THE BRITISH BROADCASTING CORPORATION ENGINEERING TRAINING DEPARTMENT

INFORMATION SHEET — COLOUR TELEVISION

COLOUR CORRECTION LINEAR MATRICES

Introduction

Any colour may be described in terms of the percentages of Red Green and Blue light required to 'match' it. A colour television camera channel is thus required to generate 'Red', 'Green' and 'Blue' signals which will ultimately cause the phosphors in a colour display tube to emit the correct percentages of Red, Green and Blue light.

This information sheet indicates the way in which the ideal camera analysis characteristics are predicted, and why they continue to be important despite display limitations. Finally the results of some practical approximations to the ideal analysis are given.

The Ideal Analysis Characteristics

These indicate the proportions of R G and B required to match a colour of any wavelength or band of wavelengths. For a given set of R G and B primaries it is inevitable that very narrow band or monochromatic radiations will require negative amounts of one or more primaries to 'match' them. The 'ideal' analysis curves - Fig. i opposite, indicate the proportion of NTSC Red Green and Blue required. (The radiation shown at 580 nm is discussed in the next paragraph). The negative lobes indicating the amounts of R G or B which must be subtracted to give a perfect match. See references (i) and (ii) for a fuller description of this aspect of colour analysis.

The Practical Importance of the Negative Lobes

A monochromatic radiation e.g. a yellow at 580 nm is seen from Fig i to require light from the primaries in the proportions 4·4 Red + 2·7 Green - 0·2 Blue. Since a phosphor cannot produce a negative output this indicates that this yellow cannot be correctly reproduced on a monitor even if fed from a camera channel with ideal analysis characteristics. In terms of a chromaticity chart any colour lying outside the RGB triangle does contain negative quantities in its specification and cannot be correctly reproduced. This is not a serious limitation since very few surfaces - under normal illumination - do plot outside the triangle.

A far more serious problem is that of the more common wide band (less saturated) colours.

Fig. ii opposite shows the energy distribution for a wide band red. To reporduce this red calculations from the curves indicate that

$$+0{\cdot}5(R) - 2(R) + 74(R)$$
$$\text{and} \quad -1{\cdot}5(G) + 34(G) - 4(G)$$
$$\text{and} \quad +10(B) - 1{\cdot}5(B) + 0{\cdot}5(B) \quad \text{would}$$

be required for correct reproduction.

$$\text{i.e.} \quad 72{\cdot}5(R) + 28{\cdot}5(G) + 9{\cdot}0(B)$$

If the analysis had, for any reason, not included the minor lobes - negative and positive - the description would have been:-

$$74(R) + 34(G) + 10(B)$$

The omission of the negative lobes would thus have introduced errors into the reproduction.

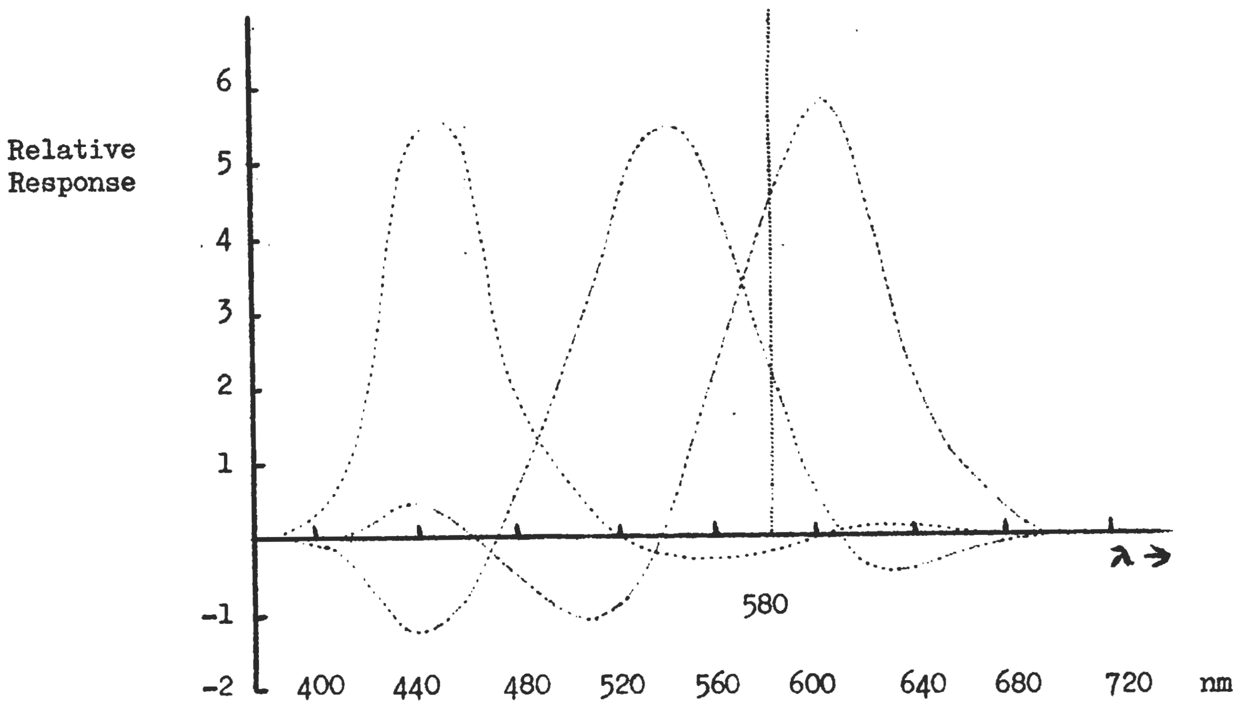
Relative
Response
6
5
4
3
2
1
-1
-2
580
400
440
480
520
560
600
640
680
720
nm
λ →

Fig. i

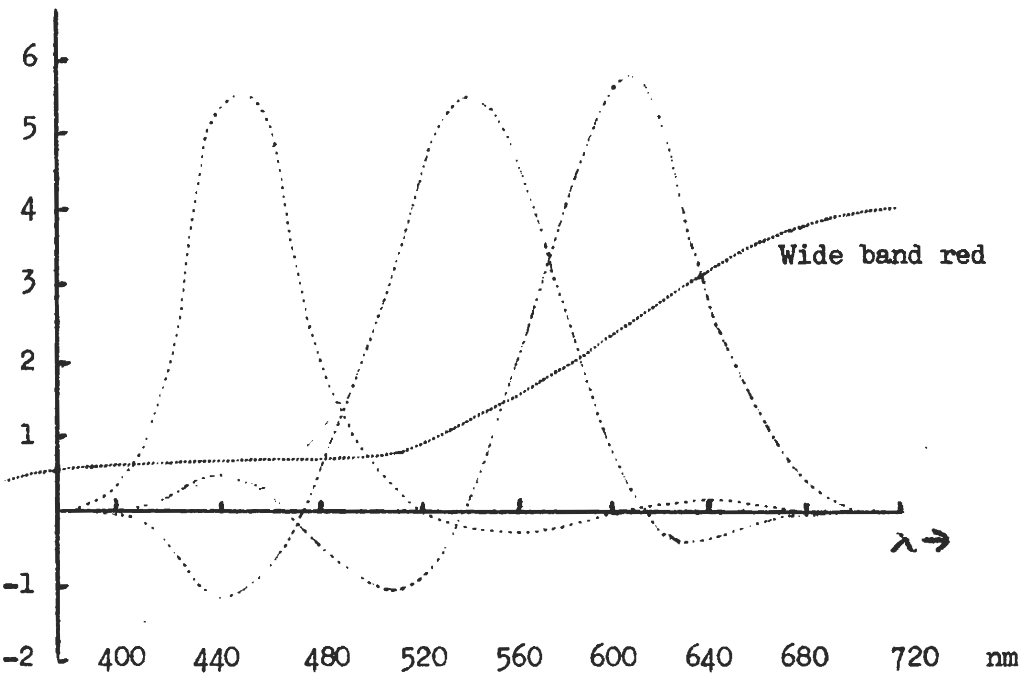
6
5
4
3
2
1
-1
-2
Wide band red
400
440
480
520
560
600
640
680
720
nm
λ →

Fig. ii

A Method of Obtaining the Negative Lobes by Matrixing

An optical analysis system employing camera tubes and filters cannot produce positive outputs over one band of frequencies and negative outputs over another. The negative lobes are obtained by matrixing the outputs of the three tubes in order to give an overall analysis approximating to the ideal analysis. Fig. iii - below - shows a set of three possible analysis characteristics and indicates that a matrix providing a 'Red' output proportional to +1·9 of the Red input, -0·53 of the Green input and -0·29 of the Blue input would produce an effective Red analysis as shown. A similar process would produce the required Green and Blue analysis.

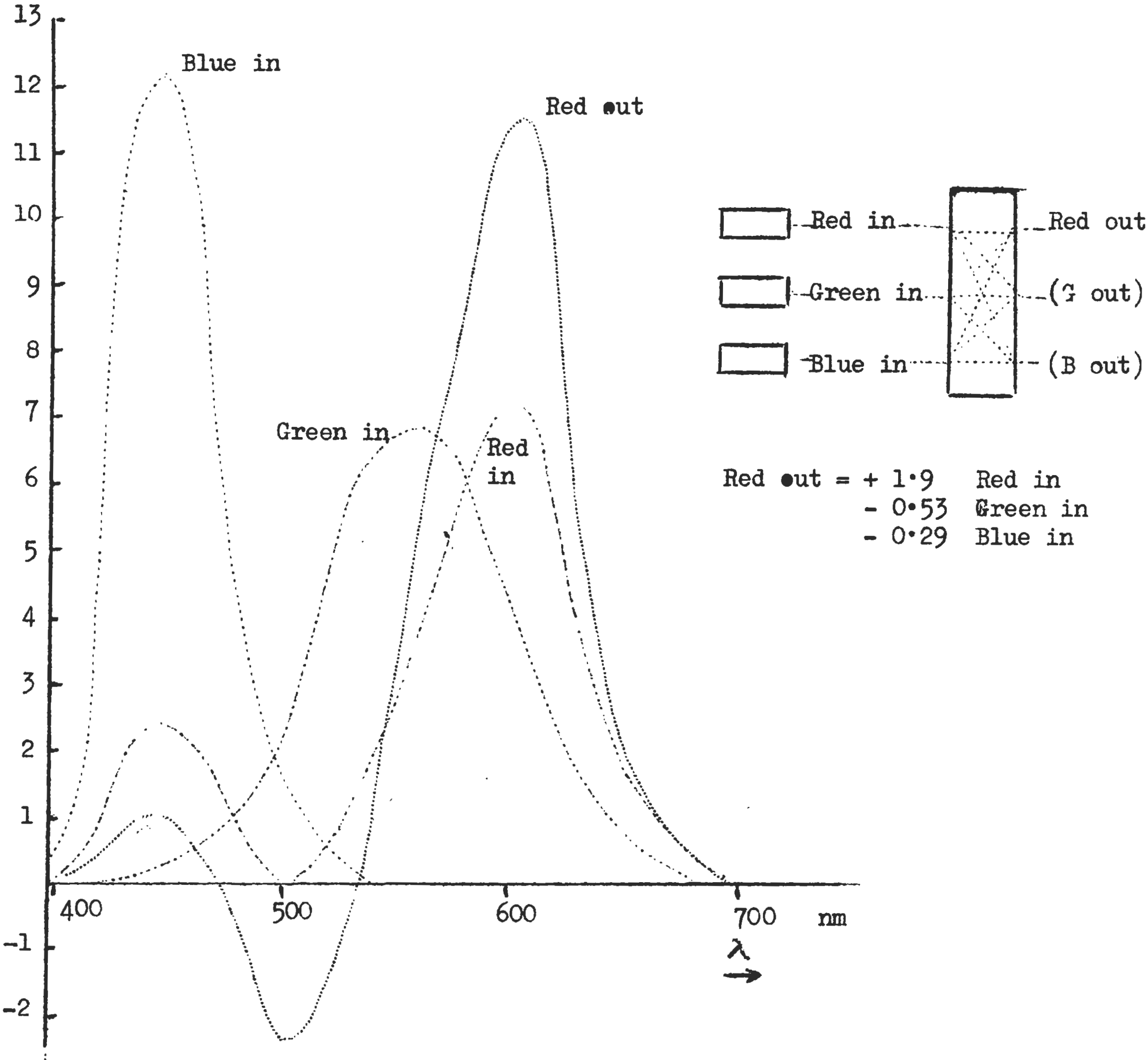

Fig. iii

Practical Analysis Characteristics

In practice limitations are imposed by: available dichroic mirrors; system sensitivity and camera tube response. A free choice of the positive lobes is thus not available. The components of the matrix are computed on the basis of optimum reproduction of a number of carefully selected colours.

Fig. iv below shows a practical set of camera analysis curves, the matrix and the overall channel response for the PC60 camera.

Fig. vi shows the chromaticity of 5 reproduced colours both with and without the matrix.

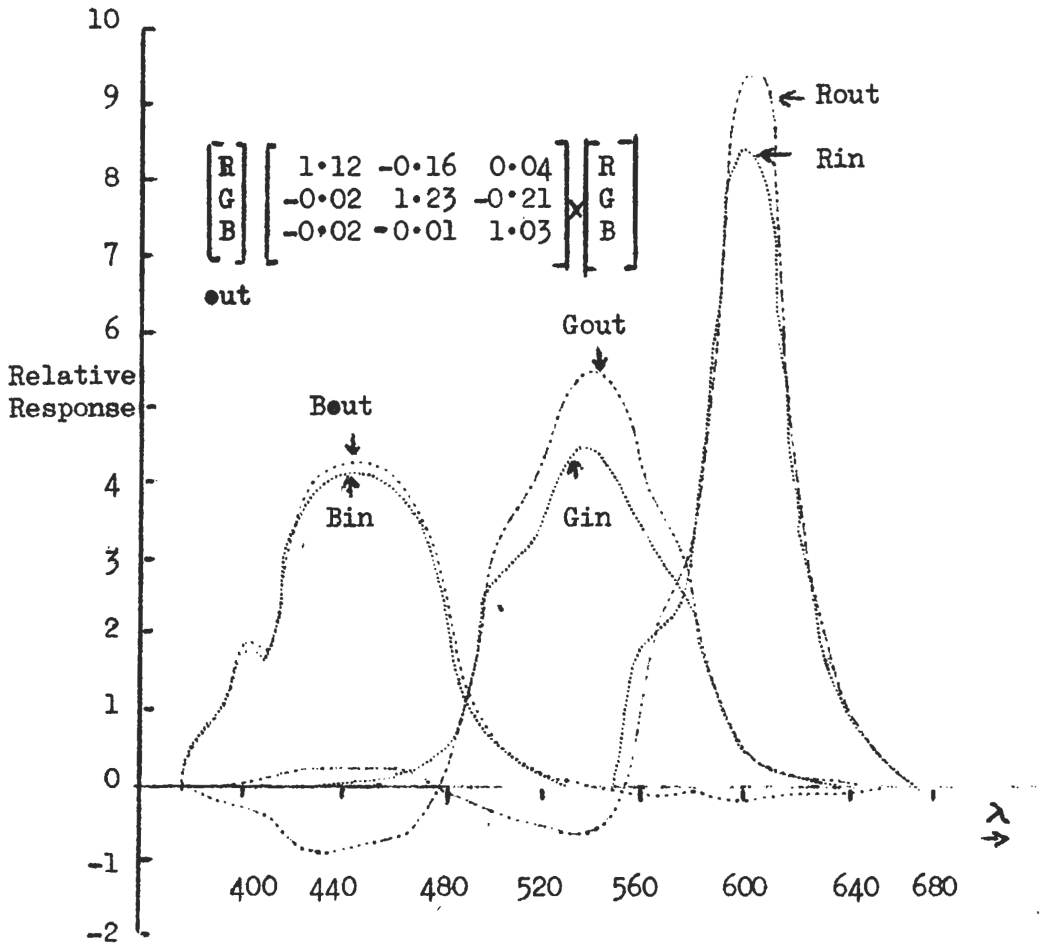

Fig. iv

The E.M.I. 2001 Matrix

Fig. v below shows the analysis curves for the E.M.I. 2001 using the version of Matrix 53 having the coefficients shown. The colour correction matrix is located in the R, G, B signal chain before the 'y' matrix.

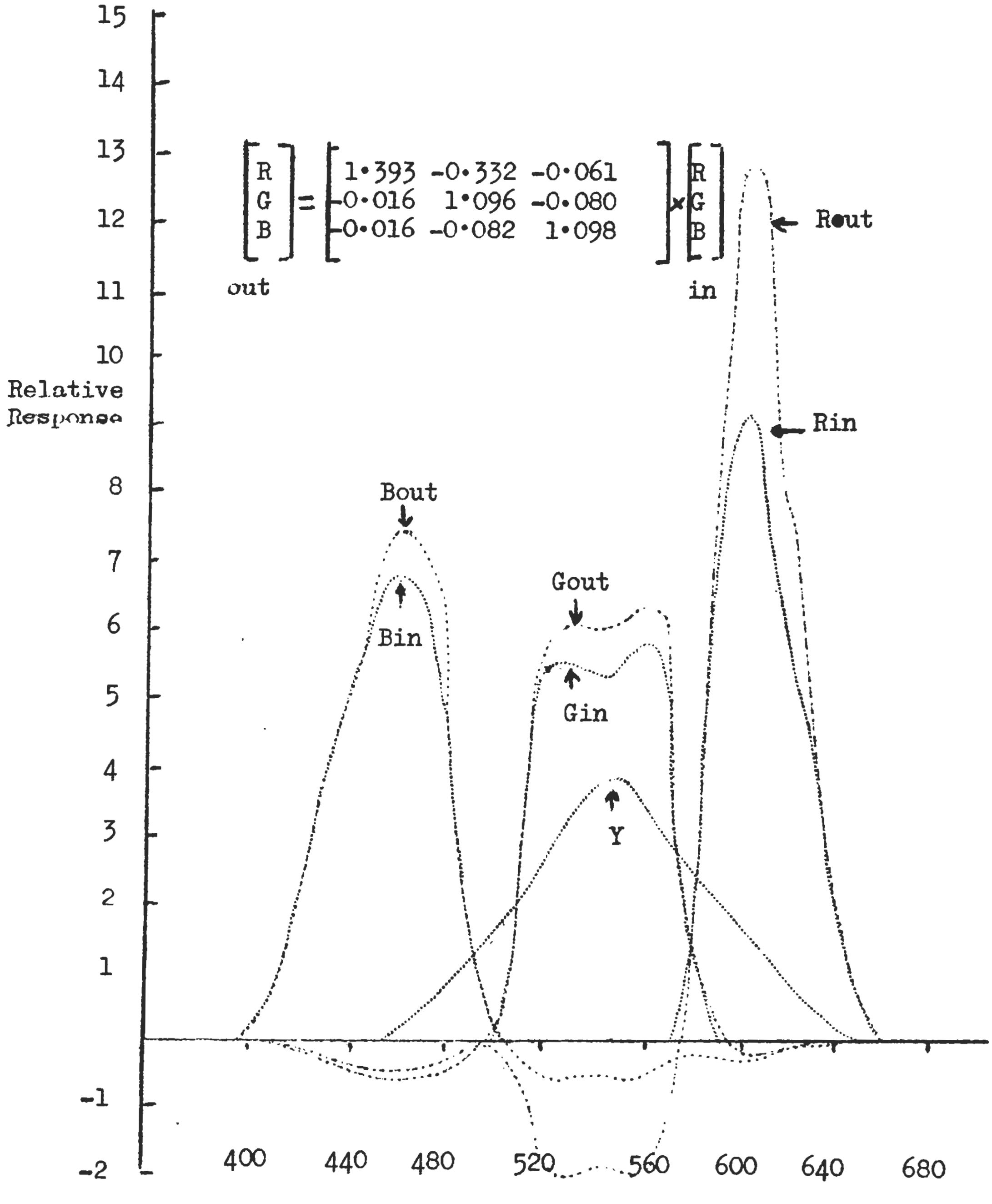

Fig. v

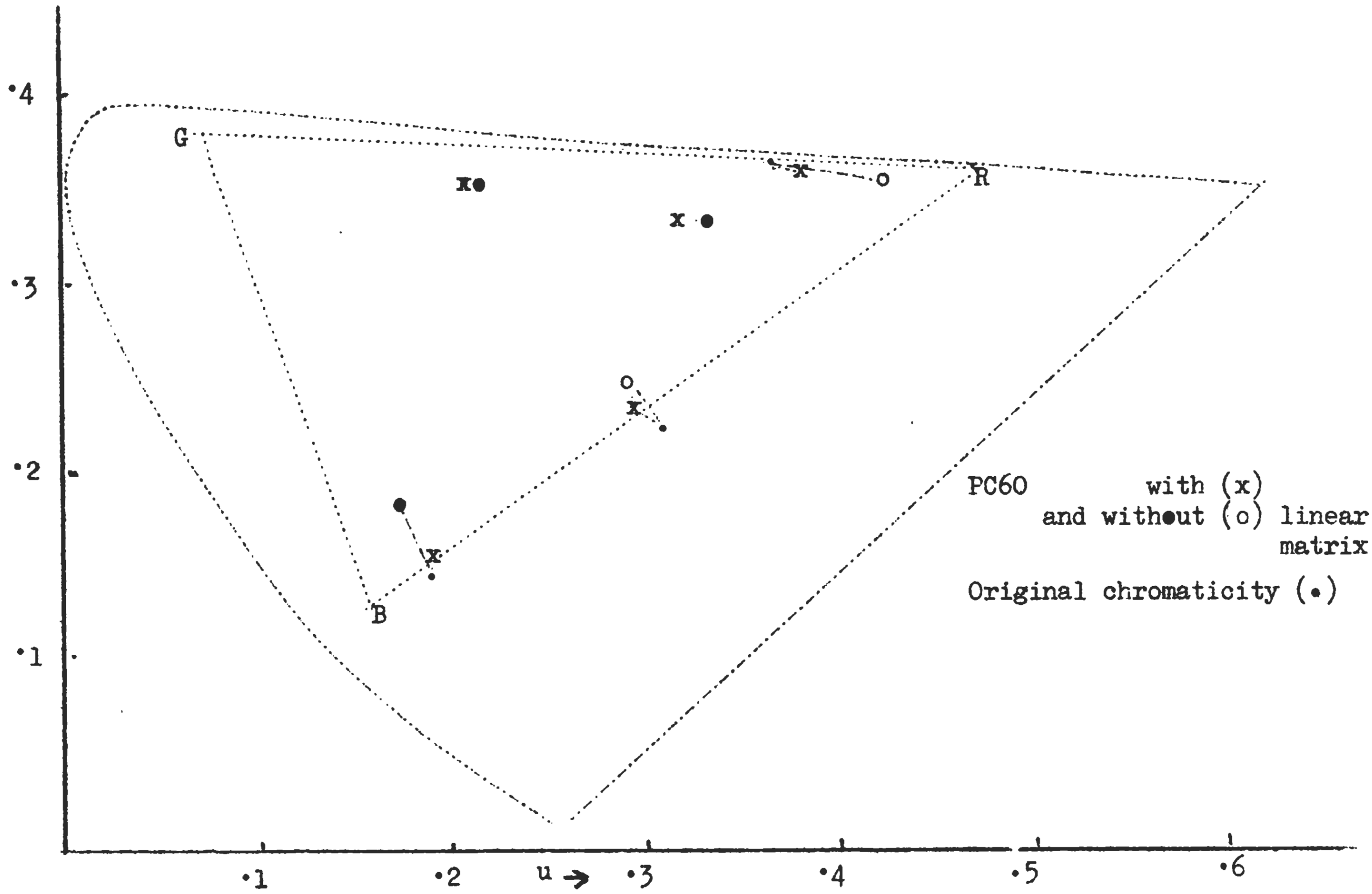

Fig. vi

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Use of a linear matrix to modify the colour analysis characteristics of a colour camera.

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3 x 3 matrices for use with plumbicon cameras using three tubes.

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The performance of a modified form of the E.M.I. type 2001 camera.

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J.R. Kirkus/JMD
21st April 1970