Nov. 9, 1948. R. B. MORRIS 2,453,335

COLOR BLINDNESS CHART FOR DETECTING ANOMALOUS VISION, DEUTERANOPES, PROTANOPES, TRITANOPES, AND MONOCHROMATS

Filed Oct. 27, 1944 2 Sheets-Sheet 1

FIG. 1.

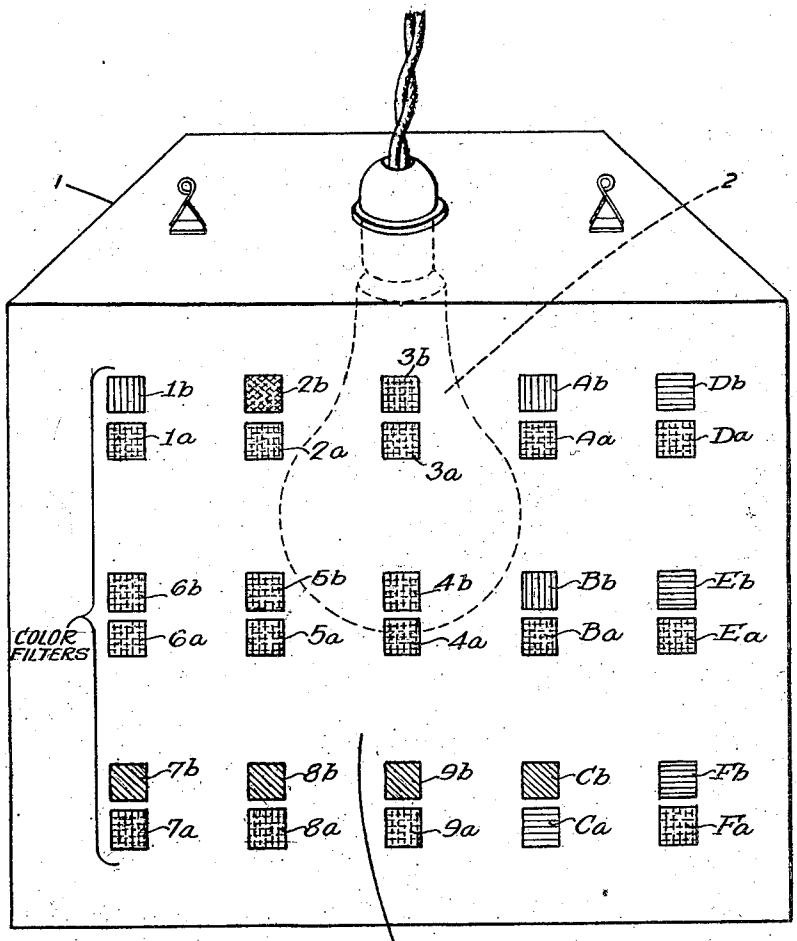


FIG. 5.

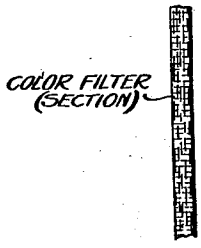
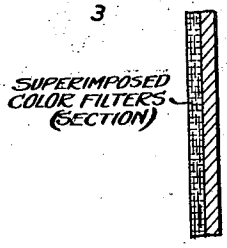


FIG. 6.



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2 Sheets-Sheet 2

FIG. 2.

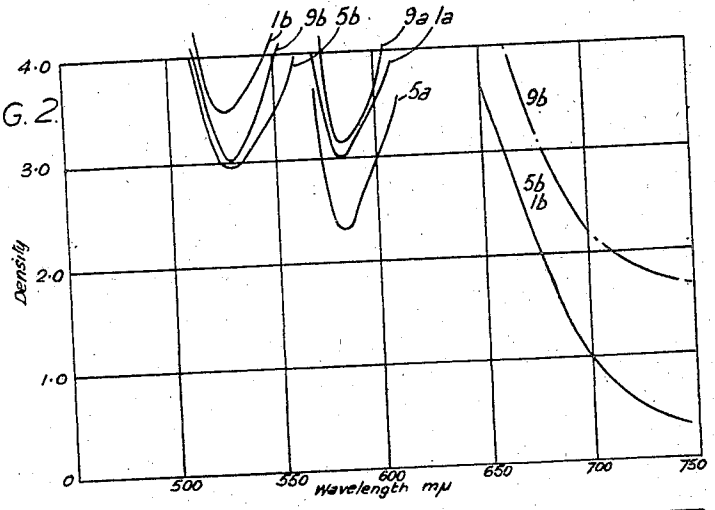


FIG. 3.

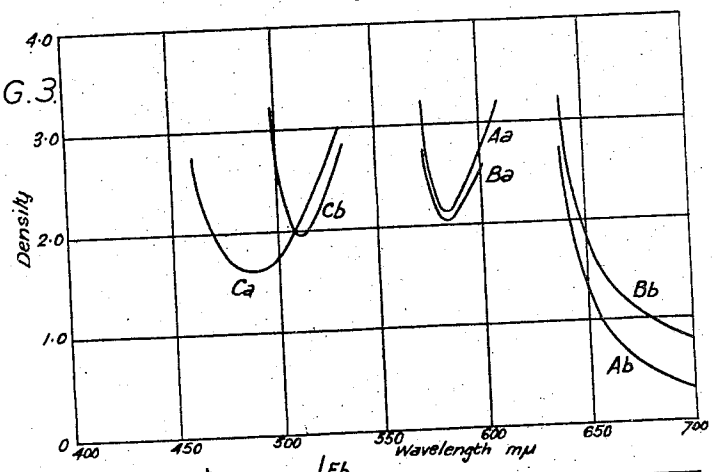
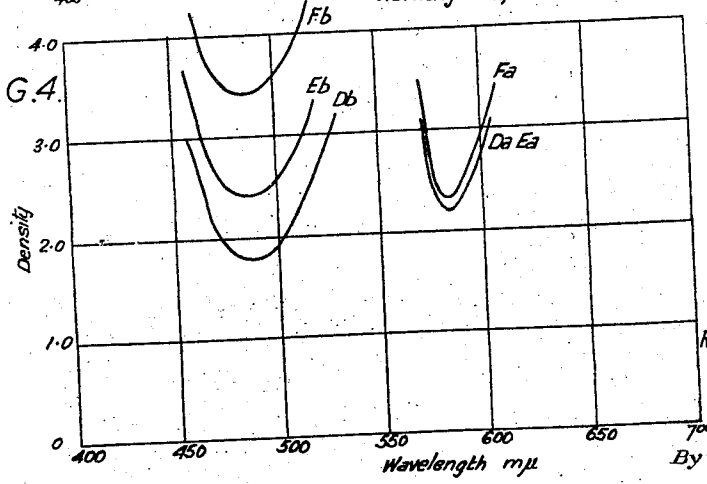


FIG. 4.



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UNITED STATES PATENT OFFICE

2,453,335

COLOR BLINDNESS CHART FOR DETECTING ANOMALOUS VISION, DEUTERANOPES, PROTANOPES, TRITANOPES, AND MONOCHROMATS

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4 Claims. (Cl. 88—20)

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This invention relates to apparatus for use in testing colour blindness.

On examining a spectrum the majority of people can recognise easily the differences in colour between green, yellow, and red. In a minority of people, however, there is some inability to distinguish between these colours, and such people are referred to as "colour blind." One of the tests capable of giving an accurate quantitative description of the type of colour blindness is provided by the Nagel "Anomaloscope." This is an optical instrument in which the observer is confronted with two adjacent bright coloured patches, one of which is illuminated with spectral yellow light, and the other is illuminated with a mixture of spectral green and spectral red. The patch illuminated by the mixture of the green and red can be made to appear the same colour as the yellow patch by suitable adjustment (means for which is provided on the instrument) of the ratio of intensity of the red to intensity of the green; and in use the observer has to so adjust the ratio as to effect, what seems to him, a match in colour between that mixture and the spectral yellow patch. Most people do require both red and green in order to effect a match between the mixture and the spectral yellow and may be called trichromats. It happens that a majority of these trichromats require a ratio between the red and the green which is not markedly different among the people in this majority; the people of this majority are classified as "normal." Of the broad class of people who require both the red and the green to match the yellow (i. e. the trichomats), some require a markedly different ratio of the red to the green than those people who are classified as "normal." These people are called "anomalous." Besides these normal and anomalous people there is a small proportion of people falling in the class known as dichromates who can use either the red or the green to effect a match with the yellow. These latter people are colour blind and there are two classes of them; a characteristic of the people of the one class is that they require the red to be of moderate intensity compared with the intensity of the yellow, and are termed "deuteranopes," while the other class requires the red to be of considerably higher intensity compared with the intensity of the yellow, and are

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called "protanopes." There is also a third class of dichromats termed "tritanopes" who have a characteristic not shared by the protanopes and deuteranopes, in that a blue appears to them to match with a blue-green providing the apparent brightnesses are equal. Then there are people who are classified as monochromats about whom little knowledge is available, but it seems that their luminosity curves are similar to the luminosity curves of deuteranopes or protanopes or they may be cone-blind, wearing dark glasses, and using only scotopic vision. An article on Monochromatism by F. H. G. Pitt appears in "Nature," volume 154, pages 466 to 468, 1944, in which the probability of incidence of these monochromatic types is calculated.

People who are either deuteranopes or protanopes can be distinguished by many wellknown tests, but the distinguishing of people who are anomalous to an important degree is not easy, although a test for them is provided by the Nagel anomaloscope. It is important that such people should be distinguishable, since they have, for instance, some disability in recognising red and green signal lights, and are under a disadvantage in any work which requires accurate colour matching. Many people who have little familiarity with the use of optical instruments find difficulty in operating it to secure a colour match, and despite its merits in other respects, has not, for this reason come into general use.

The object of the present invention is to provide an apparatus which can be used in tests for anomalous people, as well as the truly colour blind, but with the advantage that it can be used satisfactorily by people under test for colour blindness who are not necessarily skilful in colour matching with optical instruments. In the preferred form of the present invention the apparatus is one which can be used for the purpose of distinguishing people who are "normal," and all the above types of colour blindness.

According to the present invention there is provided an apparatus for testing colour discrimination of a human eye which comprises at least three pairs of coloured patches each patch of which emits light only from one or two of three bands in the visible spectrum chosen such that to "normal" people the two outer bands can be mixed to match the middle band, and each pair

of patches being such that one patch of the pair emits only the middle waveband and the other patch of that pair emits at least one of the outer two wavebands but not the middle band, the proportions ef light in such outer two wavebands being different for the different patches emitting them, there being at least one pair of which one patch emits both said outer two wavebands.

The said three bands can consist of three different very narrow wavebands. It is desirable to employ more than one pair which has a patch which emits both said other two wavebands and then to make the ratio of the emissions of said other two bands different for the different pairs. If there is more than one pair of patches in which one of each pair contains the red only, then these should differ in the ratio of the intensity of the red, compared with the yellow.

The three substantially monochromatic wavebands which we prefer to employ are as follows:

(1) A waveband having its maximum emission within the range 520 to 550 mμ and such that at those two wavelengths the emission is not more than one-tenth of that at the maximum. This we term herein "substantially monochromatic green." Preferably the maximum should be within 525 to 540 mμ, for instance at 530 mμ.

(2) A waveband having its maximum emission within the range 570 to 600 mμ and such that at those two wavelengths the emission is not more than one-tenth of that at the maximum. This we term herein "substantially monochromatic yellow." Preferably the maximum should be within 580 to 590, for instance at 585 mμ.

(3) A waveband having its maximum emission within the visible range above 600 mμ and such that at 600 mμ the visual brightness is not more than one-tenth that at the maximum. This we term herein "substantially monochromatic red." Preferably the maximum should be within 650 to 700, for instance at 680 mμ.

In a preferred form of the invention, a series of at least five pairs are employed having the following natures.

(1) Patch of substantially monochromatic yellow. Patch of substantially monochromatic red of about the same brightness as the yellow, to the majority of people.

(2) Patch of substantially monochromatic yellow. Patch of mainly substantially monochromatic red plus a small proportion of substantially monochromatic green, i. e. a smaller proportion than in the third pair, so that the patch appears more red than the yellow patch to the majority of people.

(3) Patch of substantially monochromatic yellow. Patch of substantially monochromatic red plus substantially monochromatic green in a proportion such that the patch appears of about the same colour as the patch of yellow to the majority of people.

(4) Patch of substantially monochromatic yellow. Patch of mainly substantially monochromatic green plus a small proportion of substantially monochromatic red, i. e. a smaller proportion than in the third pair, so that the patch appears more green than the yellow patch to the majority of people.

(5) Patch of substantially monochromatic yellow. Patch of substantially monochromatic red of higher intensity than the patch of red in the first pair.

People who consider pair 3 to match in colour better than any others are "normal." People who consider pair 2 or pair 4 to match in colour better than any others are "anomalous." People who consider pair 1 to match in colour are "Deuteranopes." People who consider pair 5 to match in colour are "Protanopes."

If a greater degree of accuracy is required in ascertaining the nature of an observer's eyesight, further patches can be employed having mixtures of the red and the green intermediate between those described above; and further pairs of patches can be employed which will detect the tritanopic and monochromatic colour vision either by matching a blue with a blue-green to detect the tritanopes or by matching a blue with a yellow for brightness to identify the three monochromatic types.

Fig. 1 is a perspective sketch of an apparatus incorporating the invention.

Figs. 2, 3, and 4 are spectrophotometric curves of the light transmitted by the filters used in the apparatus shown in Fig. 1.

Fig. 5 is the cross section of a color filter.

Fig. 6 is the cross section of two superimposed color filters.

A very useful apparatus consists of that shown in Figure 1 of the drawings attached hereto which employs fifteen pairs which, by way of example, can be made with transparent filters as follows.

A housing 1 about 12'' x 10'' on its face and having a 150 watt gas-filled pearled tungsten electric lamp situated as shown at 2 is provided with an opal glass on which is superimposed an opaque plate 3 having fifteen pairs of rectangular openings as shown, and in each opening fastened one of the pairs of patches in order shown by the numbers 1 to 9 and letters A, B, C, D, E, F, on the drawing. Essentially the embodiment of the invention shown in Fig. 1 is thus a box with a light inside it which more or less uniformly illuminates 30 color filters arranged as windows on one side, namely, the front side thereof. The windows or patches are arranged in series. Some observers see the patches matching each other in one pair, whereas other observers see the patches as different colors in that particular pair but matching in another pair.

Patches 1*a*, 2*a*, etc. to 9*a* are all spectral yellow and actually appear to the normal eye as very dark yellowish. The apparent color of the patches to the so-called normal person is set forth in the following table:

Pair	Patch *a*	Patch *b*
1	very dark yellowish	very dark brownish maroon.
2	do	very dark brownish orange.
3	do	very dark brownish yellow orange.
4	do	very dark brownish yellow.
5	do	very dark yellowish.
6	do	very dark yellowish green.
7	do	very dark green.
8	do	Do.
9	do	Do.
A	dark yellowish	bright red.
B	dark yellowish (slightly lighter).	bright red (darker).
C	bright (cyan) blue	bright green.
D	dark yellowish	bright blue.
E	do	bright blue (darker).
F	do	bright blue (still darker).

In each pair, except pair C, the spectral yellow patch consists of a filter such as shown in Fig. 5 made of a mixture of Eosin 2524 and Naphthol Green BNS while the other patch of the first nine pairs is dichroic and is made of a filter transmitting only the red and the green and consisting of 0.44 mgm. per sq. cm. of Soluble Blue AS, and either 1.2 mgms. per square cm. of Tartrazine N250, and 0.0045 mgm. per sq. cm. of Fluorescein

10092, or a Wratten No. 16 filter, over which is superimposed either a copper chloracetate or a Naphthalene Bordeaux B110 filter (to suppress, more or less, either spectral red or spectral green as the case may be) as given in the following table, where the figures refer to quantities as mgms. per sq. cm.

No. of Filter Pair	Spectral Yellow Filter ("a" of each pair) Eosin 2524.Naphthol Green BNS	Dichroic Filter ("b" of each pair) CuClAc	Dichroic Filter ("b" of each pair) Naphthalene Bordeaux B110
1	0.92+0.92	----------	0.029
2	0.85+0.85	----------	0.020
3	0.83+0.83	----------	0.012
4	0.73+0.73	----------	----------
5	0.73+0.73	1.8	----------
6	0.73+0.73	3.7	----------
7	0.83+0.83	6.6	----------
8	0.85+0.85	11.5	----------
9	0.96+0.96	15.0	----------
Col. I.	II	III	IV

or Col. II may be as follows.

Use standard filters of Eosin 0.73 and Naphthol Green 0.73 with the following neutral grey filters of the following density values.

Pair No.	Optical Density
1	0.74
2	0.40
3	0.35
4	----------
5	----------
6	----------
7	0.34
8	0.42
9	0.61

Pair A shown as Aa and Ab.—This pair consists of one patch A*a* made of a spectral yellow filter made with Eosin 2524 and Naphthol Green BNS both at 0.66 mgm. per sq. cm., and another patch A*b* made of a red filter made with Methyl Violet 28925 at 0.11 mgm. per sq. cm. superimposed such as in Fig. 6, on a yellow filter made with Tartrazine N.250 at 1.2 mgms. per sq. cm.

Pair B shown as Ba and Bb.—This is the same as pair A, except that a neutral grey filter of density 0.53 is superimposed on the red patch to make up B*b*.

Pair C shown as Ca and Cb.—This pair consists of one patch C*a* made of a Wratten No. 75 filter and the other patch C*b* of a Wratten No. 75 filter superimposed on a Wratten No. 12 filter. As this pair is for ascertaining tritanopes, the brightness is matched for such a person by the superimposition of a neutral grey of density 1.02 on the first mentioned patch.

Pair D shown as Da and Db.—This pair consists of one patch D*b* made of a Wratten No. 75 filter and the other patch D*a* of a spectral yellow filter as in pair No. 5 of the table. The brightnesses of the two patches have been adjusted to be equal for a person having monochromatic colour vision and a protanopic luminosity curve by the superimposition of a neutral grey filter of density 1.06 to the first patch.

Pair E shown as Ea and Eb.—This pair consists of one patch E*b* made of a Wratten No. 75 filter and the other patch E*a* of a spectral yellow filter as in pair No. 5 of the table. The brightnesses of the two patches have been adjusted to be equal to a person having monochromatic colour vision and a deuteranopic luminosity curve by the superimposition of a neutral grey filter of density 1.62 to the first patch.

Pair F shown as Fa and Fb.—This pair consists of one patch F*b* made of a Wratten No. 75 filter and the other patch F*a* of a spectral yellow filter as in pair No. 5 in the table. The brightnesses of the two patches have been adjusted to be equal to a person having monochromatic colour vision and a scotopic luminosity curve by the superimposition of a neutral grey filter of density 2.62 to the first patch.

The reason that the quantities of dyes used for the various spectral yellow patches 1*a*, 2*a*, 3*a*, 7*a*, 8*a* and 9*a* are greater at the beginning and end of the series in this table is as follows. The amount of copper chlor-acetate used for the dichroic filter 5*b* in pair 5 and also the dyes used for the spectral yellow filter 5*a* are first chosen so as to give a convenient yellow colour in both of the pairs and also that the colour and brightness should be the same. The particular amounts used here for a normal person results in a chart giving a high degree of discrimination when testing for colour blindness. Then for a person who is deuteranomalous the amount of copper chlor-acetate required in patches 6*b* to 9*b* to give the ratio of red to green which is necessary in a mixture of these two colours in order to synthesise a yellow similar to the spectral yellow colour 6*a* to 9*a* is found to be that given in the table. It will be observed that the colour of all the spectral yellow patches are the same. With this amount of acetate, although the colour matches, the brightness does not match and since it is very confusing to try to match colour when brightness appears to be different, the brightness of the yellow patch 7*a*, 8*a* or 9*a* is made to give a brightness match; this is done in the above chart by using more eosin and naphthol green in 7*a*, 8*a* or 9*a* but it can be done equally well by adding a neutral grey over a patch of the same constitution as the yellow patch in No. 5, as shown in the second table. Similarly the density may be matched for any of the other pairs of patches.

By way of illustration the absorption curves of the patches of Nos. 1, 5 and 9 are given in Figure 2; for instance the portion of the curve of No. 1 which represents the spectral yellow patch is marked 1*a*, and the portions representing the other patch are marked 1*b* which also appears yellow to some observers. The absorption curves of pairs A, B and C are given in Figure 3 and for pairs D, E and F in Figure 4.

Between the patches in each pair is an opaque strip the purpose of which is to reduce the observer's discrimination to brightness and colour just for the pair which should appear to him to be the best match. It is desirable because untrained observers often show a disinclination to decide on a "best match."

In the operation of the above apparatus the lamp is energised in the usual way and the chart is viewed by the person to be tested in a darkened or semi-darkened room. The operator first asks the observer which of the pairs Nos. 1 to 9 appear to him to be the best match for colour and brightness.

Then he is asked to view the patches A, B and C, and whether any of these appear to him to match for colour and brightness.

Lastly he is asked to view the patches D, E and F, and again is asked whether any pairs are matched. If he rejects A, B, C, D, E and F then the pair 1 to 9 acceptable defines his colour

vision; numbers 3, 2 and 1 showing protanomalous trichromatism increasing in that order; numbers 4, 5 and 6 show normality with number 5 as the mean and 4 and 6 as the limits; and numbers 7, 8 and 9 showing increasing deuteranomalous trichromatism.

Acceptance of either A, B or C but not D, E and F show dichromatism; A defines the protanope, B the deuteranope and C the tritanope.

Acceptance of either D, E or F show monochromatism, D defines a monochromat with a luminosity curve similar to the protanope, E for a deuteranopic luminosity curve and F for a scotopic luminosity curve i. e. showing cone blindness.

Although the various pairs of colour patches can according to the invention be arranged to form a tablet in which all the patches are irremovable from the tablet, it may often be desirable, for any selected pair or pairs of patches to be capable of being removed or masked or for some or all of the pairs to be interchangeable as regards their position in the tablet. The object of this is to prevent one observer under test from telling another observer known to have abnormal eyesight which pairs he should say are colour matches if he desires to mislead an examiner to the effect that his eyesight is normal.

For instance, the pairs can be arranged in groups of several pairs in a group and several groups being interchangeable, for example if nine pairs are used, these can be made in three groups of three pairs in each group and such groups can be interchangeable.

All the dyes mentioned herein are sold by Messrs. Imperial Chemical Industries, Limited, and have the following compositions with reference to Rowe's Colour Index.

Tartrazine N.250	Colour Index No. 640
Napthalene Bordeaux B.110	Colour Index No. 88
Soluble Blue AS	Colour Index No. 707
Napthol Green BNS	Colour Index No. 5
Flourescein 10092	This is composed of Dyestuffs Colour Index Nos. 786 and 768
Eosin 2524	This is composed of Dyestuffs Colour Index Nos. 768 and 774
Methyl Violet 28925	This is composed of Dyestuffs Colour Index Nos. 680 and 681

What I claim is:

1. A device for testing color discrimination of the human eye, said device having a plurality of pairs of closely adjacent patches of color filter materials and including at least three such pairs capable of being transilluminated by white light, one patch of each pair when so illuminated transmitting substantially only a yellow wavelength band of light of wavelength between 570 and 600 mμ and appearing yellow to the normal human eye, and the other three patches of said three pairs transmitting both a red wavelength band of light of wavelength about 600 mμ and a green wavelength band of light of wavelength between 520 and 550 mμ, but not appreciably transmitting said yellow light, or any other visible wavelength band except the said red and green wavelength bands, one of said three other patches, namely the other patch in one of the three pairs, transmitting said red and green bands in a proportion such that it appears to the majority of people as about the same color as the adjacent yellow patch of that pair, another of said three other patches, namely, the other patch in a second one of the three pairs, transmitting a higher proportion of red than in said one of the three pairs so that it matches its yellow patch only for people with anomalous vision with a degree of red deficiency and the third one of said three other patches, namely, the other patch in the third one of the three pairs, transmitting a higher proportion of green than in said one of the three pairs so that it matches its yellow patch only for people with anomalous vision with a degree of green deficiency.

2. Apparatus according to claim 1 including at least one pair of patches in addition to the said three pairs of patches in which one patch emits only said yellow band and the other patch emits only said red band.

3. Apparatus according to claim 1 including an additional pair of patches for detecting tritanopes consisting of a patch emitting only substantially spectral green and a patch emitting blue green.

4. Apparatus according to claim 1 including an additional pair of patches for detecting monochromats consisting of a patch emitting only said yellow band and a patch emitting substantially spectral blue.

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Certificate of Correction

Patent No. 2,453,335. November 9, 1948.

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It is hereby certified that errors appear in the above numbered patent requiring correction as follows:

Column 5, line 53, for "Co" read *Co.*; column 7, line 65, claim 1, for the word "about" read *above*;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 8th day of March, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.