June 3, 1924. 1,496,374

L. A. JONES

COLORIMETER

Filed May 6, 1921 4 Sheets-Sheet 1

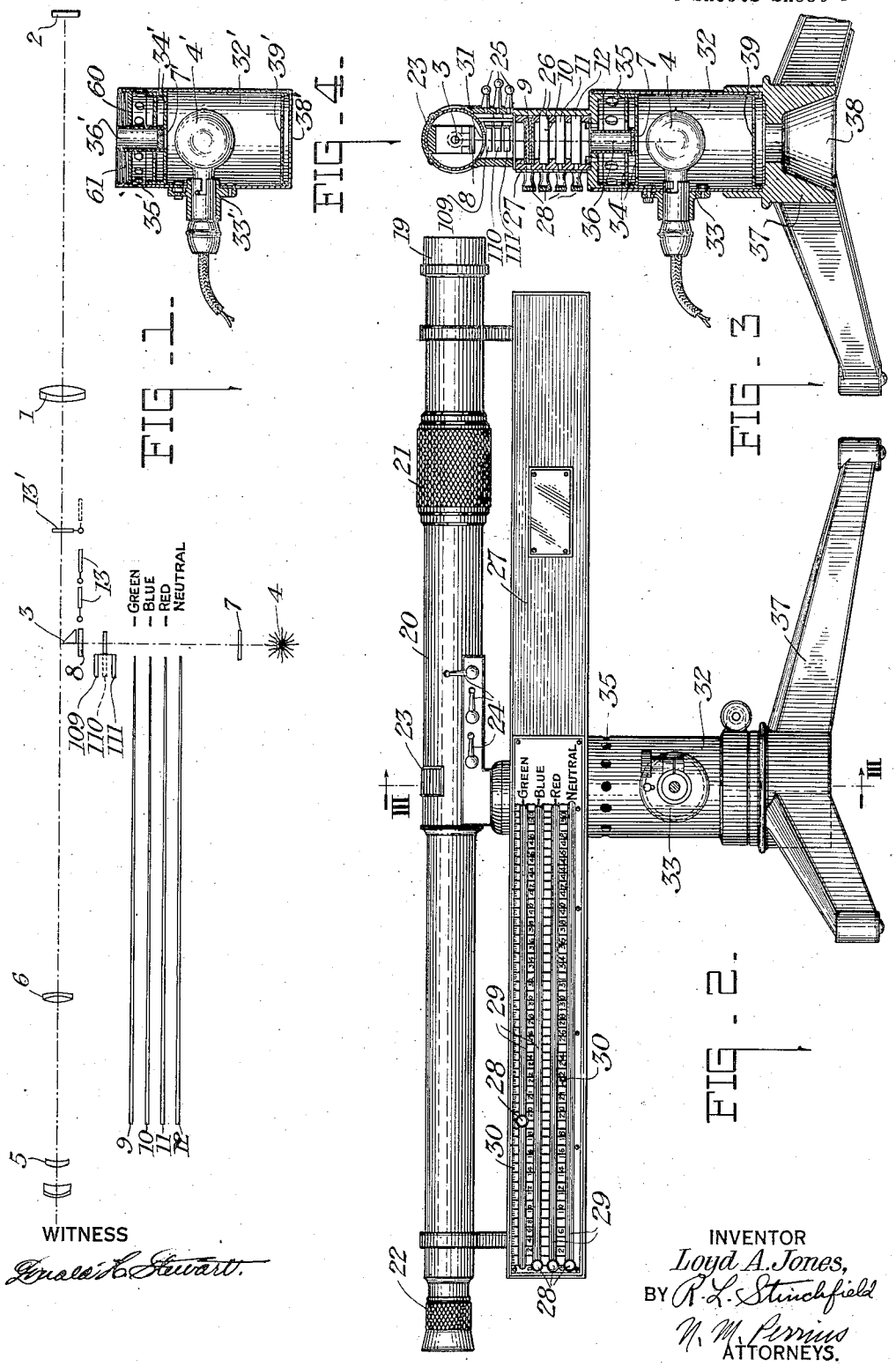


FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

WITNESS

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COLORIMETER

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FIG. 5.

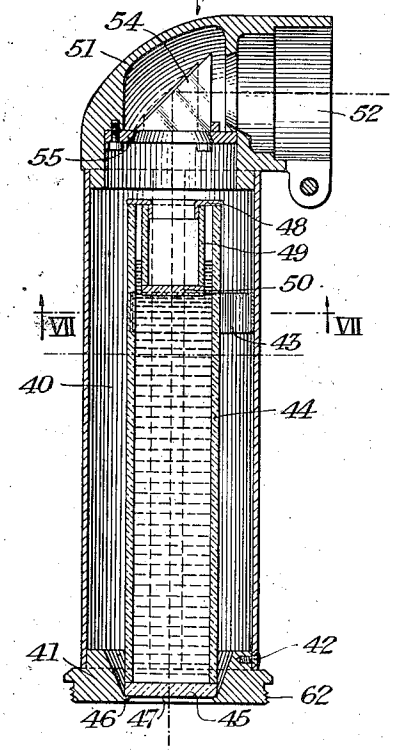


FIG. 6.

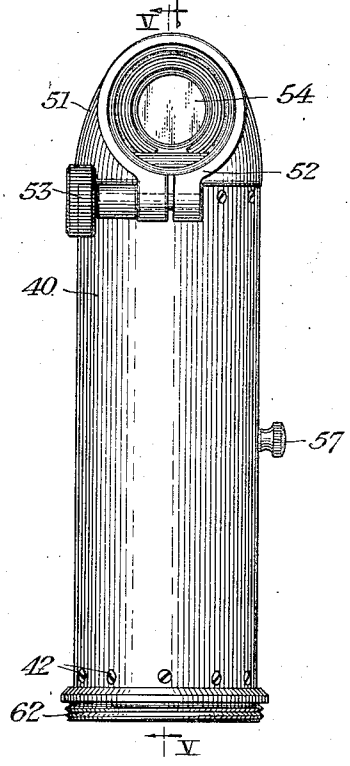


FIG. 7.

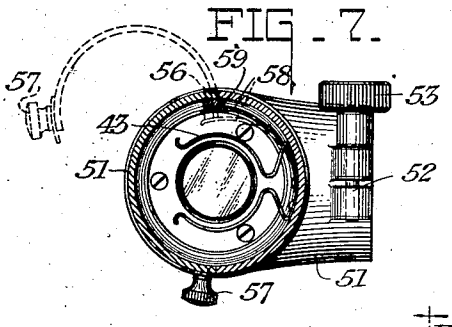


FIG. 8.

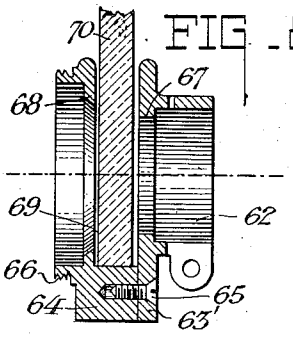
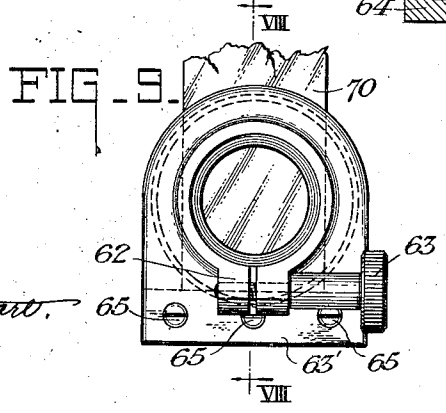


FIG. 9.



WITNESS

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L. A. JONES

COLORIMETER

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FIG. 10.

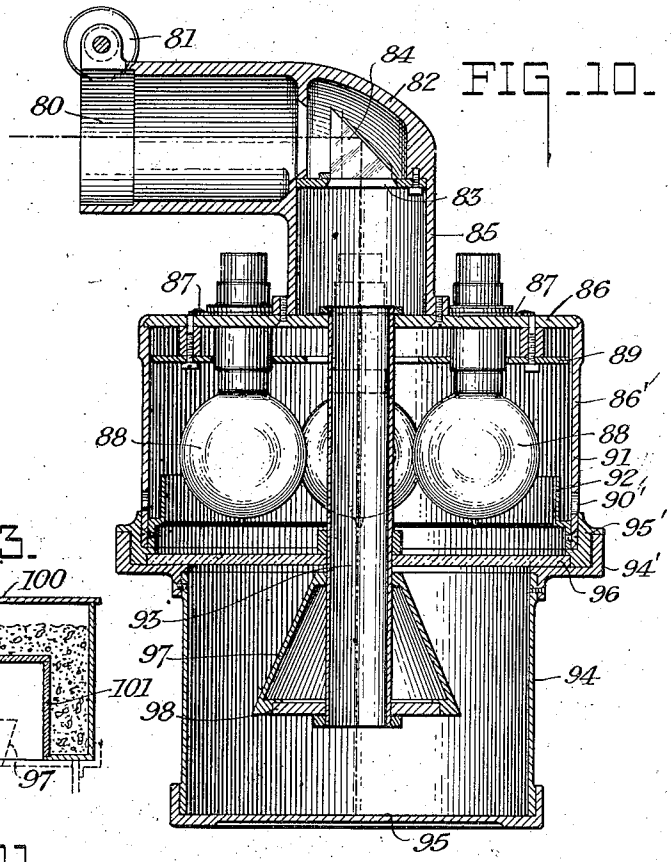


FIG. 13.

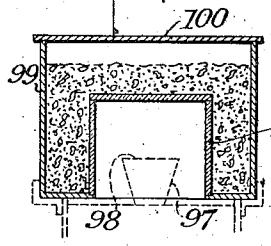
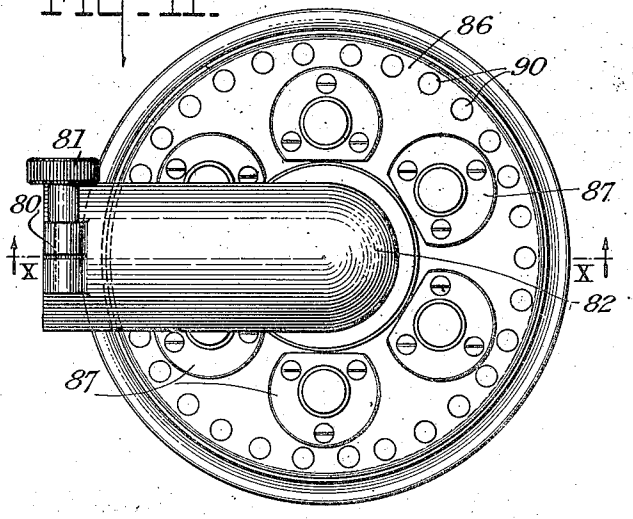


FIG. 11.



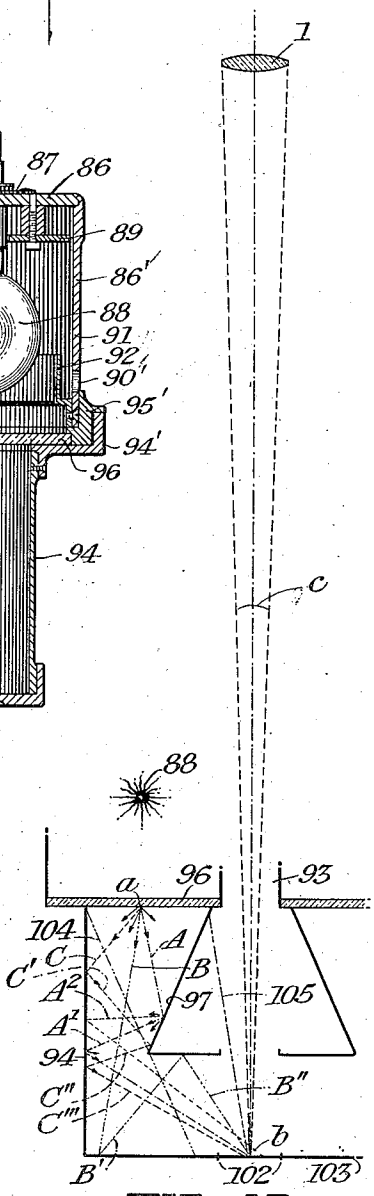


FIG. 12.

WITNESS

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L. A. JONES

COLORIMETER

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FIG. 14.

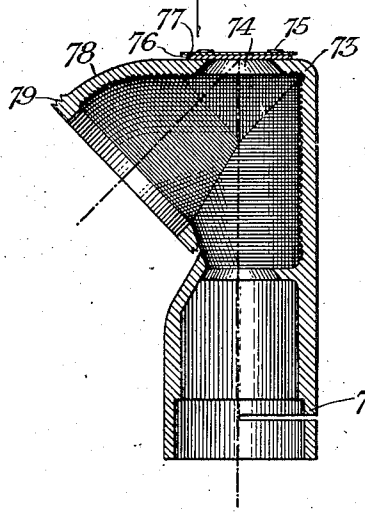


FIG. 15.

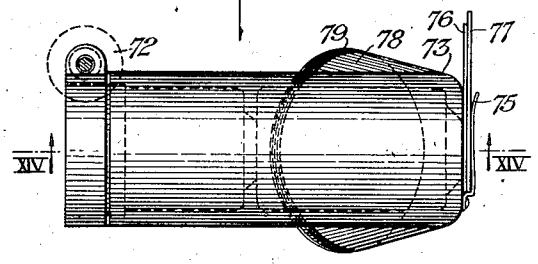


FIG. 16.

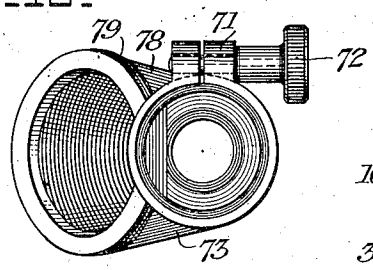


FIG. 17.

WITNESS

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ATTORNEYS.

Patented June 3, 1924. 1,496,374

UNITED STATES PATENT OFFICE.

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COLORIMETER.

Application filed May 6, 1921. Serial No. 467,404.

To all whom it may concern:

Be it known that I, LOYD A. JONES, a citizen of the United States of America, residing at Rochester, in the county of Monroe and State of New York, have invented certain new and useful Improvements in Colorimeters, of which the following is a full, clear, and exact specification.

This invention relates to a colorimeter and more particularly to a colorimeter operated on the subtractive principle,—that is to say, one in which a color to be inspected is compared with white light from which light rays of certain wave lengths have been subtracted, leaving such wave lengths as will give to the eye the same color impression as the specimen examined.

The object of this invention is to provide an instrument of this type which will be simple in construction and in operation, which will give dependable results in the hands of an operator who is not highly trained, which is adapted for use with materials of many different kinds and which has a provision for adjustment to different conditions, and to which attachments of appropriate design may be readily secured, such attachments being also a part of my invention.

Other objects of this invention and the way in which these objects are attained will become evident in the specification following, in which reference will be made to the accompanying drawings throughout which the same reference characters are used to denote the same parts.

Fig. 1 is a diagram illustrating the principles of my invention;

Fig. 2 is a side elevation of the colorimeter;

Fig. 3 is a section on line III—III of Fig. 2;

Fig. 4 is a section of a lamp house used with certain attachments;

Fig. 5 is a section taken on line V—V of Fig. 6, showing the construction of an attachment;

Fig. 6 is a side view of the attachment shown in Fig. 5;

Fig. 7 is a view upwardly taken on line VII—VII of Fig. 5;

Fig. 8 is a section of another attachment, taken on line VIII—VIII of Fig. 9;

Fig. 9 is a view from the right of Fig. 8;

Fig. 10 is a section of a still different attachment, taken on line X—X of Fig. 11;

Fig. 11 is a plan view of the attachment shown in Fig. 10;

Fig. 12 is a diagram used to illustrate the operation of the attachment shown in Figs. 10 and 11;

Fig. 13 is a section showing a modified form of the attachment shown in Fig. 10;

Fig. 14 is a section of still another attachment taken on line XIV—XIV of Fig. 15;

Fig. 15 is a view from the right of the attachment shown in Fig. 14;

Fig. 16 is a view from the left of Fig. 15, and

Fig. 17 is a diagram of a different arrangement of the colorimeter parts.

The sensation of light may be said to consist of two factors,—brightness and color, the former being dependent on intensity and the latter upon the quality of the radiated light waves. The quality of the radiation may be specified by stating its wave length in case radiation of but one frequency is present; or, in case it is composed of a mixture of frequencies by stating the wave length and intensity of each of the component elements. This constitutes complete objective specification of the quality of the radiation and hence of the color. The retina, however, being a synthetic rather than an analytic receiving organ, does not recognize the individual component parts of the radiation as such, but receives the mixed radiation as a single stimulus producing a single sensation. This color factor may be split into two components, hue and saturation, hue referring to the position in the spectrum of the dominant quality, and saturation referring to the approximation to monochromatism. The patent to Nutting, 1,026,878, defines these terms and describes a method of measuring these factors.

Various methods of giving a specification of color have been proposed from time to time, such as that outlined above, or additive methods in which light of three colors is added in varying proportions, or subtractive methods in which three color screens are simultaneously placed in a beam of white light to obtain by a subtractive method the desired color. I have found that with three properly selected screens in the

form of optical wedges any hue can be matched, and moreover that only two of such screens need to be used at a time.

In Fig. 1 is represented a diagram showing the arrangement of the essential parts of my subtractive colorimeter. The lens 1 forms an image of the surface 2, the color of which is to be measured. An image of 2 is formed at the photometer head 3 which can be of any design, and which, in this case, comprises merely a reflecting prism for a light source 4 which covers half of the field. Through the optical system at 5 and 6, constituting an eyepiece, the image of 2, formed above the prism at 3, is viewed in comparison with the light from 4 falling upon the prism. 7 is a diffusing screen placed in front of the light source 4. A "daylight filter" 8 is used to reduce the color of the light illuminating the photometer head from the source 4 to match a standard white. Four gelatine wedges are placed, as indicated at 9, 10, 11 and 12, each wedge being adjustable in a horizontal direction, so that it may be inserted to any extent or withdrawn completely from the path of the beam of light from the source 4 to the photometer head at 3. A set of two neutral gray filters is provided at 13, in order that the intensity of the light from the object may be controlled, and 13′ is a daylight filter used to correct the light from the object to a standard condition when a lamp is used to illuminate it. As indicated in the figures, the colored wedge 9 is minus-green, that is, it transmits red and blue light but absorbs light in the green portion of the spectrum. Wedge 10 is minus-blue, transmitting red and green. Wedge 11 is minus-red, transmitting green and blue. Wedge 12 is of a neutral tint, transmitting waves of all lengths non-selectively. If light is transmitted through the wedge 9 only, it is obvious that the green will be absorbed and the red and blue transmitted, giving light of a violet color. When wedges 9 and 10 are both in the path of light, one will absorb the green and another the blue light, so that only the red will be transmitted, and by inserting these wedges to different degrees, any shade from violet through the reds and orange to yellow may be obtained, yellow being the color sensation produced by the red and green transmitted by the wedge 10 only. When wedge 11 only is used, a blue-green sensation is obtained, and by combining wedges 10 and 11 all colors from yellow through the greens to blue-green may be obtained. By combining wedges 11 and 9 there may be obtained all colors from blue-green through the blues to violet of wedge 9 alone. In this way, by proper adjustment, any color whatever may be matched by two wedges only. When speaking of color in this connection, I mean the dominant hue. Since colors such as brown and chocolate are degraded oranges, these may be matched by the combination of the two color wedges 9 and 10 with the neutral wedge, thereby varying the intensity. In a similar way the drabs and slate colors are degraded blue-greens, and may be matched by suitably adjusting wedges 10, 11 and 12.

It will be seen that I do not determine as separate factors intensity, hue and saturation, since changes in the position of the color wedges alter all three factors of the transmitted light, while a change of the neutral wedge affects intensity only. I am able, however, to obtain repeatable readings completely defining any particular color in the constants of the instrument used, and it is possible, if desired, to evaluate these in the three factors stated. This instrument is intended, however, as a practical one that may be used by manufacturers and others who desire to obtain repeatable, precise readings of colors of products of all kinds, and it will not usually be necessary or desirable to have further data than the constants of the instrument used.

It would be possible by the use of the three color wedges only to match the degraded colors such as brown and drab, but it is simpler to use only two color wedges and a neutral wedge, since there are then only two variable hues used and it is also possible to adjust the intensity independently of the other factors.

In order to obtain a delicate adjustment over a long range in a compact instrument, I employ, in addition to the color wedges, three color filters 109, 110, and 111, which have the same color absorption characteristics as wedges 9, 10, and 11 respectively and have the densities of the wedges at their densest portions. If, as in the instrument shown in Fig. 2, the reading is 50 when the wedge is fully inserted, the density of the auxiliary filter corresponds to that of the wedge at this reading. It is possible, therefore, to insert the filter, reset the wedge at the zero setting, and adjust it further, thus doubling the effective range of the instrument.

In all of the figures a dash-dot line denotes the path of an axial ray.

Turning now to a detailed description of my apparatus with its various attachments, 20 indicates a telescope tube having a knurled rotatable adjusting ring 21 for the objective 1 within, and having a similar adjustable means 22 for the eyepiece 5. A removable cap 23 near the center of the tube carries the photometer head 3 and filter 8, and handles 24 are connected to the filters 13 and 13′. By swinging these handles the filters may be thrown selectively into position. The filters 109, 110

and 111 have handles 25, as shown in Fig. 3, these being on the rear side of the apparatus, as shown in Fig. 2. Each of the wedges slides in suitable ways 26, as indicated in Fig. 3, in a long box 27 supported beneath and parallel to a tube 20. Each of these wedges has a handle 28 which also acts as a pointer. The handles 28 slide in slots 29 opposite suitable calibrations 30, by which the position of each wedge may be read.

In the bottom of the tube 20, beneath the photometer head, is an opening 31 which is in line with suitable openings in the top and bottom of the box 27. A tubular support and lamp box 32 are mounted beneath the box 16. This lamp box consists of a tubular casing having a removable door 33 carrying the lamp or light source 4, and having suitable ventilating light baffles 34 and apertures 35 in its upper part surrounding a central tube 36 in which is a diffusing glass 7. This lamp box is supported by a suitable tripod or stand 37 in the center of which is a ventilating opening 38 beneath an apertured baffle plate 39 in the casing.

When it is desired to determine the apparent color of an object at a distance, the telescope is focused upon this object and no attachments are necessary. When, however, the instrument is to be used with materials, it is desirable to mount small specimens of these in suitable attachments, so that they may be illuminated by standard lights and in a standard position with relation to the instrument.

I will now describe certain useful attachments.

An attachment in which light transmitted through a liquid may be examined is shown in Figs. 5, 6, and 7. This comprises a tubular opaque casing 40 having a removable bottom 41 secured thereto by screws 42. Within the casing are secured spring arms 43 within which may be held a glass tube 44 having a flat base 45 seated upon ledges 46 surrounding a central aperture 47 in the bottom 41. In order that the depth of the liquid may be a constant, there is provided an annular member 48 adapted to fit over the top of the tube 44 and carrying a tubular member 49 with a glass bottom 50. When this is in place, the distance between the bottom of plate 50 and the top of the plate 45 is known, so that great care need not be taken in measuring the amount of liquid. This casing is secured to and carried by an elbow member 51 having a split tube 52 controlled by a thumb screw 53 by which it may be clamped to the end of the telescope at 19. Within this elbow there is positioned a reflecting prism 54 carried on a suitable apertured plate 55. The casing is split and one half hinged as at 56, indicated in Fig. 7, so that it can be swung open by means of the knob 57. A spring 58 bearing against a projection 59 holds the door in open or closed position in a well known manner.

In order to secure a standard lighting for this and the other attachments to be described later, a lamp box similar to 32 already described is provided. This lamp box consists of a casing 32′ having a removable door 33′ carrying a lamp 4′ and having apertured baffle plates 34′ and 39′, analogous to those already described, and ventilating apertures 35′ and 38′. It also carries a tube 36′ with a diffusing glass 7′, all of these parts being similar to those already described. It also carries an upper plate 60, preventing light from emerging except through the tube 36′. The end of the casing is internally screw threaded at 61 and is adapted to engage the external threads 62 on the bottom 41 of the attachment shown in Fig. 5.

In Figs. 8 and 9 is illustrated an attachment by which may be examined light transmitted through sheets of material, such as glass, gelatine or the like. This attachment has a split flange 62 and thumb screw 63 by which it may be attached to the end 19 of the telescope tube. As shown, it consists of two apertured pieces 63′ and 64 connected by screws 65. 64 has a tubular member externally screw threaded, as shown at 66, for the attachment of the casing 32′, shown in Fig. 4. Between the apertured portions 67 and 68 of these two pieces there is left a space 69 into which a sheet of material 70 to be examined may be slipped.

Still another attachment is shown in Figs. 14, 15 and 16, these being used where sheets of reflecting material, such as paper, are to be mounted. This attachment has a split tube 71 and thumb screw 72 by which it may be attached to the telescope at 19. The attachment consists of a tubuar elbow casing 73 having in one wall an opening 74. In back of this opening are mounted spring fingers 75 adapted to hold firmly a sheet 76 to be examined, and an opaque backing sheet 77. In the side of this casing there is an oblique extension 78 which is externally screw threaded at 79, so that the casing 32′ may be secured thereto. It is obvious that light from the lamp box will fall obliquely upon the surface of the material 76, the color of which may be observed through the instrument.

Still another attachment is shown in Figs. 10 to 13. This attachment is adapted to be secured by the split tube 80 and thumb screw 81 to the end 19 of the telescope tube. It comprises an elbow member 82 in which there is suitably mounted upon an apertured plate 83 a reflecting prism 84. To a tubular extension 85 is secured the cylindrical lamp

box 86′. In the upper wall of this lamp box are a number of removable doors 87, each carrying a lamp 88. An apertured baffle plate 89 and apertures 90 in the plate 86, together with apertures 90′ in the side wall 91 of the casing and baffle plate 92, provide suitable ventilation for the lamp box. In the center of the plate 86 is an opening in which is secured an opaque tube 93 which extends through the lamp box. A second casing 94 is secured to the lamp box by means of suitable annular members 94′ and 95′ which also serve to hold in place a sheet of diffusing material 96, such as opal glass, between the lamp box and the casing 94. The tubular casing 94 has an opaque cover 95 which is frictionally held in place. The tube 93 extends within the casing 94 and carries a frustro-conical member 97 closed at its end with an annular member 98.

When it is desired to examine sheet material in this attachment, a strip of it is cut out, the cover 95 is removed and the strip is placed within the casing 94, being held by its natural tendency to straighten against the wall 94. A disk of the material is cut to fit the cap 95 which is then replaced, the material being held between the end of the wall 94 and the cap 95. Although the attachment is shown pointing downwardly and may be so used, it may, when in use, be placed on the instrument pointing upwardly. When so positioned, this attachment may also be used for the examination of the color reflecting power of powders, liquids or pulp materials. In this case, a metallic casing 99 with a cover 100 and a glass internal wall 101, of the shape shown in Fig. 13, is placed over the frustro-conical reflector 97. When used with sheet material, a strip of material may also be cut out and fitted around this frustro-conical surface, the ends of the strip being pasted together, and when the instrument is pointed upwardly, an annulus of the material may be laid upon the surface of 98. The surfaces of both 97 and 98 are non-color selective reflecting surfaces.

The use of this attachment will now be more fully explained by reference to the diagram in Fig. 12. Rays from the lamps 88 fall upon the annular diffusing sheet 96. This sheet, therefore, comprises an extended source of diffusing light in one wall of the casing. From every point of this source light rays radiate in all directions. Through the tube 93 light rays can pass from only a very small portion of the end surface 103 of the casing. The frustro-conical reflector is so proportioned that no direct ray from the diffusing annulus 96 can fall upon this portion 102. A limiting ray is indicated by line 104. As is shown, this ray from the extreme edge of the annular source and touching the extreme edge of the frustro-conical reflector cannot reach the portion 102. All rays which reach the visible portion 102 must, therefore, have been reflected at least once. From every point a of the annular source there radiate rays in all directions. For instance, the ray A proceeds to the surface 97 and, as its surface is more or less diffusing, depending upon the material, there proceed from each point of it secondary rays A′, A², etc. One of these rays is again reflected on the wall 94 and finally reaches the portion 102. The paths of other rays are indicated by B, B′, B″, and C, C′, C″, and C‴. The only rays which the observer perceives are those which reach the objective 1, and for any point b in the portion 102 the only rays which reach the objective 1 are those emanating from the point b within the angle c subtended by lines connecting b with the edges of the objective. Other rays, as, for instance, 105, emanating from point b at a greater angle impinge the inner surface of the tube 93, which is a black absorptive surface. If desired, this tube may not extend beyond the opalescent glass 96, as shown in Fig. 12, and the inner surface of 97 is then blackened, so as to absorb substantially all light rays.

It is, therefore, apparent that even if paper with a highly glossy surface is being examined, the light reaching the observer will be almost entirely that obtained by diffused reflection and not by regular reflection. This eliminates practically completely the dilution of the true body color by specularly reflected light. Since the saturation factor is increased by repeated reflection from a colored surface, it is obvious that this type of attachment will be very useful where the saturation of the surface to be examined is so low as to be barely perceptible or even imperceptible to the eye. When multiple reflection is relied upon, as with this attachment, it is obvious that light falling upon the observed portion 102 must necessarily have undergone an indefinite number of reflections at each of which a proportion, frequently large, will have been absorbed. The construction here shown permits a high intensity of light to be used and the maximum light to reach the observed area. Since the casing is a closed system, all of the light that is not absorbed will continue to undergo reflection until it reaches the observer.

A different arrangement of the parts of the colorimeter is indicated diagrammatically in Fig. 17. Photometer head 3′, as shown, is of the Lummer-Brodhun type, and this with the showing of Fig. 1 indicates that any type may be used. Lenses 5′ and 6′ and filters 9′, 10′, 11′, 12′, 109′, 110′, and 111′ correspond to the analogously numbered parts in Fig. 1. A suitably supported tube 44′, analogous to that shown in Fig. 5, contains a liquid to be examined. Two dif-

fusing plates 7′ are adjustably mounted between the source of light 4″ and the tube 44′. By adjustment of these relatively to each other and to the source, the intensity of the illumination of the tube may be varied. This setting is made only when a new lamp is inserted. Light from the lamp 4″ traverses the tube and is reflected from the reflecting field of the photometer head to the eyepiece. Other rays are reflected from the prisms 120 and 121 to the diffusing screen 122, the condensing lens 123 serving to make illumination of the screen as uniform and intense as possible. Light from the diffusing screen 122 traverses such of the wedges and filters as are between it and the photometer head, where the fields of transmitted and reflected rays are compared.

If an instrument is intended for the examination of certain specific materials only, such as oils having a rather limited color range, there need be supplied only the wedges necessary for that range.

It is necessary that the lamps used be standardized, and that they be operated under fixed conditions, in order that the emitted light shall be of constant color. Since the quality and intensity of the light emitted by a lamp run at a fixed current may change with the age of the lamp, the lamps used should be checked from time to time by comparison with a standard.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. An instrument for measuring the color of an object comprising means for directing light rays from the object to a field of view, means for directing light rays in a beam from a standard source of light to an adjacent field of view, and four optical wedges transmitting respectively minus-green, minus-red, minus-blue and neutral light, and adapted to be independently adjusted entirely across said beam between the source and the second field of view.

2. An instrument for measuring the color of an object comprising means for supporting and illuminating the object in a position to be viewed, means for directing light rays from the object to a field of view, a source of white light, means for directing light rays in a beam from said source to a field of view whereby the two sets of light rays may be compared, four optical wedges adapted to be adjusted entirely across said beam between said source and said second field of view said wedges transmitting respectively minus-green, minus-red, minus-blue and neutral light.

3. An instrument for measuring the color of an object comprising means for supporting and illuminating the object in a position to be viewed, means for directing light rays from the object to a field of view, a source of white light, means for directing light rays in a beam from said source to a field of view whereby the two sets of light rays may be compared, four optical wedges adapted to be adjusted entirely across said beam between said source and said second field of view, three of said wedges absorbing light waves of three different portions of the spectrum respectively, and the fourth absorbing light non-selectively.

4. An instrument for measuring the color of an object comprising means for supporting and illuminating the object in a position to be viewed, means for directing light rays from the object to a field of view, a source of white light, means for directing light rays in a beam from said source to a field of view whereby the two sets of light rays may be compared, four optical wedges adapted to be adjusted entirely across said beam between said source and said second field of view, three of said wedges absorbing substantially all light waves of three different zones of the spectrum respectively and transmitting other wave lengths, each of said three wedges having a transmission zone in common with each of the others, and the fourth wedge absorbing light non-selectively.

5. A colorimeter comprising a hollow upright standard, a horizontal telescope on said standard comprising an eyepiece and an objective, a photometer head in said telescope above the standard and between the eyepiece and the objective, an aperture in the telescope below the photometer head, a source of light in the standard below said aperture, and photometric wedges, some of which are colored, independently adjustable above the source of light and below the aperture.

6. The method of measuring the apparent hue of an object which consists in choosing not over two of three optical wedges respectively transmitting minus-green, minus-red, and minus-blue light, interposing the wedges thus chosen in the path of white light, comparing the light thus transmitted with light from the object and in adjusting the wedges to match the hue of the transmitted light with that from the object.

7. The method of measuring the apparent color of an object which consists in choosing not over two of three optical wedges respectively transmitting minus-green, minus-red, and minus-blue light, interposing the wedges thus chosen and also a non-color selective wedge in the path of white light, comparing the light thus transmitted with light from the object and adjusting the wedges to match the color of the transmitted light and that from the object.

8. Apparatus for holding material for color examination comprising a closed cas-

ing, there being in one wall an annular source of diffuse light, said wall having within said annulus an aperture through which only a portion of the opposite wall is visible, a hollow frustro-conical member with an external reflecting surface surrounding said aperture and extending within said casing sufficiently to exclude from said visible portion all direct rays from the source, and an annular reflecting ring on said member facing said opposite wall.

9. Apparatus for holding material for color examination comprising a closed cylindrical casing, there being in one end wall an annular source of diffuse light, said wall having within said annulus an aperture through which only a small portion of the opposite wall is visible, a hollow frustro-conical member with an external reflecting surface surrounding said aperture and extending within said casing sufficiently to exclude from said visible portion all direct rays from the source, and an annular reflecting ring on said member facing said opposite end wall.

10. An attachment for a colorimeter comprising means whereby the attachment may be secured to the colorimeter, a material holding chamber, a tubular light directing means extending into the chamber and adapted to direct light rays therefrom to the colorimeter, a lamp house surrounding said tube and light diffusing means between the chamber and the lamp house.

11. A colorimeter comprising means for directing light rays from an object to a field of view, means for directing light rays from a standard source of light in a beam to an adjacent field of view, and a series of optical wedges adjustable across said beam between the source and the second field of view, one of said wedges absorbing light non-selectively and the other wedges absorbing light rays each from different zones of the spectrum.

12. A colorimeter comprising means for directing light rays from an object to a field of view, means for directing light rays from a standard source of light to an adjacent field of view, a series of optical wedges some of which are colored adjustable between the source and the second field of view, and a series of light filters adapted to be inserted between the source and the second field, each of said filters corresponding in light absorbing characteristics to one of said wedges, and of a uniform density to that of the densest portion of the corresponding wedge.

Signed at Rochester, New York, this 3rd day of May, 1921.

LOYD A. JONES.