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PROVISIONAL SPECIFICATION
No. 19562, A.D. 1933.

Improvements in or relating to Colour Photography

We, DUFAYCOLOR LIMITED, of 19, New Bridge Street, London, E.C. 4, a British Company, THOMAS THORNE BAKER, of The Hut, Hatch End, Middlesex, a British Subject, PAUL LAMBOIT, of Falmouth House, Weech Road, West Hampstead, London, N.W. 6, a British Subject, and WALTER CHAPMAN, a British Subject, of 71, Grovelands Road, Palmer's Green, London, N. 13, do hereby declare the nature of this invention to be as follows:—

This invention consists of improvements in or relating to colour photography. The invention is applicable to the reproduction, in natural colours, of transparencies or of prints to be viewed by light reflected from a permanent base from master transparencies of the type in which a colour screen or reseau is associated with the master emulsion.

The colour elements of master transparencies are often found in practice to transmit a proportion of light common to two or more of the primary colours of the screen. For example the red elements of a master transparency may transmit a proportion of light which is also transmitted by the green elements. In order, however, to reproduce satisfactorily the colours in a print produced from the master transparency it is important that the sensitive emulsion of the print or portions of the print which is to correspond to each of the primary colours should not record any of the light common to two or more of the primary colours of the screen.

The invention accordingly provides the method of printing from transparencies of the colour screen type which comprises the step of using a printing light of colour containing substantially no component of colour common to two or more of the primary colours of the screen.

According to one form of the invention a filter having elements which each transmit light of colour corresponding to one of the primary colours of the colour screen but which transmit substantially no light common to two or more of the said primary colours is placed in the path of the beam of light used for printing. Preferably the filter elements are in the form of sectors of a disc which is rotated in the path of the beam of light.

The following is a description, by way of example, of one way of carrying the invention into effect in the printing of a cinematograph film in natural colours.

A master positive transparency in natural colours is produced by exposing, developing and reversing a colour screen film produced by the method described in Patent No. 322,432. In order to obtain for this transparency a film having sufficient speed for the taking of moving pictures it is necessary for the colour elements of the screen to transmit light having as wide a band of wave-lengths as possible and it is even found desirable that the wavelengths transmitted by the various colours of the screen should overlap slightly. Thus in the present example the green elements transmit some light which is also transmitted by blue elements and some which is also transmitted by the red elements.

It is important, however, in order to obtain true reproduction of the colours in the copy to ensure that light which is transmitted by two or more colours of the master screen should not act on the copying emulsion.

The master transparency in the present example therefore is printed with light containing in suitable proportions the three primary colours of the master screen but containing no light of the overlapping wavelengths.

A convenient way of providing light of the desired wavelengths is to insert a filter disc either between the light source and the master transparency or between the master and the copy if projection printing is used. This disc is divided into three sectors each having a gelatine layer dyed to transmit one of the three primary colours of the master screen but without any of the wavelengths that overlap in the master screen. The disc is rotated in the path of the rays and eliminates from the beam any light of colour which would be transmitted by two of the

[*Price* 1/-]

colours of the master screen.

The disc may be rotated once per exposure or it may, preferably, be rotated at a high speed so as to ensure a good mixture of the three colours.

By varying the area of each coloured sector the ratio of three colours can be conveniently adjusted to allow for the colour sensitivity of the copying emulsion, the light transmission of the filters themselves or of the elements of the colour screens or for the composition of the light source.

The cinematograph film in the above example is printed onto a copying film of the same type which is then developed and reversed to form a positive but the invention is also applicable to the production of prints on paper or the like by a method in which several separate colour separation records are produced for example the method described in Specification No. 17733/33 (Serial No. 406,663).

Dated this 10th day of July, 1933.
BOULT, WADE & TENNANT,
111 & 112, Hatton Garden, London,
E.C. 1,
Chartered Patent Agents.

PROVISIONAL SPECIFICATION
No. 5242, A.D. 1934.

Improvements in Colour Photograph Reproduction

We, WALTER CHAPMAN, of 71, Grovelands Road, Palmer's Green, London, N. 13, and THOMAS THORNE BAKER, of The Hut, Hatch End, Middlesex, and PAUL LAMBOIT, of Falmouth House, Weech Road, West Hampstead, London, N.W. 6, all British Subjects, and DUFAYCOLOR LIMITED, of 19, New Bridge Street, London, E.C. 4, British Company, do hereby declare the nature of this invention to be as follows:—

Our present invention relates to an improvement in the apparatus used when making copies on multi-coloured screen transparent material from multi-coloured screen master transparencies. Such copies can be made either by contact or projection printing, the master photographs being either negatives or positives. The invention may be used for any pattern mosaic screen and for a multicolour system, but we are more concerned with a regular geometric pattern screen and a tricolour system and we will therefore confine our description to these. We have found four difficulties when making copies of such a screen. The first is the formation of dark and light bands on the copies; this effect is technically called moire. The second is the dilution or degradation of the colours in the copies due to the fact that considerable overlap in the colour transmission of the colour screen elements in both original and copy is allowed, in the original to allow of a short exposure, and in the copies to give greater screen brilliancy when projected. The third is the problem of obtaining the correct colour value printing light from say a tungsten incandescent filament in which the colour mixture is approximately red 150, green 110 and blue 30 to suit a colour screen and panchromatic emulsion which requires for correct colour reproduction say red 150, green 140, blue 120. The fourth difficulty is that of moderating the printing light to allow for varying densities in the master copy without varying the colour light value. The use of a rheostat as for black and white photography is not permissible as the colour temperature varies with the resistance used; the more resistance introduced into the circuit, the greater the proportion of red in the printing light.

The present invention is broadly characterised by the provision of means for successively passing variable light ray deviating elements across the path of the projected light beam when making colour copies from colour screen masters in which there is a simultaneous printing of a number of colours.

The preferred form of our invention may be said to consist in the provision of a rotating transparent disc formed with a plurality of variable deviation elements and light filters each of which only transmits light which is transmitted by one colour of the colour screen elements and absorbs the light which is common to one or more of the other colour screen elements.

This invention may be said to comprise a new and improved rotating colour disc for use in the light path and adapted to be located between the illuminant and the master photograh to overcome the four difficulties enumerated hereinbefore.

For three colour photography the device consists of a transparent disc which rotates one or more times during each picture exposure. This disc is covered with prisms leaving occasional parallel surfaces, the prisms being so orientated relative to the geometric colour screen that the light passing through the disc is deflected to either side of the axis of the

printing light path and also passes along it; the deviations thus produced being such as to obviate the formation of moire in the copy photograph.

We prefer to place a light condenser in the light path immediately in front of the master photograph. To avoid the colour degradation we cover the surface of the disc with one or more sets of special tricolour filters, these we call the main filters. We so select these main filters for absorption that any one of them for example the red, does not transmit the rays which are common to the other two colour screen elements, in this case the blue and green elements. Superimposed upon these sharp cut tricolour filters are placed other, secondary, light filters, each of which have the same colour as that on which it is placed, but not necessarily transmitting such a sharp cut portion of the spectrum. These secondary filters will slightly reduce the total light transmission, and tend to give a little sharper cut spectrum value. These secondary filters can be rotated relative to the main filters so as to overlap the adjacent main filter colour and this overlapping portion will render the light passing through it photographically impotent.

The areas allocated to each colour of the combined main and secondary filters are such that the final printing light has the correct colour value, and the rotation of each of the colours of the secondary filters relatively to the main filters must be such as to keep the ratio between the light transmitting area of each of the colours a constant.

This relative rotation between the two filters can be operated by hand or automatically, for example through the medium of the known method of notches on the edge of the master film.

The secondary filters need not have the same total area as the main filters for example if the desired light moderation is from full to half light and if the colour areas be assumed as red 2, green 4, blue 6, and the adjacent colours be red green, green blue, blue red, and secondary filter red rotates on to green, green rotates on to blue, and blue rotates on to red, then the areas of the secondary filters need be only red 2, green 3, blue 1, or alternatively for this particular colour light mixture the red secondary filter could be omitted and a blue of an area of 1 could be provided to overlap half of the red area, a blue of an area 2 to overlap half of the green area and a green of an area 3 to overlap half of the blue area.

Dated this 16th day of February, 1934.

HUGHES & YOUNG,
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Agents for the Applicants.

COMPLETE SPECIFICATION

Improvements in or relating to Colour Photography

We, DUFAYCOLOR LIMITED, a British Company, of 19, New Bridge Street, London, E.C. 4, THOMAS THORNE BAKER, a British Subject, of The Hut, Hatch End, Middlesex, PAUL LAMBOIT, a British Subject, of Falmouth House, Weech Road, West Hampstead, London, N.W.6, and WALTER CHAPMAN, a British Subject, of 71, Grovelands Road, Palmer's Green, London, N.13, do hereby declare the nature of this invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement:—

This invention consists of improvements in or relating to colour photography and is applicable to the reproduction, in natural colours, of transparencies from master transparencies of the type in which a multi-colour screen is associated with the master emulsion.

The colour elements of master transparencies of this type are often arranged in practice to transmit a proportion of light common to two or more of the primary colours of the screen. For example the red elements of a master transparency may transmit a proportion of light which is also transmitted by the green elements. In order, however, to reproduce satisfactorily the colours in a print on multi-colour screen material produced from the master transparency it is important that the sensitive emulsion of the portions of the print which are to correspond respectively to each of the primary colours of the master screen should not record any of the light common to two or more of the primary colours of the master screen.

With this requirement in view the invention provides the method of printing a photographic copy on multi-colour screen material from a multi-colour screen master record in which the colour transmission bands of the screen colours overlap which comprises using, as the printing light, a beam of light from which colour common to two or more of the colours of the master screen has been substantially eliminated by passing in succession across the beam of light a series of

colour filters having colour transmission bands corresponding respectively to the colours of the master screen but each having substantially no colour transmission corresponding to the overlapping portions of the colour transmission bands of the master screen colours. Preferably the colour filters are carried on a disc rotated in the path of the light beam.

A well-known difficulty that occurs in the printing of multi-colour screen material on to multi-colour screen material is the formation of dark and light bands on the copies: this effect is technically known as moire. According to a feature of the preferred form of the invention a succession of light deviating elements are also passed across the beam of light and are arranged to cause small successive deviations of the light in different directions for the purpose of reducing moire.

When black and white photographs are being printed it is customary to vary the exposure by controlling the intensity of an electric printing light by means of a rheostat inserted in the lighting circuit. It is found, however, that this method is unsuited for printing coloured photographs of the kind to which this invention relates since the use of a rheostat varies the temperature of the light source and consequently the colour of the light emitted. This difficulty is overcome according to a preferred feature of the present invention by providing means (e.g. a neutral grey screen) in the light beam for reducing, by absorption of a portion of the light, the intensity of the light reaching the copy, without altering the colour of the light.

The invention includes apparatus for use in carrying out the method described above and comprising a disc rotatable in the path of the printing light and carrying colour filters having colour transmission bands corresponding respectively to the colours of the master screen but each having no colour transmission corresponding to the overlapping portion of the colour transmission bands of the master screen colours.

The invention will now be described, by way of example, with reference to the accompanying drawings in which:—

Figure 1 is a diagram showing the relative positions of various parts of the apparatus;

Figure 2 represents a combined filter disc and shutter;

Figure 3 represents a filter disc having a plurality of sets of filter elements;

Figure 4 is a view of the disc shown in Figure 3, with the coloured sectors omitted for simplicity and showing diagrammatically the arrangement of the light deviating elements;

Figure 5 is a section along the line 5—5 of Figure 4;

Figure 6 represents the disc shown in Figure 3 with a second set of colour filters arranged for adjustment to reduce the light intensity and shown in the position of maximum intensity;

Figure 7 is a diagram showing the relative positions of the two sets of colour filters shown in Figure 6;

Figure 8 represents the two sets of colour filters shown in Figure 6, but in the position of minimum light intensity, and

Figure 9 is a diagram showing the relative positions of the two sets of filters as shown in Figure 8.

The invention is equally applicable to the printing of multi-colour screen material either in contact with similar material or by projection on to multi-colour screen material. The invention will, however, be described with reference to projection printing as shown in Figure 1. A master positive transparency is produced by exposing, developing and reversing a colour screen film produced by the method described in British Specification No. 322,432. The film on which this transparency is made, in order to provide sufficient speed for the taking of moving pictures, is arranged in such manner that the colour transmission bands of the elements of the screen overlap. Thus, in the present example the green elements transmit some light which is also transmitted by the blue elements and some which is also transmitted by the red elements. If, therefore, due to lack of registration during printing, a green element falls on a red or blue element of the copy screen, light which is common to the two colours will affect the copy emulsion under the red or blue element and produce a false record.

It is important, therefore, in order to obtain true reproduction of the colours in the copy, to ensure that light which is transmitted by two or more colours of the master screen should not be contained in the printing light.

The light source 2 employed in this example is an ordinary half-watt printing lamp and the light is condensed by means of a lens system 3 on to the master film 1, and an image of the picture of this film is focussed by means of a lens system 4 on to the copy film 5. If desired an image duplicating or diffusing device 6 may be employed. A rotating shutter 7 having a sector of 240° opaque is used in the usual manner to cut off the light during movement of the film.

Inserted between the light 2 and the lens 3 is a colour disc 8. This disc may be as shown in Figure 2 consisting of a sector C of 240° which may be left clear, in which case the disc is synchronised with the shutter 7 and so arranged that the portion C passes through the printing light at the same time as it is cut off by the shutter or it may be made opaque in which case the shutter may be dispensed with. The remaining portion of the disc is divided into three sectors R, G, B, each comprising a filter element of colour corresponding to one of the colours of the screen elements of the master film but so sharply cut as not to transmit any light transmitted by any of the other colours of the screen. The angles of the sectors R, G, B, are so selected that a correct colour balance is obtained in the copy and are arranged to compensate for any excess or deficiency of the several colours in the illumination, the over-all tints of the master and copy screens, the colour sensitivity of the copy emulsion and the light transmissions of the filters themselves.

When it is preferred not to synchronise the disc with the shutter (for example, when it is desired to rotate the disc a considerable number of times for each exposure to obtain good mixing of the colours) the form of disc shown in Figure 3 is employed. In this form of the disc there are six equal sectors each divided into red, green and blue parts shown respectively as R, G, and B, and forming sharply cut filters as described above. It is found desirable to employ at least three, and preferably six, sectors since if the disc is not rotating in synchronism with the shutter there may for example, be a blue sector interposed in the light beam both at the beginning and the end of the exposure and consequently if this sector is of large angular width the exposure to blue may be excessive.

As shown in Figure 5, the disc is made up of a circular sheet of plain glass 9, a circular sheet of glass 10, and, between these, stained gelatin filter elements 11. The two discs are mounted on a spindle 12 and held in position by two metal discs 13. The sheet glass 10 is divided into six equal sectors as indicated in Figure 4. Two of these sectors 14, 15 are left parallel while the remaining are ground to form prisms. The sector 16 is ground to form a prism with its axis parallel to the arrow shown in the sector and having its thicker end at the periphery of the disc so that the light passing through the sector is deviated in the direction of the arrow. The angle of the prism is made very small and may be for example about $1\frac{1}{2}°$. The sector 17 is ground in similar manner but in this case the angle is half that employed for sector 16. Sector 18 is ground with its axis parallel to the arrow in that sector, but with its thicker end at the centre of the disc so that light passing through the sector is deviated towards the centre of the disc—the angle of this prism is similar to that for sector 16. Sector 19 is ground similar to sector 18, but in this case the angle is only half that employed in the case of sector 18. For convenience in the lay-out of the apparatus the picture frame 20, is arranged with its shorter sides parallel to but slightly offset from a vertical diameter of the disc as shown in Figures 3 and 4 and to compensate for this the several prisms are not ground with their axes bisecting the sectors, but as shown in the drawings—i.e. when the radius bisecting a sector passes through the centre of the picture frame the axis of the prism is parallel to the shorter side of the frame.

The effect of the prisms is to cause variable deviations of the light beam and it will be seen that if the disc shown in Figures 3 to 5 be rotated in the anti-clockwise directon then in the position shown the light is deviated the maximum amount upwards and as the disc rotates the light is deviated to the left with increasing amount until the sector 14 comes in front of the beam when there will be no deviation. When the sector 18 starts to come into the beam the light will be deviated downwards and to the left and as rotation continues it will reach the maximum downward deviation and then deviate to the right and still downwards. Similar deviations will occur as the other sectors pass through the beam but the amounts of deviation will vary in accordance with the angles of the prisms.

In order to control the light intensity two neutral grey screens 21 may be inserted in the light beam either together or separately and these screens are given different opacities so that various intensities of light may be obtained by employment of one, or other, or both of the screens.

An alternative method of controlling the light intensity is shown in Figures 6—9 in which a series of secondary light filters B_2, B_{22}, and G_2 are placed in front of the main filters B_1, R_1, G_1. These secondary filters are of colour corresponding to the main filters but need not be so sharply cut and consequently when they are in position over a filter of similar colour as shown in Figures 6 and 7 they will cause very little extra absorption of light.

In this example the secondary filters

are placed for minimum absorption and maximum light intensity as shown in Figures 6 and 7, i.e.,

One green G_2 with an angular width of 3 units on G_1 which has an angular width of 4 units and having one edge in juxtaposition with one edge of B_1. One blue B_2 on B_1 (which has an angular width of 6 units) with an edge adjacent to G_1 and having an angular width of 2 units and a second blue B_{22} on B_1 with an edge adjacent to R_1 and having an angular width of 1 unit. There is no secondary light filter overlying the red R_1 (which has an angular width of 2 units). If now G_2 be caused to move by any desired mechanism over B_1, B_2 to move over G_1 and B_{22} to move over R_1 with a ratio of angular movements of 3, 2 and 1 respectively then they will reach a position of maximum effect at the position shown in Figures 8 and 9, when B_2 covering half of G_1 will absorb the light transmitted by half of G_1, G_2 will stop half of the light transmitted by B_1 and since B_{22} has an area of 1 unit and R_1 has an area of 2 units, one half of the light transmitted by R_1 will also be stopped.

In one specific case according to the invention which gave good results the light source employed was a half-watt projection type lamp having an emission approximately equivalent to Red 150 Green 110 and Blue 30. The colour transmissions of the master and copy screen elements as obtained from a spectrograph wedge negative were Blue 390—540$\mu\mu$ with a maximum at 455$\mu\mu$, Green 455—615$\mu\mu$ with a maximum at 520$\mu\mu$ and Red 565—710$\mu\mu$ with a maximum at 625$\mu\mu$ and the colour transmissions of the colour filters also as obtained from a spectrograph wedge negative were chosen to be:—Blue a maximum at 415$\mu\mu$ and no transmission above 455$\mu\mu$, Green 535—565$\mu\mu$ with a maximum at 555$\mu\mu$ (a standard Wratten "Mercury Green" filter) and Red having no transmission below 630$\mu\mu$ and a maximum at 720$\mu\mu$. With these filters each 60° sector of the filter disc was divided into Blue 34°, Green 16° and Red 10°. The colour sensitivity of the copy emulsion as obtained from a spectrogram using a half-watt light had the following values:—

Wavelength	Relative Density.
400	0
450	0.5
490	0.25
525	0.7
550	0.6
580	0.4
610	0.55
645	0

As described above the invention has been applied to the case where false reproduction of the colours is caused by over-lapping of the transmission bands of the master screen. False reproduction may also occur (even when the transmission bands of the master screen do not overlap) if the transmission bands of the master and copy screens have not the same values. Thus the transmission of the green of the master screen may extend over a portion of transmission of the blue of the copy and consequently a portion of the light passed by the master green will affect the emulsion behind the blue of the copy. Accordingly in a modified form of the invention the printing light used consists of a beam of light from which colour common to a colour of the master screen and a different colour of the copy screen has been substantially eliminated by passing in succession across the beam of light a series of colour filters having colour transmission bands corresponding respectively to the colours of the screens but each having substantially no colour transmission corresponding to the overlapping portions of the colour transmission bands of the master and copy screen colours of different colour.

Although in the above examples the invention has been described with reference to a master positive it is of course equally applicable to the case in which the master is a negative.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. The method of printing a photographic copy on multi-colour screen material from a multi-colour screen master record in which the colour transmission bands of the screen colours overlap which comprises using, as the printing light, a beam of light from which colour common to two or more of the colours of the master screen has been substantially eliminated by passing in succession across the beam of light a series of colour filters having colour transmission bands corresponding respectively to the colours of the master screen but each having substantially no colour transmission corresponding to the overlapping portions of the colour transmission bands of the master screen colours.

2. The method of printing as claimed in claim 1 wherein the colour filters are carried on a disc rotated in the path of the light beam.

3. The method according to claim 1 or claim 2 wherein a succession of light deviating elements are also passed across

the beam of light and are arranged to cause small successive deviations of the light in different directions.

4. The method according to claim 3 wherein the light deviating elements are also carried on the disc as claimed in claim 2.

5. The modification of the method claimed in claim 1 in which the colour transmission bands of one or more of the master screen colours (which may or may not themselves overlap) overlap the colour transmission bands of one or more of the copy screen colours of different colour which comprises using, as the printing light, a beam of light from which colour common to a colour of the master screen and a different colour of the copy screen has been substantially eliminated by passing in succession across the beam of light a series of colour filters having colour transmission bands corresponding respectively to the colours of the screens but each having substantially no colour transmission corresponding to the overlapping portions of the colour transmission bands of the master and copy screen colours of different colour.

6. The method according to any one of the preceding claims wherein the relative areas of the colour filters are so selected as to produce a correct colour balance in the copy.

7. Apparatus for use in carrying out the method according to any one of the preceding claims comprising a disc rotatable in the path of the printing light and carrying colour filters having colour transmission bands corresponding respectively to the colours of the master screen but each having no colour transmission corresponding to the overlapping portions of the colour transmission bands of the master screen colours.

8. Apparatus according to claim 7 wherein means are provided in the light beam for reducing, by absorption of a portion of the light, the intensity of the light reaching the copy without altering the colour of the light.

9. Apparatus according to claim 8 wherein the intensity reducing means comprise two or more neutral grey screens having different opacities and arranged for use separately or in combination.

10. Apparatus according to claim 8 wherein the intensity reducing means comprise a second set of colour filters arranged for adjustment with respect to the first set substantially as described.

11. Apparatus according to any one of claims 6—10 and comprising a series of prisms carried on a disc rotatable in the path of the printing light and so arranged as to deviate the light in different directions on rotation of the disc.

12. Apparatus according to any one of claims 6 to 11 wherein the disc is formed of two glass plates having between them as a sandwich the filter elements and one of which is ground to form light deviating elements.

13. The method of printing photographic copies from multi-colour screen material substantially as described.

14. A photographic copy on multi-colour screen material when produced by the method claimed in any one of the preceding claims.

Dated this 28th day of June, 1934.

BOULT, WADE & TENNANT,
111 & 112, Hatton Garden, London,
E.C. 1,
Chartered Patent Agents.

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