture can be filmed through this "filtered" lens, but the lens diaphragm

* IP for December 1948, p. 35.

will have to be opened wide in order to admit sufficient light.

By using a *lenticulated* black-and-white film in the movie camera, however, a *natural-color* motion picture can be photographed through the lens which has one-third of its area covered by a vermilion filter, another third by an emeraude filter, and the last third by an indigo filter.

Lenticulated film is exactly the same photographically as ordinary black-and-white camera film. The only difference is the presence, on the lenticular film, of innumerable tiny semi-cylindrical ridges side by side. These are impressed in the film base on the side opposite the emulsion by means of embossing rollers. In the old 16-mm Kodacolor process, these corduroy-like lenticulations ran lengthwise on the film; and each had a width of 0.045-mm—about 559 ridges to the inch.

Each "ridge" on the lenticulated film functions as a tiny cylindrical lens.

Light Action Thru Lenticulations

To use the lenticular film, it must be threaded up in the camera with the lenticulated side of the film facing the lens. (In ordinary photography, the emulsion-side of the film faces the lens.) All of the light focused on the emulsion by the lens must accordingly pass through the tiny cylindrical lenses. The second precaution is to have the three colored gelatine strips on the lens parallel to the embossed lenticulations. In the case of Kodacolor, the filter strips were positioned vertically.

Each embossed lenticulation has a focal length of only 0.0045 mm. The lens-action of the tiny ridges causes the image to be split up into three "color bands" in the emulsion of the film, each band corresponding to one, and only one, of the three filter strips on the camera lens.

One color band contains a vermilion record of a very thin strip of the scene photographed; the second an emeraude record; and the third an indigo record. There is thus a partial image in each of the three primaries under each tiny lenticulation. The sum total of all the partial images on the film is the complete color record of the scene photographed.

The Projection Process

After reversal-development, the lenticular film looks like an ordinary black-and-white positive print. The lenticulations are too small and close together to be visible; and no actual color is present in the film.

To project the film in natural color it is only necessary to place *an exact replica* of the 3-strip camera-lens color filter over the projector lens. As in the camera, the gelatine filter strips must be parallel to the lenticulations of the film.

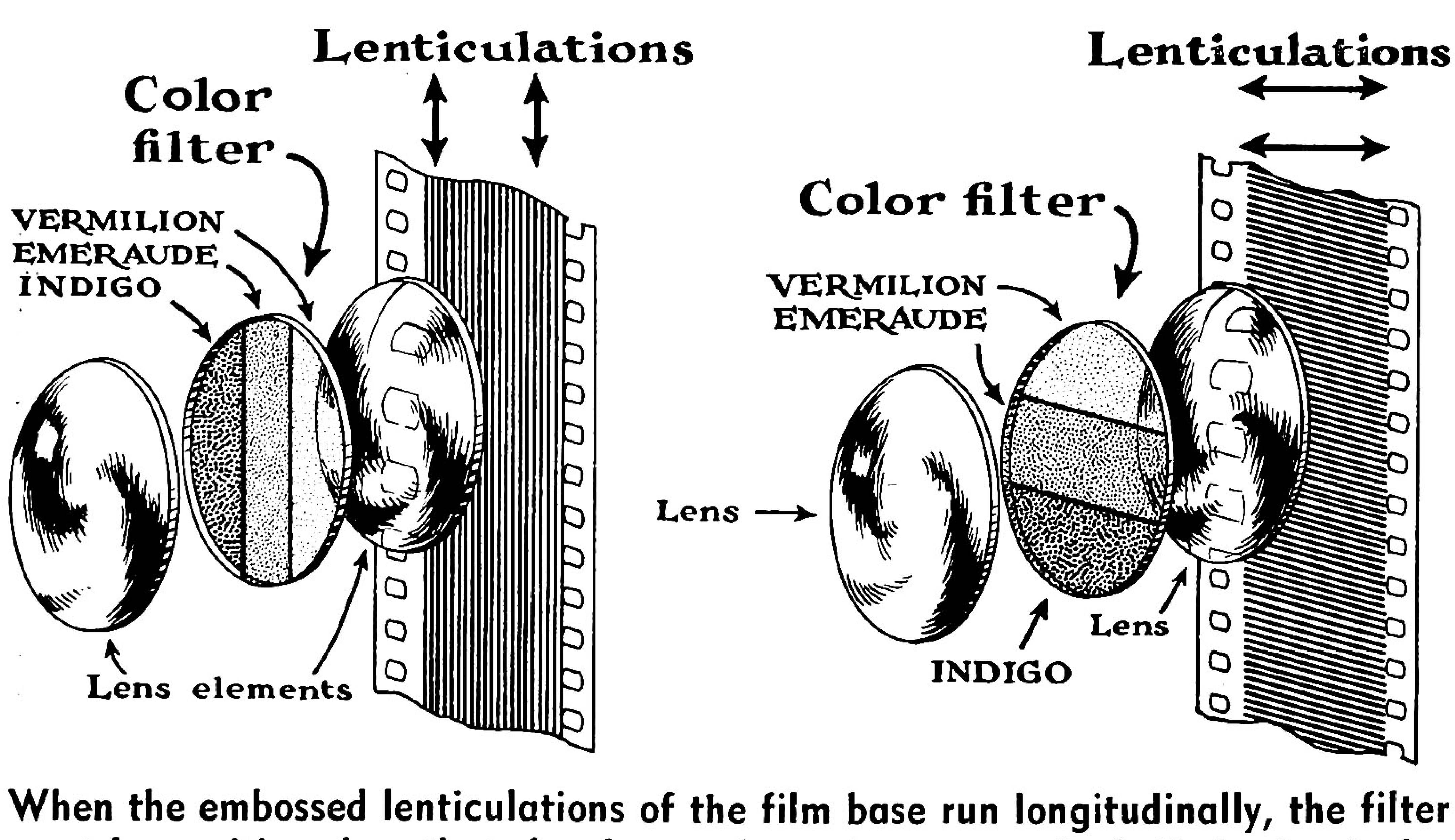
When the film is projected, light from all the vermilion "color bands" is refracted by the lenticulations to fall upon the vermilion filter-strip on the lens; and light from the emeraude and indigo bands is likewise directed to the corresponding strips of colored gelatine.

By the additive combination of varying intensities of V, E, and I light rays, all the colors originally photographed are reproduced on the screen.

Light Loss Thru Filters

The enormous loss of light occasioned by the filter strips is one of the most serious defects of the Keller-Dorian process, as it is also of *all* additive color-projection processes without a single exception. When Kodacolor 16-mm film was in use for home service, an aluminum-surfaced screen was necessary in order to obtain sufficient picture brightness. And even with a "specular" screen of this type, a picture no larger than 16½ by 22 inches could be obtained with a projector having a 200- or 300-watt incandescent lamp. Other serious deficiencies of this color process will be examined in detail.

FIGURE 1. TWO SYSTEMS OF THE LENTICULAR-FILM COLOR PROCESS.



When the embossed lenticulations of the film base run longitudinally, the filter must be positioned so that the three color-strips are vertical. If the lenticulations are lateral, the filter color-strips must likewise be horizontal. Note that the color filter is placed between the lens elements, whether in camera or projector.

Tests have been conducted quietly with 35-mm film stock embossed with lenticulations 0.03 mm wide—approximately 850 per inch on unshrunken stock. This is about as small as the lenticulations can be without introducing a disastrous loss of color values due to overlapping of two or more "color bands" (each slightly less than 0.01 mm in width) by clumps of reduced silver in the film emulsion.

Emulsion Silver Content

The so-called silver grains in photographic emulsion are really clumps made up of several grains stuck together in a solid mass. When exposed film is developed, an entire clump of silver bromide crystals is either reduced completely to metallic silver or not reduced at all. There is no "half-way" reduction. In the highlights of a photographic image, the clumps of reduced silver are comparatively far apart; in the shadows they are near together, hence much more numerous. The actual size of the individual clumps of reduced silver is influenced by the type of photographic emulsion and the nature of the developing chemicals used.

This overlapping, or "running together," of the color bands can be avoided by altering the form of the lenticulations and the thickness of the film base in order to separate the color bands by extremely thin blank bands. It is estimated that this measure, while improving the purity of the reproduced colors, would result in an additional 25% loss of light.

Screen Image Character

It might be thought that the lenticulations would show up on a large theatre screen as rather wide lines, because of the tremendous magnification of the picture in projection. Such is not the case. When the lenticulations are 0.03 mm in width, they are magnified to a width of 9 mm—almost ⅜-inch—on a 15 x 20 ft. screen. The effect is a slight fuzziness of focus, but the individual bands are invisible to the audience.

The inevitable loss of sharp focus is much more serious, however, when lenticulated *prints*, not reversal-processed *negatives*, are projected. Lenticulated prints cannot by any manner or means be made in a standard contact printer. They must be made by optical printing through lenses having the three color strips over them. Loss of definition is doubled in the print, hence the sharpest line possible on a 20-foot screen would be a fuzzy band about ¾-inch wide. This figure assumes the use of a perfect propection lens, "on-the-nose" focusing by the projectionist, and it does not include the ever-present factor of normal emulsion graininess.

In short, lenticulated color is in a fog, as far as focus is concerned.

Filter Quality, Positioning

In order to obtain the best possible color from lenticular film, the color filters in the projection lens must be positioned with great accuracy in regard to azimuth and distance from lens elements. (Of these two factors, a slight error in rotational, or azimuthal, alignment is the less serious, since color-rendition efficiency in this single respect varies directly as the *sine* of the angle subtended by the direction of the film-lenticulations and the direction of the lens filter-strips.)

Moreover, the spectral characteristics of the three filter strips must be well-nigh perfect if any semblance to good color is to be reproduced on the screen. The vermilion filter must transmit only the vermilion region of the spectrum *without a trace of wavelengths lying in the emeraude and indigo regions.* The other two filters must have equally good spectral characteristics.

Filter Dye Factor

But even though such a vermilion (or emeraude or indigo) filter can be prepared, it cannot transmit *all* of the V or E or I) light, *but only a fraction of it.* This is because dyes which are perfect from the standpoint of spectral characteristics are far from efficient from the standpoint of light transmission. This unfortunate fact cannot be corrected until chemists discover new and better dyes—absolutely *perfect* dyes, in fact.

The Keller-Dorian process demands perfect filters—but perfect filters have not yet been made.

Summary of Deficiencies

If it be objected that even the (subtractive-process) dyes used for printing Technicolor films are not absolutely perfect, it should be borne in mind that a wide latitude of printing densities is available to Technicolor, making the process 100% efficient as to purity of color, and very nearly 100% efficient in regard to light transmission relative to standards set by black-and-white prints. Technicolor is a remarkably faithful and flexible process. The lenticulated-film process is not.

Why is the lenticulated-film process inherently inefficient in regard to color rendition? Because of:

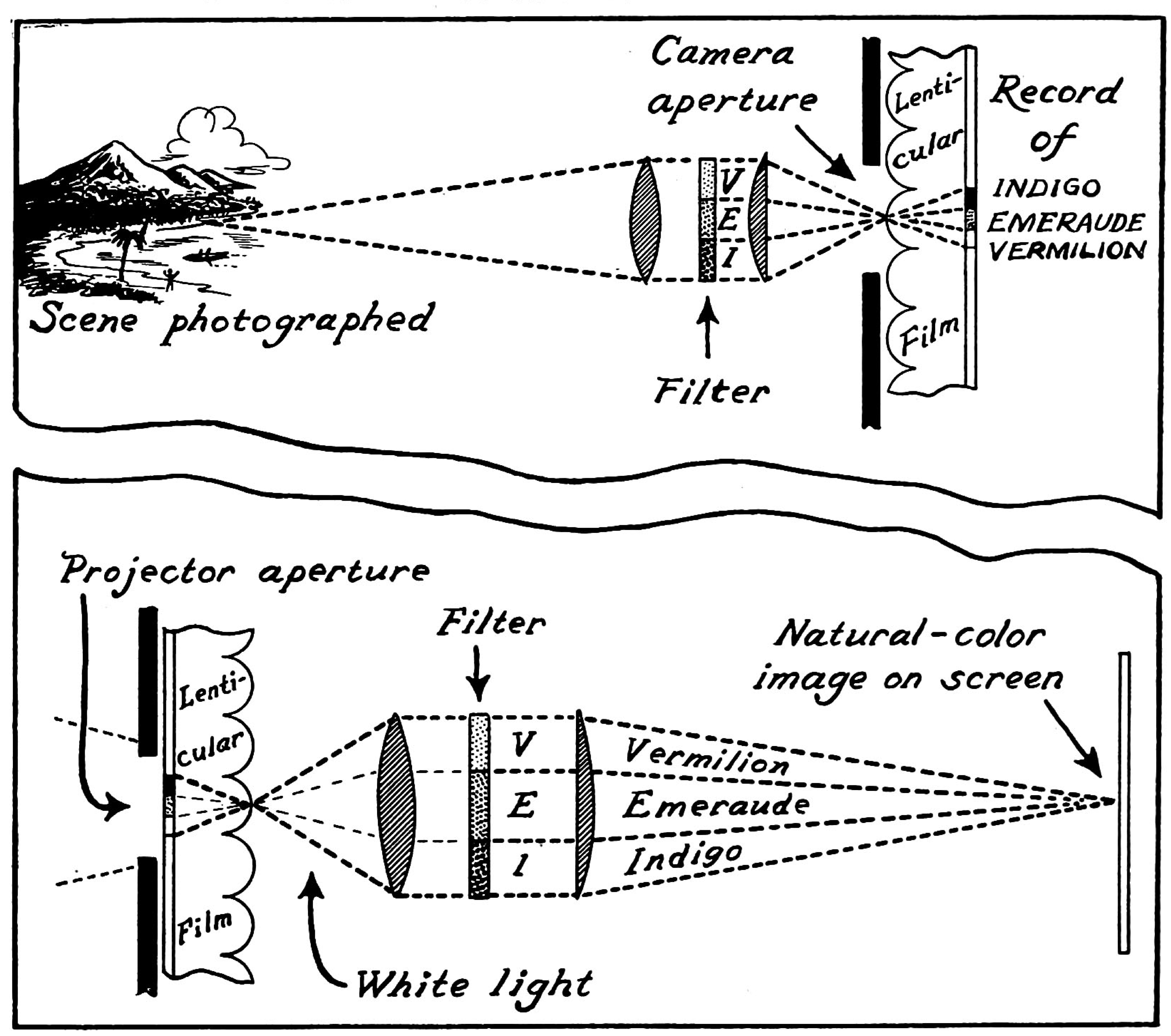
1. Unavoidable optical-positioning errors in camera and projector color filters. These arise from differences in the diameters, the focal lengths, and the design of camera and projector lenses.
2. Unavoidable variations in film-base thickness, due to shrinkage and other causes, deforming the lenticulations and resulting in spill-over of light onto the wrong color-filter strips, and even onto the walls of the lens-tube, "washing out" the color and wasting light.
3. Dirt and oil between the embossed ridges, cutting down light and destroying the extremely critical refraction and transmission balance of the lenticulations. Scratches in the film and otherwise worn and damaged lenticulations would cause spurious colors, "fluttery" colors, and low saturation of the reproduced hues.
4. Loss of color intensity in the printing process.
5. The impossibility of using spectrally perfect color filters in the projection lens (to minimize 1, 2, and 4, above) because of the very low transmission efficiency of such filters.
6. The dissimilar shapes of the three filters—two of them being segments of circles, and the middle filter a narrow oblong—and the anaxial optical positions of the two segment-shaped filters results in (*a*) objectionable color fringes when the projection lens is but very slightly out of focus and (*b*) *extreme color distortion*, altering the chromaticity of hues in a very unpleasant manner, whenever "vignetting" is produced either by the lens, the lamp optics, or both—which is usually the case in present-day equipment.
7. The impossibility of avoiding extremely objectionable color fringes on either the horizontal or vertical edges of out-of-focus objects in the picture. This spurious color-fringing is quantitatively much more serious than the chromatic aberration of simple uncorrected lenses, and it restricts lenticular color photography to the use of short-focus camera lenses to avoid out-of-focus backgrounds in closeups and out-of-focus foreground objects in long shots.

Cinematographers have always had available a wide range of lens focal-lengths for both standard black-and-white and color filming. The advantages of such a large assortment are obvious.

For example, the distance of the camera from a scene is sometimes fixed by the physical limitations of the set; yet perfect picture "composition" can be

(*Continued on page* 29)

FIGURE 2. HOW LENTICULATED COLOR FILMS ARE PHOTOGRAPHED AND PROJECTED.



No actual color, but only color values in black and white reside in the film. Color is supplied in projection by a 3-strip filter through which light is directed by the tiny film lenticulations, which act as cylindrical lenses.

LENTICULAR COLOR FILM

(*Continued from page 9*)

achieved by use of a lens of the correct E.F.

Also, the common practice of simultaneously shooting long shots, medium shots, and closeups by a battery of cameras operating in a restricted area is made possible only by the use of camera lenses having different focal lengths. This technique minimizes the number of necessary retakes, thus saving hundreds of thousands of dollars a year.

Process Projection Impractical

Then, too, out-of-focus backgrounds and foreground objects are frequently desirable from an artistic standpoint. Lenticular color therefore denies the cinematographer much of the flexibility of his art.

8. Great economy is also effected by the use of background projection in studio sets. Lenticular color, because of poor illumination efficiency, slightly fuzzy image definition, and unsatisfactory color-distribution characteristics when projected through translucent background screens, would render the valuable tool of process projection impractical. All of these are matters of tremendous importance, not a single one of which may safely be overlooked.

Filter Transmission Data

Tremendous loss of screen illumination is a fatal defect of all additive color-projection processes.

Three primary-hued filter strips must be placed side by side over the projection lens in the proper optical plane, as previously mentioned. (This plane would probably intersect the lens barrel somewhere near the middle of its length, the filters thus being inside of the lens barrel.)

Each of these filters, if possessing

perfect transmission characteristics (which existing filters most assuredly do not), would transmit 1/3 of the light falling upon it, as reckoned on the basis *not* of actual "luminosity" but of color balance. Thus 2/3 of the total projection light is absorbed by the filters and converted into heat, reducing screen illumination to 33 1/3% of the illumination obtained without color filters. But as things actually are, the most efficient existing filters have approximately the following transmission efficiencies:

Vermilion	80%
Emeraude	40
Indigo	60

Because each filter represents one-third, or 33 1/3%, of the total light (total color balance), use of these filters would result in 20% of standard screen illumination. (The V filter transmits 80 x 33 1/3%, or 26.66%, of 1/3 of the total light; the E filter 13.33%, and the I filter 20%, giving an over-all average of 20%.)

Filter Balance Requisite

However, this filter combination *will not work!*

It is mandatory that the three filters be *balanced* so that *equivalent proportions* of V, E and I light reach the screen (to give pure white light) when the projector is run without film. The transmission efficiency of *each* filter must be the *same* as the transmission efficiency of the *least* efficient filter! (In actual practice the emeraude filter happens to be the least efficient.) So, instead of the figures given in the foregoing tabulation, we must use the following:

Vermilion	40%
Emeraude	40
Indigo	40

This reduction in the light transmissions of the V and I filters will enable more satisfactory color reproduction to be obtained, because better V and I dyes can be used, but the screen illumination will be only about 14% of that obtainable with Technicolor and other non-lenticulated standard prints!

Enormous Light Increase

The lenticulated color-film process, therefore, demands projection lamps about 7¾ times more powerful than present-day lamps.

Can projector arclamps nearly 8 times more powerful than those now in use be manufactured on a practical commercial basis? *Probably not.*

If such powerful lamps *could* be made, would exhibitors be willing to pay increased carbon and power costs merely to maintain levels of screen illumination which obtain *now* in theatres?

Is any present film capable of withstanding the terrific blast from lamps so powerful?

Would the theatre-going public accept a color process which is decidedly inferior to the least desirable color process in use today?

The answer to the three foregoing questions must be an emphatic "No".

This, then, is the sad, sad story of lenticulated color-film processes. The disadvantages of this process are obvious to everyone except a coterie of short-sighted producers who have the strange notion that color footage should cost not a penny more than black-and-white.

Existing Processes Superior

We already *have* natural color on our screens. Not enough of it, to be sure, but more and more of it all the time. Technicolor is regarded as the ideal color by all movie-goers. It is brilliant, clear, and faithful to the colors seeen by the camera's eye. Agfacolor, Ansco-Color, Super-Cinecolor, among others, are close runners-up for top honors.

These processes are available to all producers who wish to employ them. There are no color processes, not even in the blueprint stage, which are in any way the equals of processes we already have.