COLOUR TELEVISION SYSTEMS

SUPPLEMENTARY INFORMATION

This volume contains information that is supplementary to that contained in the Colour Television Systems package, and should be read in conjunction with that volume. Ideally it should be read after you have completed Section 5 but can be left until the end of the volume if you prefer.

MATCHING SPECTRAL COLOURS

1.1 THE PROBLEM

This section considers the problem of trying to match the colours of the spectrum. Take as the three primaries, three monochromatic light sources. Take as the colour to be matched, small parts of the spectrum selected in turn.

If as an example you tried to match a monochromatic cyan, you would find that the colour obtained from the primaries would always look too red. If you look at the three receptor responses, as shown in figure 1.1 you can see why.

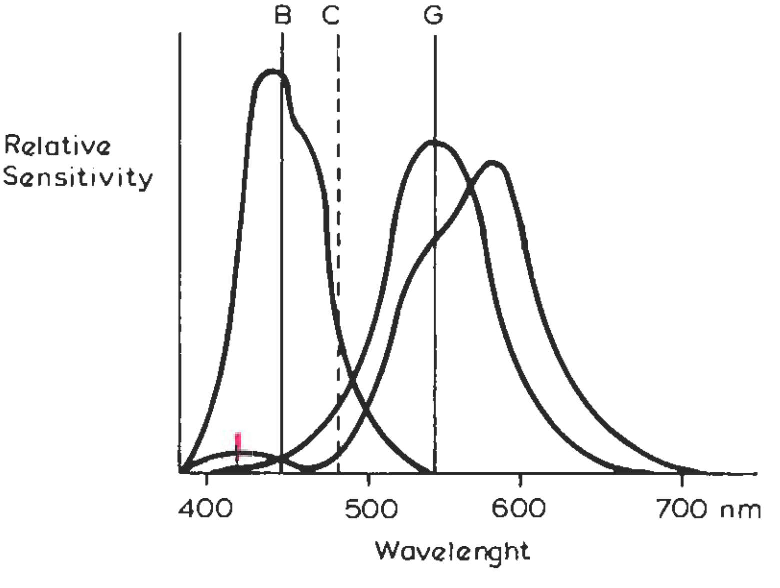


Fig. 1.1 Eye Receptor Responses

Q. Notice that monochromatic cyan stimulates mainly the blue and the green receptors, but hardly stimulates the red receptor at all. However, when you turn up the blue and green primaries, which receptors in the eye do they stimulate?

The blue primary stimulates mainly the blue receptor in the eye. But, the green primary not only stimulates the green receptor, but also the red receptor. This means that on adjusting the blue and green primaries, the colour match obtained would always look too red.

Is it possible to obtain a visually correct colour match?
When using a visually matching colorimeter the answer is to add three more variable primaries to the left hand (sample) side of the colorimeter. This gives a visually matching colorimeter as shown in figure 1.2.

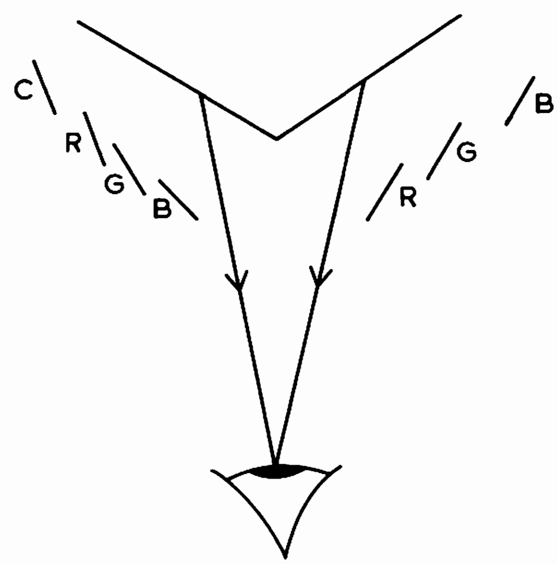


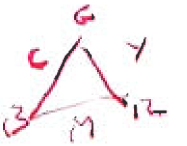
Figure 1.2 Visual Matching Colorimeter

You can now take a mixture of the original cyan, plus a small amount of the red primary on the left-hand side of the screen, and match it by adjusting the amounts of the blue and green primaries on the right-hand side of the screen. This would give a match of:-

Cyan + red = blue + green.
Therefore cyan = –red + blue + green.

Most spectral colours require this idea of negative colour in order to obtain a visual match. It results from the eye receptor responses which are both broad band and over-lap.

A spectrum would plot on a chromaticity chart as shown in figure 1.3



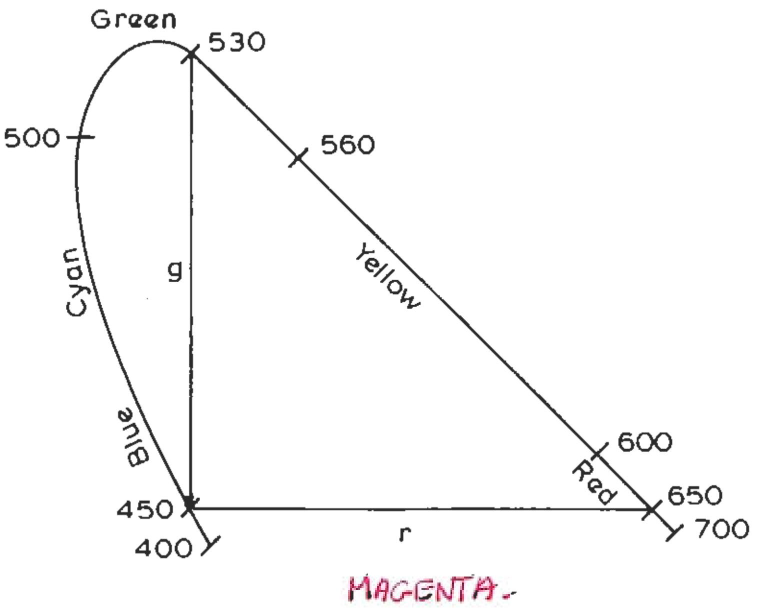


Figure 1.3 Spectrum Locus

The points so plotted are known as the spectrum locus.

Example

50(Cy) + 10(R) = 25(G) + 35(B)

Therefore 1(Cy) = –.2(R) + .5(G) + .7(B).

This will plot on a chromaticity chart as shown in figure 1.4

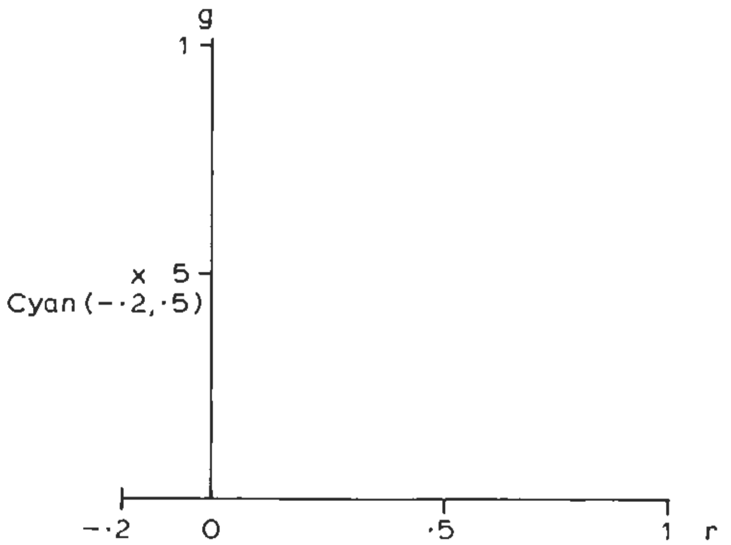


Figure 1.4 Plot of Spectral Cyan

1.2 COLOUR MATCHING FUNCTIONS

Another way of describing the spectrum is by using *Colour-matching functions.* The colour-matching functions define the amount of red, green and blue light required to match unit power of each wavelength of the spectrum. i.e. Take each wavelength of the spectrum in turn and obtain a colour match in terms of the red, green and blue primaries. Then plot the amount of stimulation required from each primary against wavelength.

For the wavelengths between 500 nm and 600 nm the functions would plot as shown in figure 1.5.

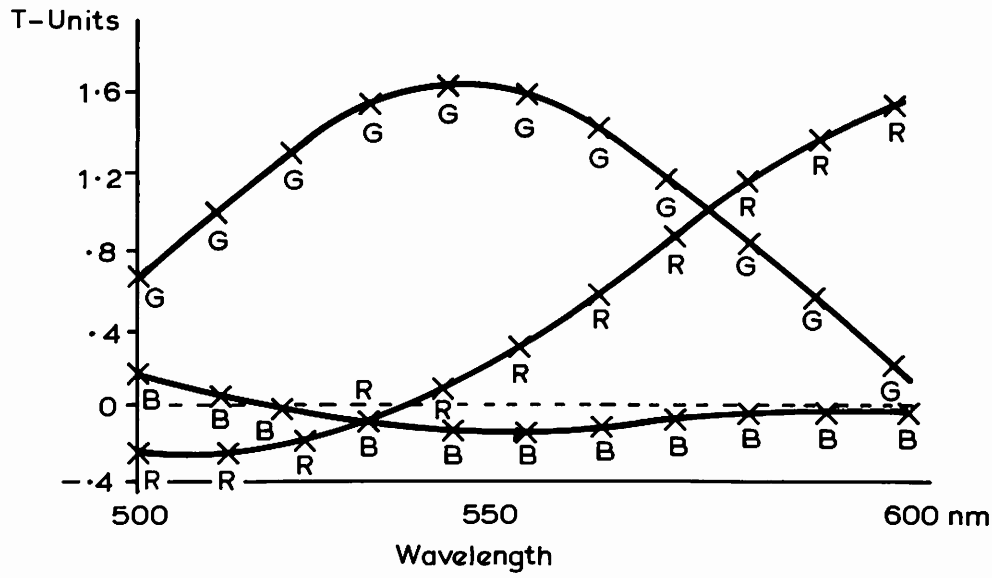


Figure 1.5 Colour Matching Functions

By joining together all the red, green and blue stimuli you obtain curves showing the relative amounts of N.T.S.C. red, green and blue primaries required to match any point in the spectrum.

If this procedure is carried out for all wavelengths in the visible spectrum, then a set of curves is obtained which will be the ideal camera response curves for correct colour analysis. These curves are shown in figure 1.6.

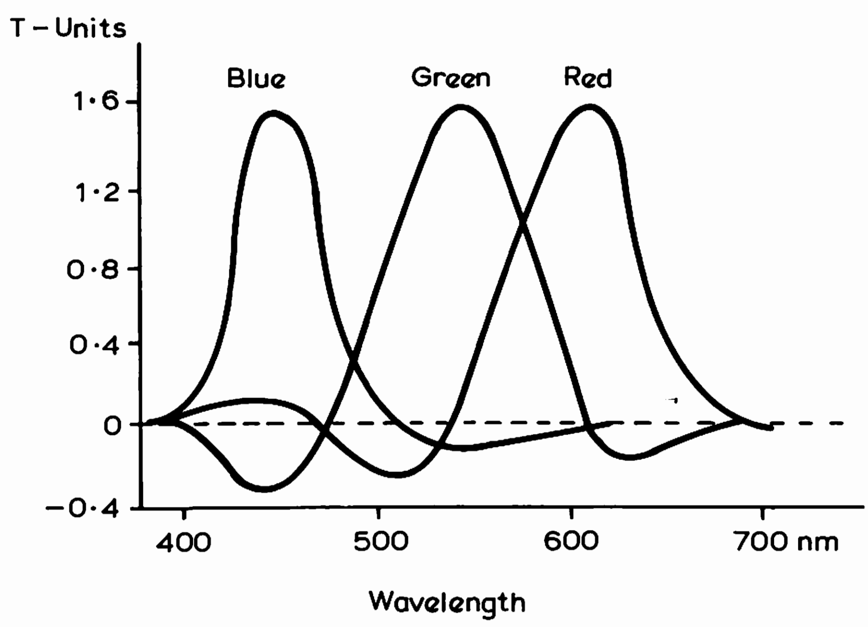


Figure 1.6 Ideal Camera Channel Response Curves for NTSC Phosphors

The problem now is how to obtain these curves in practice. A basic colour camera can only give positive outputs around the blue, green and red parts of the spectrum. It is not possible to make a camera tube that gives a positive output at some wavelengths and a negative output at others.

One way would be to provide a camera tube with its output suitably shaped, and inverted if necessary, for each portion of the response curves. You would need a tube for:

(a) the positive blue output
(b) the positive green output
(c) the positive red output
(d) the negative blue output
(e) the negative cyan output
(f) the negative green output
(g) the negative red output
(h) the low level of red stimulation required at the blue end of the spectrum.

The outputs from these tubes could then be combined to give the final Red, Green and Blue response curves.

This would result in a large and expensive colour camera.
The practical solution to use a resistor matrix and sum and difference inputs to amplifiers to combine the outputs from three tubes in order to provide the camera response curves, as shown in figure 1.7

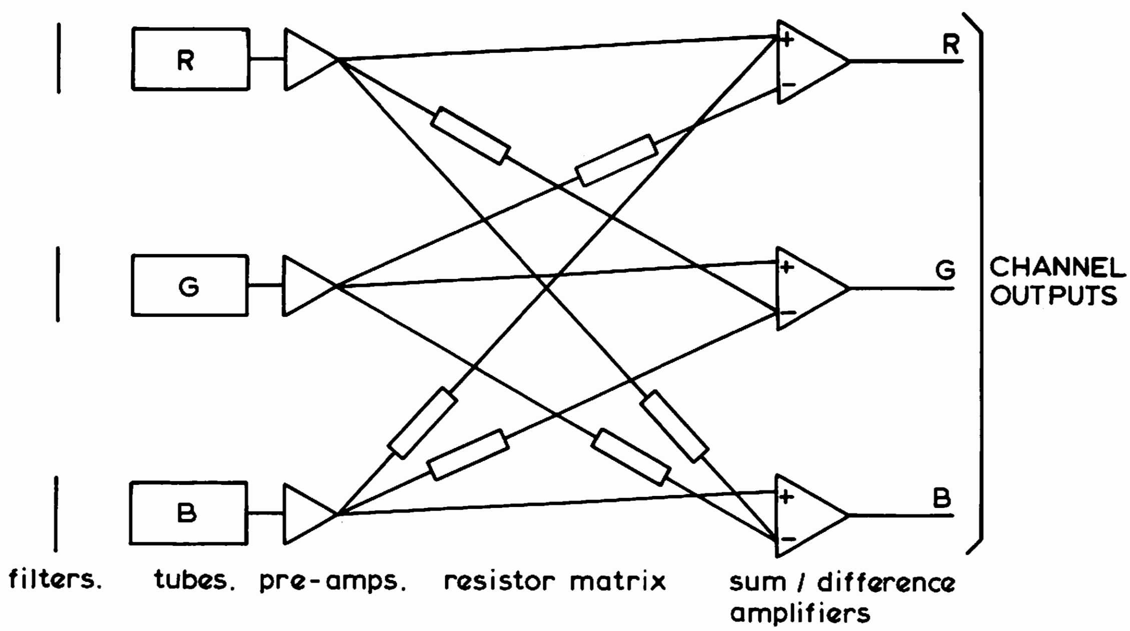


Figure 1.7 Colour Camera with a Matrix

Q. How are the resistor values and cross connections chosen?

These values depend upon the required camera channel outputs. As we have already seen, these outputs depend upon the phosphors in the television tube.

Figure 1.8 shows the practical response curves after matrixing

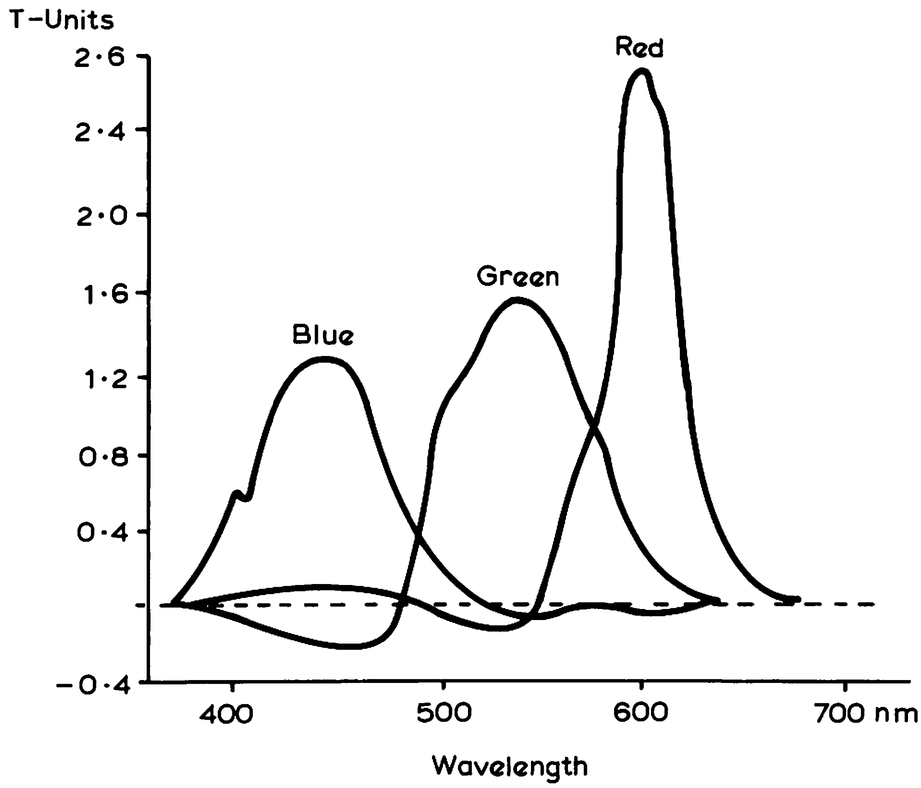


Figure 1.8 Practical Camera Channel Response Curves after Matrixing

1.3 THE NEED FOR NEGATIVE LOBES

By matrixing we have managed to produce negative lobes to the response curves. Unfortunately, the colour television display tube is unable to glow negatively and therefore we are still unable to produce colours lying outside the NTSC chromaticity triangle. However, in figure 1.9 the shaded area represents the gamut of chromaticities occurring from all naturally occurring pigments illuminated by daylight. As you can see only a few lie outside the triangle.

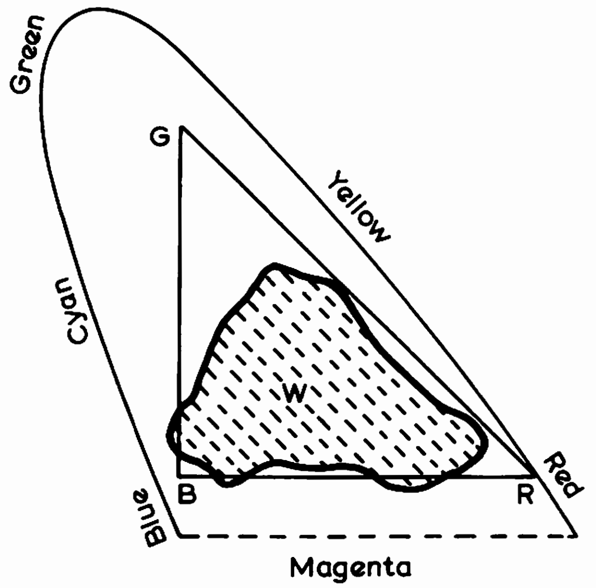


Figure 1.9 NTSC Chromaticity Triangle

The inability to reproduce the spectral colours on a colour monitor, and the fact that most known pigments lie within the chromaticity triangle, does not mean that we do not require matrixing. For ordinary pigments, in order to reproduce them accurately, we still need negative lobes and the idea of negative colour.

The following example of colour matching shows the need for negative colours, even for those pigments that lie within the chromaticity triangle.

Example

Take the previous example of cyan where (in T units)

$50(Cy) + 10(R) = 25(G) + 35(B)$

$\therefore\ 50(Cy) \equiv -10(R) + 25(G) + 35(B)$

$\therefore\ 1(Cy) \equiv -.2(R) + .5(G) + .7(B)$ Equation 1.

This point is shown plotted on the chromaticity chart of figure 1.10a.

Now take a cyan of the same *hue* which has been desaturated by the addition 30 T units of white.

Therefore $80(Cy) + 10(R) \equiv 25(G) + 35(B) + [10(R) + 10(G) + 10(B)]$

[Remember $30\ W = 10(R) + 10(G) + 10(B)$]

$\therefore\ 80(Cy) \equiv 35(G) + 45(B)$.

$\therefore\ 1(Cy) \equiv .44(G) + .56(B)$ Equation 2.

This is shown plotted on the chromaticity chart of figure 1.10b

Points one and two have been analysed using a visual matching colorimeter. If we now look at these two same colours with a camera, the camera outputs should be the same as the right-hand side of the equation. If not, then the camera is distorting the reproduction of the colours, i.e. it does not have correct colorimetry.

Take the first example of cyan, and look at it with a camera. The camera tube outputs would be 25T units of green and 35T units of blue. If there was not a matrix, then the channel output would also be 25T units of green and 35T units of blue.

Therefore cyan $\equiv 25(G) + 35(B)$

The camera would therefore be giving a total reading of 60 T units.

$\therefore\ 60(Cy) \equiv 25(G) + 35(B)$.

$\therefore\ 1(Cy) \equiv .42(G) + .58(B)$. Equation 3.

This point is plotted on the chromaticity chart of figure 1.10a.

A matrix could not improve the reproduction of this colour as any negative red component introduced could not be reproduced by a monitor.

Now, take the desaturated cyan. What will the camera outputs be without the matrix?

$Cyan \equiv 25(G) + 35(B) + 10(R) + 10(G) + 10(B)$

$Cyan \equiv 10(R) + 35(G) + 45(B)$

$\therefore\ 90(Cy) \equiv 10(R) + 35(B) + 45(B)$

$\therefore\ 1(Cy) \equiv .11(R) + .39(G) + .5(B)$ Equation 4.

This is plotted on the chart of figure 1.10b.

If the matrix is now included it will introduce the necessary 'negative lobe' of 10T units of red. The equation thus becomes:

$Cyan \equiv 25(G) + 35(B) + 10(R) + 10(G) + 10(B) - 10(R)$

$Cyan \equiv 0(R) + 35(G) + 45(B)$

$80(Cy) \equiv 35(G) + 45(B)$

$1(Cy) \equiv .44(G) + .56(B)$ Equation 5

Which is identical to the original match (Equation 2) and plots correctly

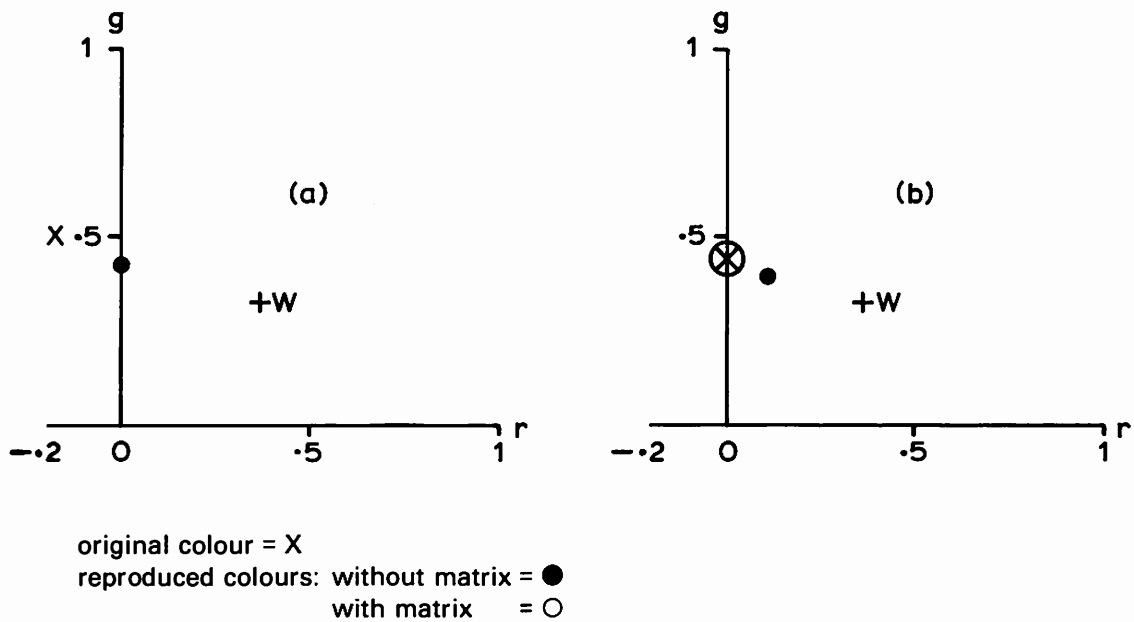


Fig 1.10 Chromaticity Chart showing orignal and reproduced cyan colours a) full and b) with reduced saturation

The conclusions to be drawn from this exercise are:-

(a) If the camera channel has a matrix, then it can introduce negative lobes.

(b) If negative lobes are produced, then the camera will correctly analyse the colour and the colour will be correctly plotted on the chromaticity chart, provided the colour lies within the chromaticity triangle of the phosphors.

(c) Fully saturated spectral colours cannot be displayed correctly on a monitor because, even with negative gun drives the phosphors cannot glow negatively.

(d) Reduced saturation spectral colours (e.g. natural pigments) will not only plot correctly. but will also be displayed correctly.

(e) If a camera does not have a matrix to produce negative lobes, then colours which lie within the boundary of the chromaticity triangle may not only plot incorrectly, but can also be displayed incorrectly. Typically they will appear desaturated and of slightly the wrong hue.

NOTES