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THE ADVANTAGES OF PHOTO-CONDUCTIVE CAMERA TUBES FOR COLOUR TELECINE

INTRODUCTION

The purpose of colour telecine equipment is to reproduce on a colour monitor the best subjective reproduction of an original scene, through the medium of a photographic camera and various film materials and processes. The word 'best' in this connection is subject to a number of different interpretations and will depend both on the original scene and the context in which the film is to be used.

In the most straightforward case, where a studio scene has been especially lit for the purpose, the meaning is fairly clear. The various hues and their relative brightness would, ideally, be reproduced on the display tube. If, however, the film is to be used as an insert into a live broadcast, 'best' may well mean a final interpretation near to that given by the live camera from a similar scene, rather than a faithful reproduction of the original.

Possibly the most difficult case, that of newsreel film demands a 'best' on the part of the equipment which means being able to produce good pictures from a wide variety of film material, some of it of indifferent quality, rather than perfect reproduction from ideal film.

However, before considering the interpretation of the colour film image into television signal terms,

we should perhaps refresh our memories as to the nature of that image and look at some of the deficiencies of the dyes used in the film industry, together with the special problems these limitations impose when the film is used for telecine.

The image on a normal piece of positive colour film is made up of three dyes, yellow, magenta, and cyan. These are the colours that each of the dyes looks when present by itself and white light is passed through it.

COLOUR FILM IMAGES

Each of these dyes passes two of the primary colours and absorbs the third. That is the yellow dye transmits green and red and absorbs blue; magenta transmits blue and red and absorbs green; and cyan transmits blue and green and absorbs red. Each dye therefore can be considered as having a density, dependent on the concentration present, related to the primary colour of which it is the complementary.

If two dyes are present, say cyan and magenta, they will jointly stop red and green and the result will be blue. Similarly, if all dyes are present, because their density curves overlap sufficiently, the result will be black. It is here that the difference between additive and subtractive colour systems can be most clearly distinguished. In an additive system such as television the summation of the three primaries results in white.

Let us now consider the nature of the dyes a little more closely. Ideally, one might consider dyes as shown in figure 1, often called block dyes. Patently, if all these dyes were present when illuminated by white light, the film would appear substantially black, and the absence of any one of the dyes, or for that matter two, would give the results we have just considered.

Equally obvious is the fact that in this world of compromises no such dyes exist. Figure 2 shows, dotted, a typical set of film dyes, density plotted
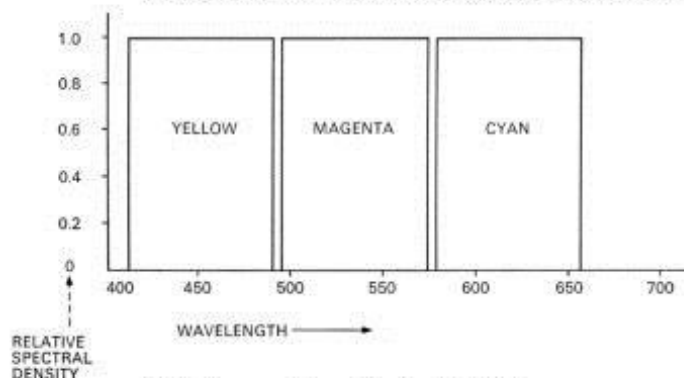

Fig.1 Representation of idealized block dyes.

against wavelength, and it can be seen that at least the condition for a reasonable black when all dyes are present is maintained. This, however, is about as far as the likeness to the block dyes is maintained.

If the colouring channels of a telecine camera could measure to what densities the three dyes were present and could interpret this information into suitable electronic signals of the right gamma law a good interpretation of the film could be made.

In fact the result would depend to a large extent on the exact choice of width of the camera taking lobes and also the position of the lobes on the spectral scale; and we will now look more closely at the various aspects which affect these particular parameters.

COLOUR FILM DYES

One of the deficiencies of the dyes shown in figure 2 is the interference to the transmission of any primary colour by the other two dyes which are only intended to vary the transmission in their own particular colour. For instance, it can be seen that the density to green is modified over the whole green band, not only by the magenta dye, but by the presence or absence of both yellow and cyan dyes.

On direct projection, this 'crosstalk' as we can call it, gives rise to little error as far as the viewer is concerned. The film is projected with white light at high contrast and high brightness, and if we consider, say, a bright green object with high saturation in the original scene, it should be represented on film by the complete absence of the magenta dye and full deposition of the other two. The viewer will see the integrated effect over the whole spectrum where each part of the spectrum will be analysed in its own right. Further, with an effective contrast range of several hundred to one any slight change in the maximum density to blue and red will have negligible effect.

If however, we consider this film to be looked at by a television camera, whose taking lobes are fairly broad, shown in solid in figure 2, and if the peak levels of the colouring channels have been set up with clear film in the gate and the black levels have been set with 'black' (that is with all dyes present) in the gate, it can be seen that the colouring output of the green channel will be considerably reduced by the presence of the yellow and cyan dyes, while some output from the blue and red channels will be inevitable, due to the absence of the magenta dye.

On the final display tube, with its limited contrast range and brightness this will result in a severe degradation of the green image, which will appear desaturated and somewhat muddied in colour by the presence of the unwanted signals (it will be seen that certain colours will be produced in the final display in the red and blue area where virtually none would have occurred on direct projection).

Again taking green as an example, we can see from the density curves that if the green taking lobe were a narrow line at about the intersection of the unwanted yellow and cyan dyes and if this co-incided with the peak of the magenta dye, the ratio of wanted to unwanted information would be a
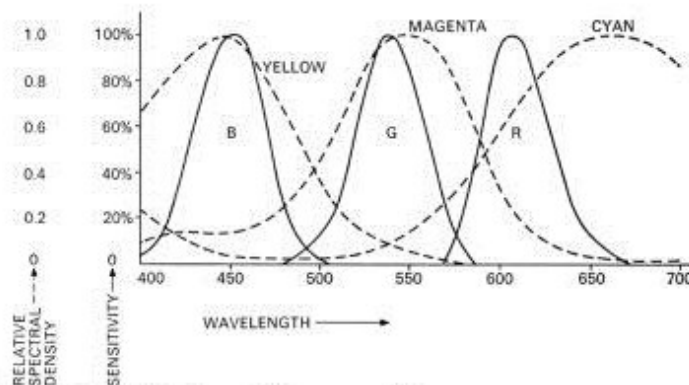

Fig.2 Typical film dyes and live camera taking responses.

maximum. As the breadth of the taking lobe is increased this ratio is reduced and the degree of crosstalk increases. Similar arguments can be applied to the other colours.

One other basic factor influences the positions of the taking lobes and that is gamma. As has been said, the maximum immunity to crosstalk occurs when the taking responses coincide with the peaks of the density curves, but the contrast and hence the gamma, vary as the lobes are moved from this position. This reduction in contrast is not particularly significant in itself, but the need for all three colour signals to track is of the utmost importance, thus the degree of offset for each colour must be the same in terms of peak density. Actually a reduced effective contrast might well help in the case of normal cinema prints and in any case will more nearly represent the gamma as seen by direct projection. This will be the integrated gamma over the whole density range for each colour and will necessarily be lower than that at the peaks.

One other limiting factor in the case of the standard Plumbicon* tube, is its poor sensitivity to red, but fortunately this just allows the red response to be pushed out far enough for the crosstalk from the magenta dye to be reasonably small, and the resulting offset matches well with the position of the green taking response when it coincides with the crossover point of the yellow and cyan dyes. This allows the blue to be chosen for good response to yellow, while maintaining reasonable immunity

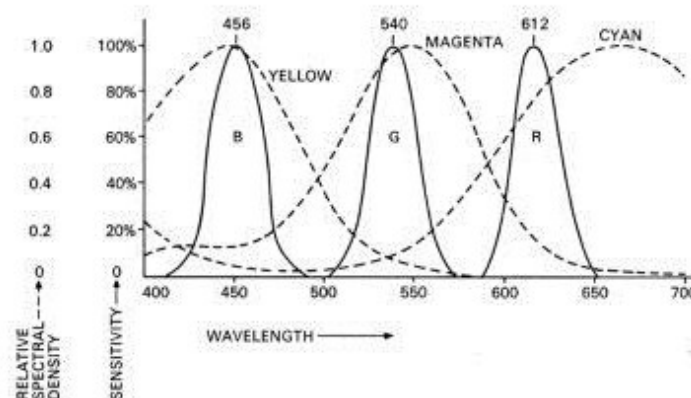*Registered trademark, Philips Gloeilampenfabrieken

Fig.3 Typical film dyes and telecine camera taking responses.

from the cyan dye which, unfortunately, increases in density at the blue end of the spectrum.

MASKING

Even with the narrow taking lobes as shown in figure 3, again with the same dye density curves, it is not possible to remove entirely the effects of crosstalk between the dyes, and this can best be done by means of the technique known as 'electronic masking'. As with all corrective techniques of this type, the less one has to do the better, and the penalties of added noise, increased optical shading and variation of gamma, which are the inevitable result of excessive masking, are reduced to a minimum when narrow taking lobes are used in the original analysis.

Briefly, all these techniques result in loss of sensitivity and since poorly exposed or processed films have to be shown without a decrease in the signal to noise ratio, some ten times the amount of light necessary for good film should be available.

SENSITIVITY

In the final analysis this comes down to sensitivity and available light, and it is only with Plumbicons that all the foregoing conditions can be met and the good colour response of the original be preserved.

The sensitivity of the Plumbicon tube is sufficient to allow the tubes in the colouring channels of a four-tube camera to be run at approximately the same signal current as the luminance tube and so their contribution to the overall noise is negligible. Even more important, the signal currents in the colouring channels can be matched so that the lag, particularly differential (coloured) lag may be reduced to insignificant proportions.

NEGATIVE FILM

The high sensitivity which results from an efficient illuminating system also makes it possible to produce good pictures from negative colour film on this type of equipment. Negative film involves a number of special problems, not the least of which, is the orange mask or coupler which is incorporated in negative film of the Eastman Kodak type. This coloured coupler modifies the transfer characteristic of the film in such a way that not only are many of the weaknesses of the dyes used in the negative film corrected, but also some allowance may be made for the dyes in the positive print for which no coloured couplers may be used, because they give rise to real colour errors which would not be acceptable to the viewer.

Because of these coloured couplers there is an insertion loss of approximately 18dB in the blue region. This means that where a yellow object of high reflectance is photographed, the negative would normally be expected to have a high transmission in blue, but in practice this will be only 12% at best. In the printing process this necessitates rebalancing the light in the printer, but presents little in the way of a practical problem. In telecine, however, lack of blue light can easily become a limiting factor and only the use of Plumbicons ensures adequate sensitivity and noise immunity with dense film.

As has been mentioned earlier the red-taking lobe of the colour camera is already placed slightly to the green side of the peak density of the cyan dye, and the density read is slightly less than the ideal. One of the effects of the coloured coupler is to steepen the side of the cyan dye density curve on the green side, and hence the density reading error is considerably greater with negative film, that is about 0·6 to 0·8 with the peak value taken as being 1·0. To correct for this, the red channel gamma is set to unity, as against 0·7 in the other channels.

Certain practical problems also arise in connection with the operation of the equipment. For instance, the black level control and the white control have to be interchanged, and what was 'black' colour balance control has to become 'white' balance control, and vice versa. It is noticeable that these last two controls operate in a much more interdependent manner than is the case with positive film, due mainly to the very low contrast of the image on the negative film.

In the case of a live camera, colour balance errors are due, mainly, to changes in the colour temperature of the light, and will be most noticeable in areas of high reflectance. A 'white' balance control will be the most useful for putting this right as obviously a black object reflecting virtually no light cannot give rise to this particular form of colour error.

In the case of positive film colour balance, most errors are due to dye depositions, and these errors will decrease to zero in the light areas where there are no dyes to be wrong. In the case of negative film, however, the maximum dye concentration is in those parts which will ultimately appear white, and it is the white control, therefore, that gives the most useful correction for this type of film, although experience shows that a skilled operator can improve the presentation of either type of film with both black and white balance controls.

Fig.4 One colour and two black and white telecine machines installed at Yorkshire Television.

The Plumbicon is at present the only type of camera tube available which allows these methods to be employed, thereby getting the best results from all types of film material with the minimum sacrifice of other parameters, such as colorimetry, signal to noise, and shading, with the added ability to make reasonable pictures from film which would normally be considered too dense to use.

Colour and black and white telecine machines are shown in figure 4.