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Davidson

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[54] APPARATUS FOR CALCULATING HALFTONE SCREEN EXPOSURES

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[73] Assignee: **Platemakers Educational & Research Institute,** Park Forest, Ill.

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[52] **U.S. Cl.** ....**235/64.7,** 235/61 B, 235/78, 235/70 R

[51] **Int. Cl.** **G06c 3/00**

[58] **Field of Search**.......235/61 B, 61 A, 70 R, 70 A, 235/89, 64.7, 85 R, 78

[56] **References Cited**

UNITED STATES PATENTS

1,575,911	3/1926	Gomez	235/61 B
1,713,025	5/1929	Castleman, Jr.	235/61 B X
2,423,822	7/1947	Averbach	235/78
2,436,352	2/1948	Downs, Jr.	235/61 B
2,721,032	10/1955	Gresham	235/64.7
3,047,221	7/1962	Alfaya et al.	235/64.7

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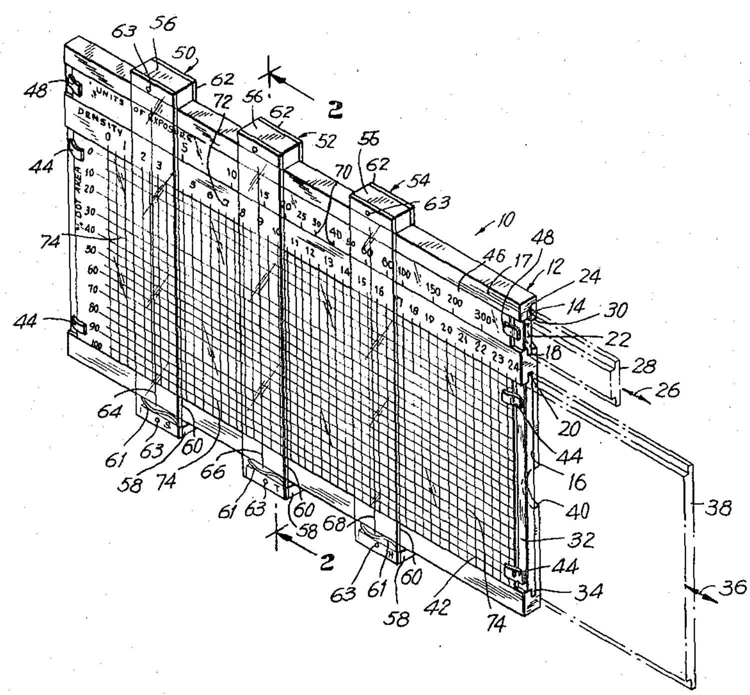
Assistant Examiner—Stanley A. Wal
Attorney—Alex Friedman et al.

[57] ABSTRACT

An improved method and apparatus for calculating halftone screen exposures to produce photographic halftone reproductions useful in printing applications. In one embodiment, a slide-rule type computing apparatus incorporates plots of information including percent dot area versus continuous tone photographic densities, main exposures, percent basic flash exposures (BFE), and percent bump exposures derived empirically from the performance capabilities of the particular halftone reproduction facility used. The method and apparatus permits the coordinate calculation of main, bump and flash exposures.

76 Claims, 11 Drawing Figures



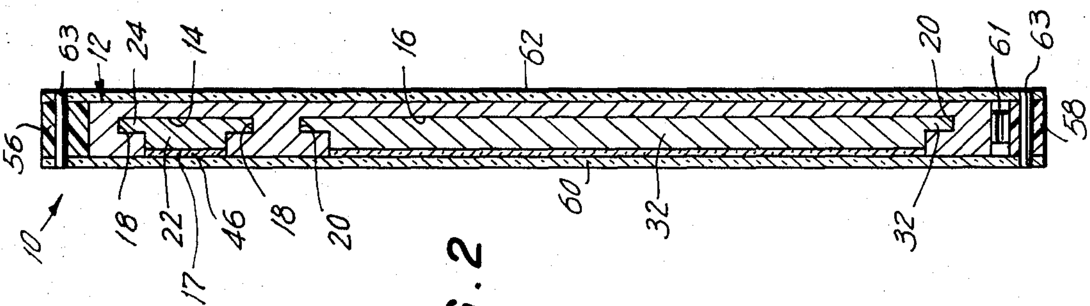


FIG. 2

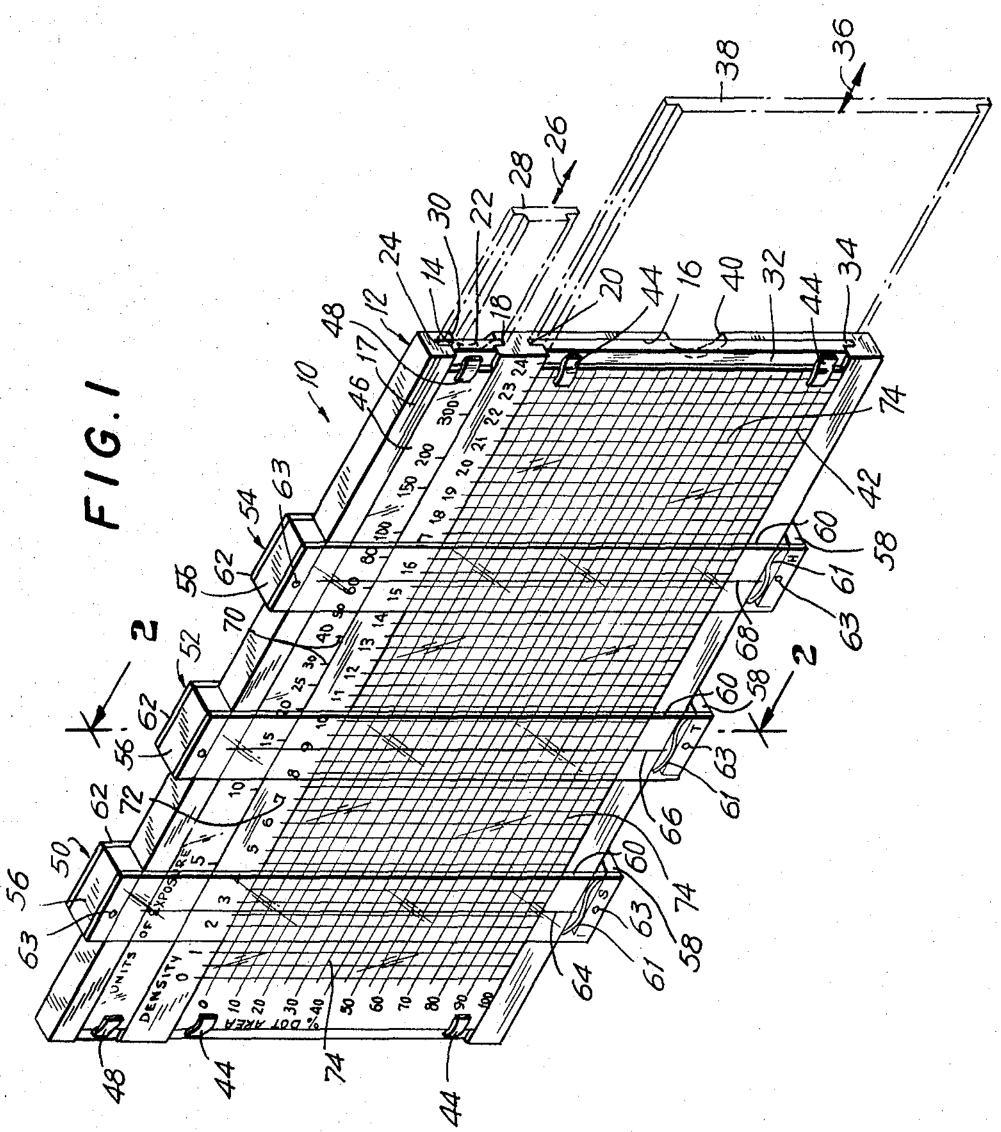


FIG. 1

FIG.3

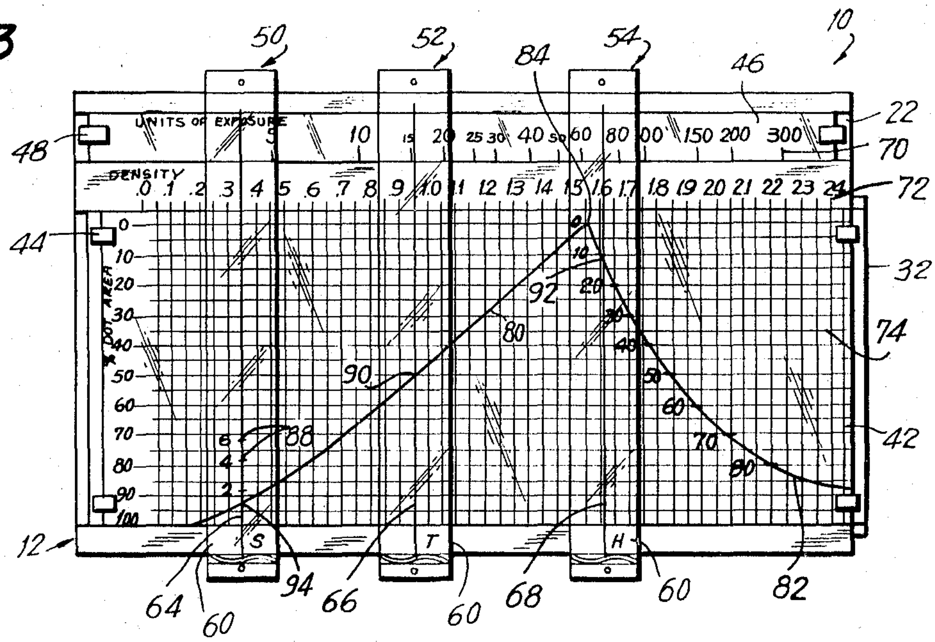

UNITS OF EXPOSURE
5
10
15
20
25
30
40
50
60
80
100
150
200
300
DENSITY
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4
% DOT AREA
0 10 20 30 40 50 60 70 80 90 100
S
T
H
10
12
22
32
42
44
46
48
50
52
54
60
64
66
68
70
72
74
80
82
84
88
90
92
94

FIG.4

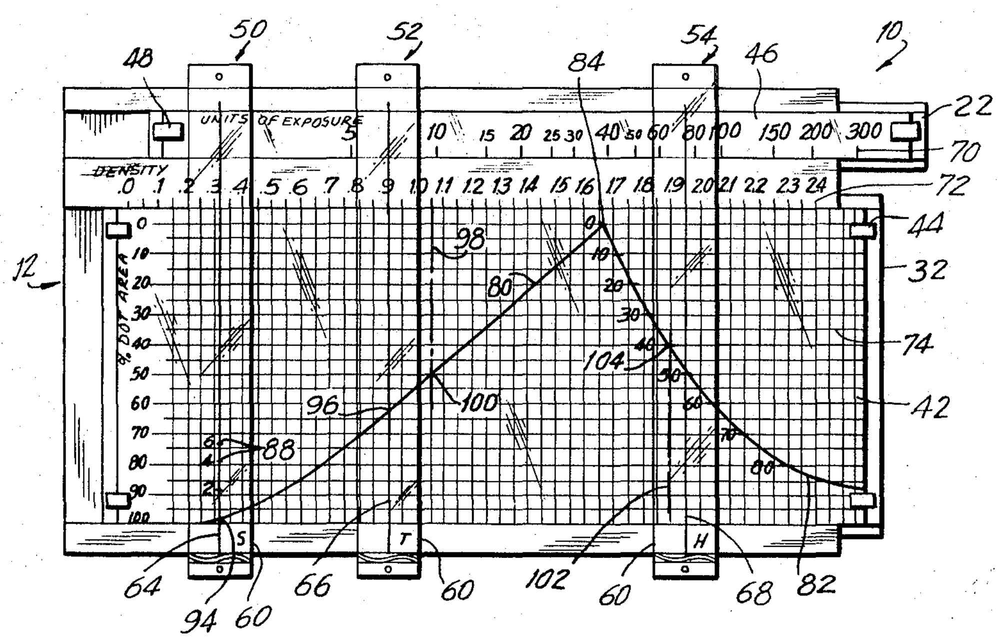

UNITS OF EXPOSURE
5
10
15
20
25
30
40
50
60
80
100
150
200
300
DENSITY
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4
% DOT AREA
0 10 20 30 40 50 60 70 80 90 100
S
T
H
10
12
22
32
42
44
46
48
50
52
54
60
64
66
68
70
72
74
80
82
84
88
94
96
98
100
102
104

FIG. 5

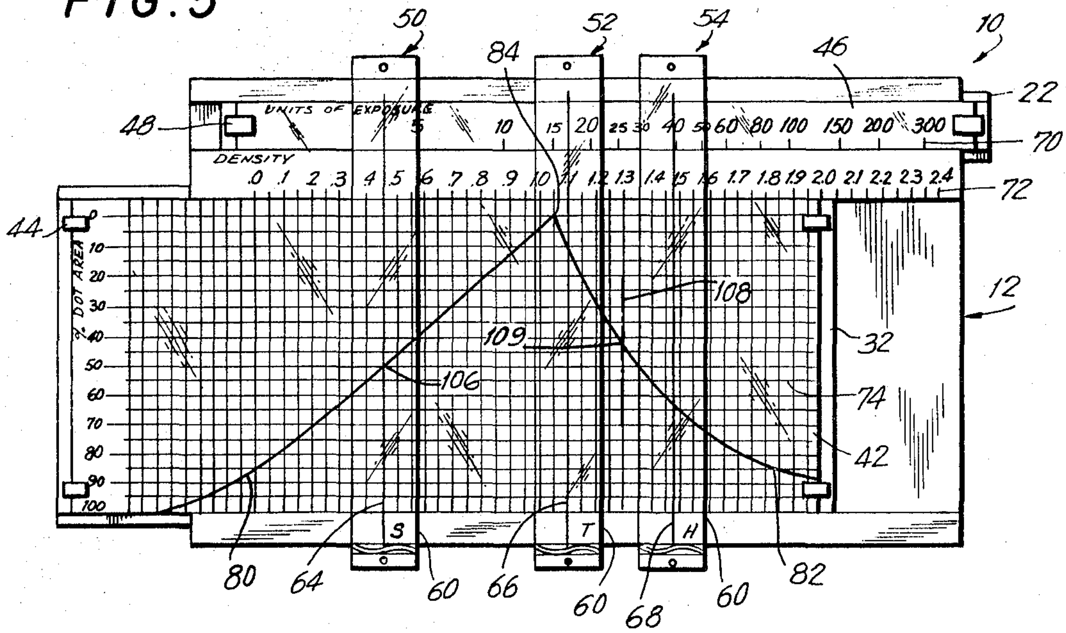
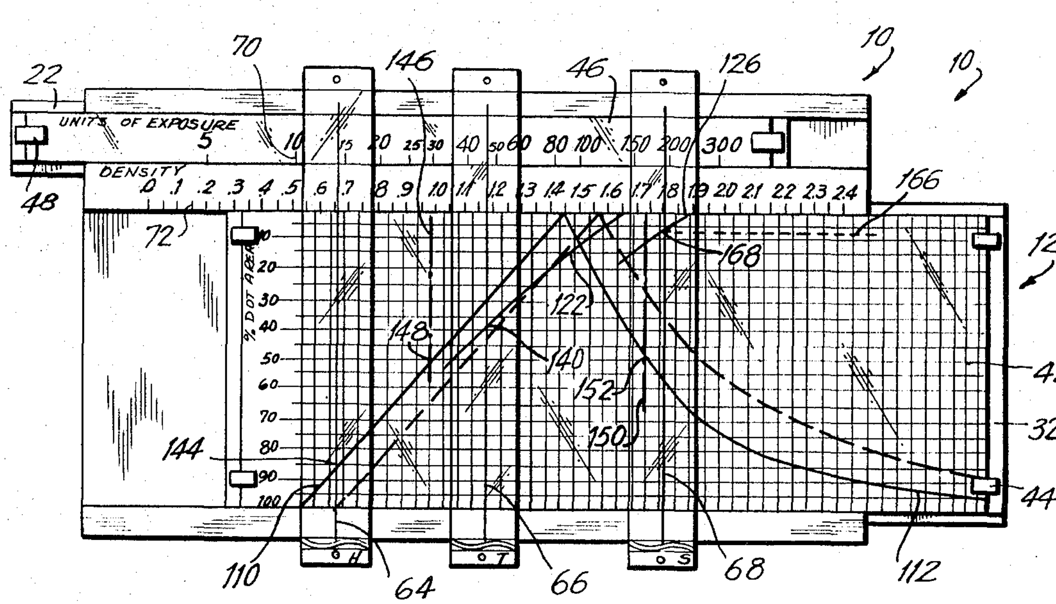


FIG. 8



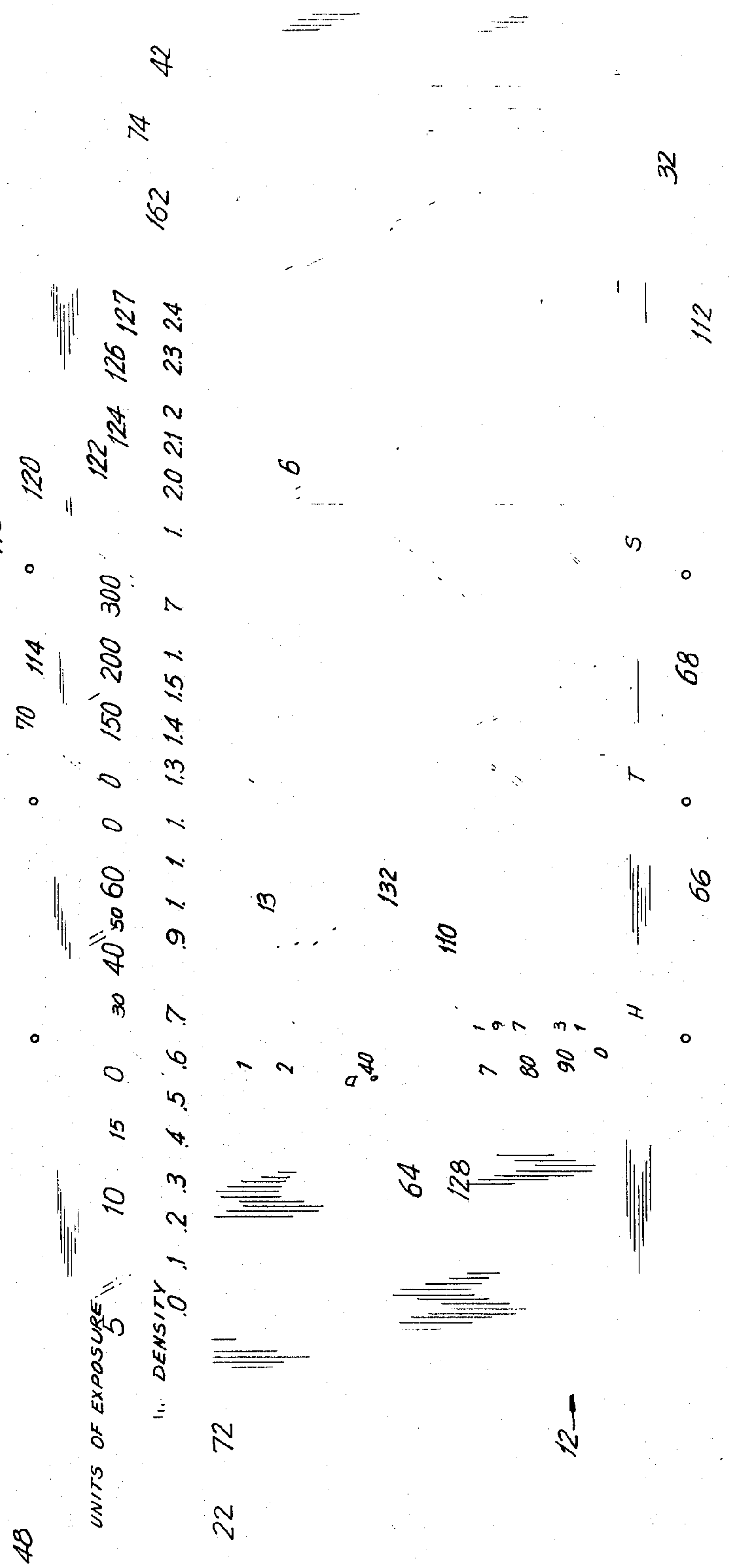


FIG. 6

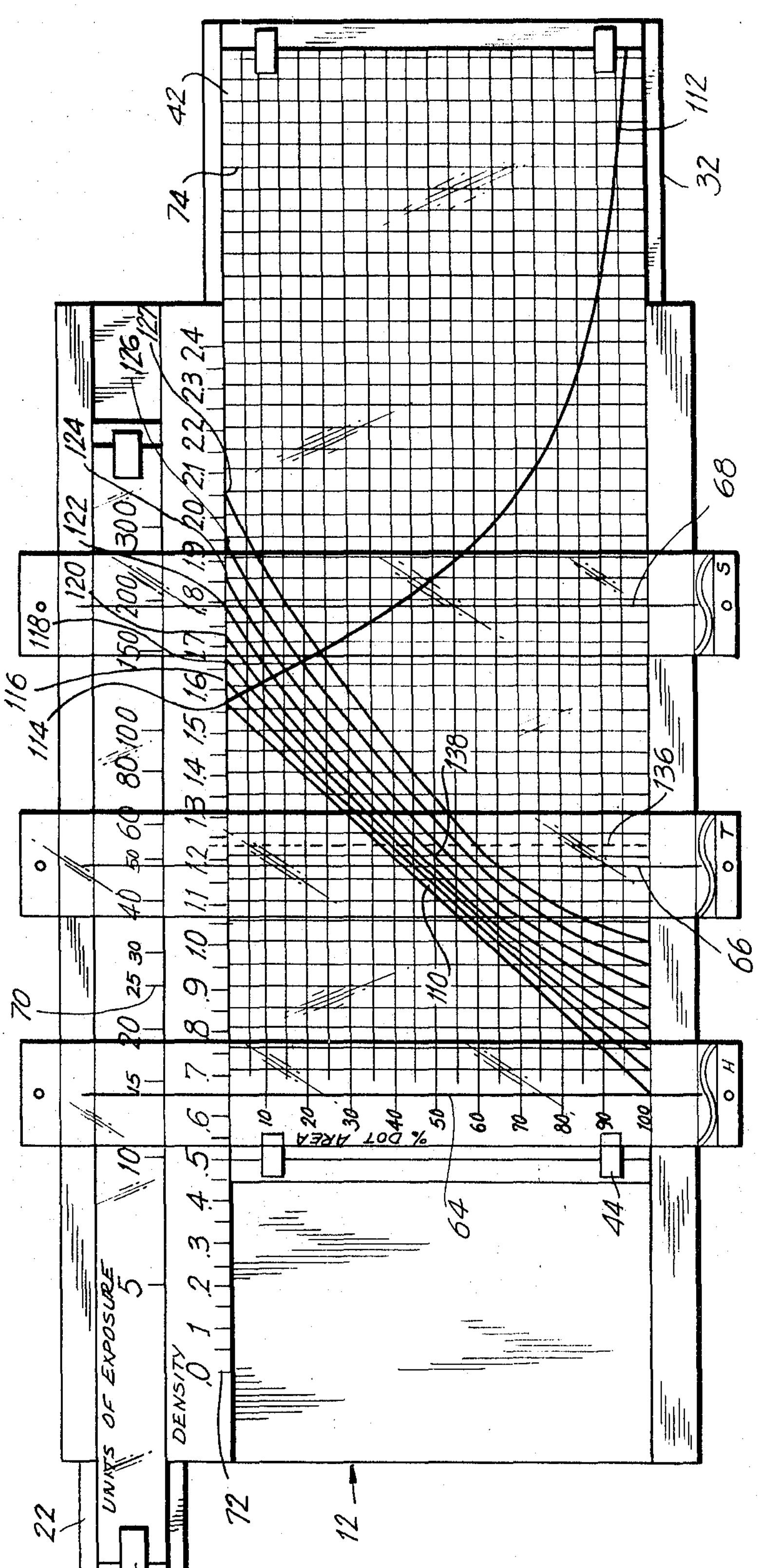


FIG. 7

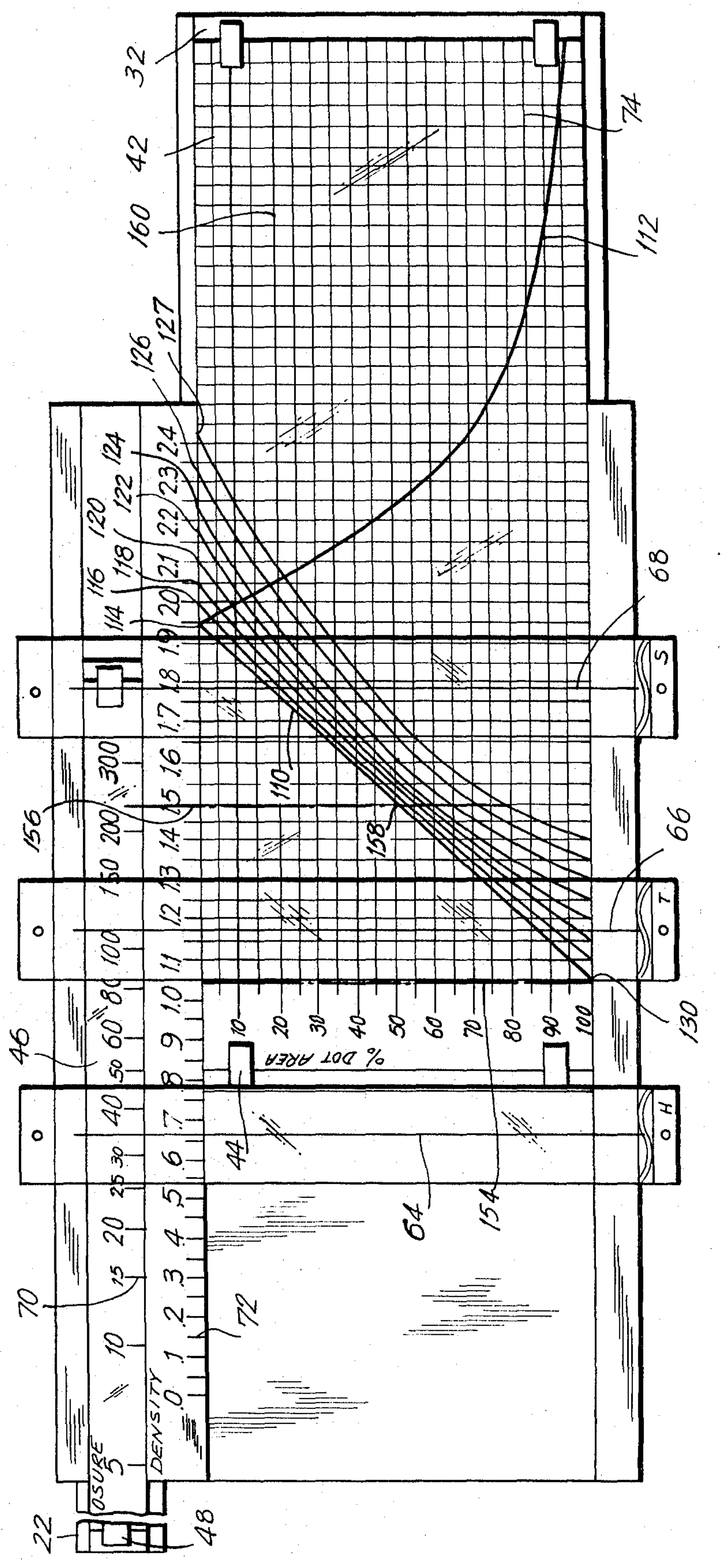


FIG.9

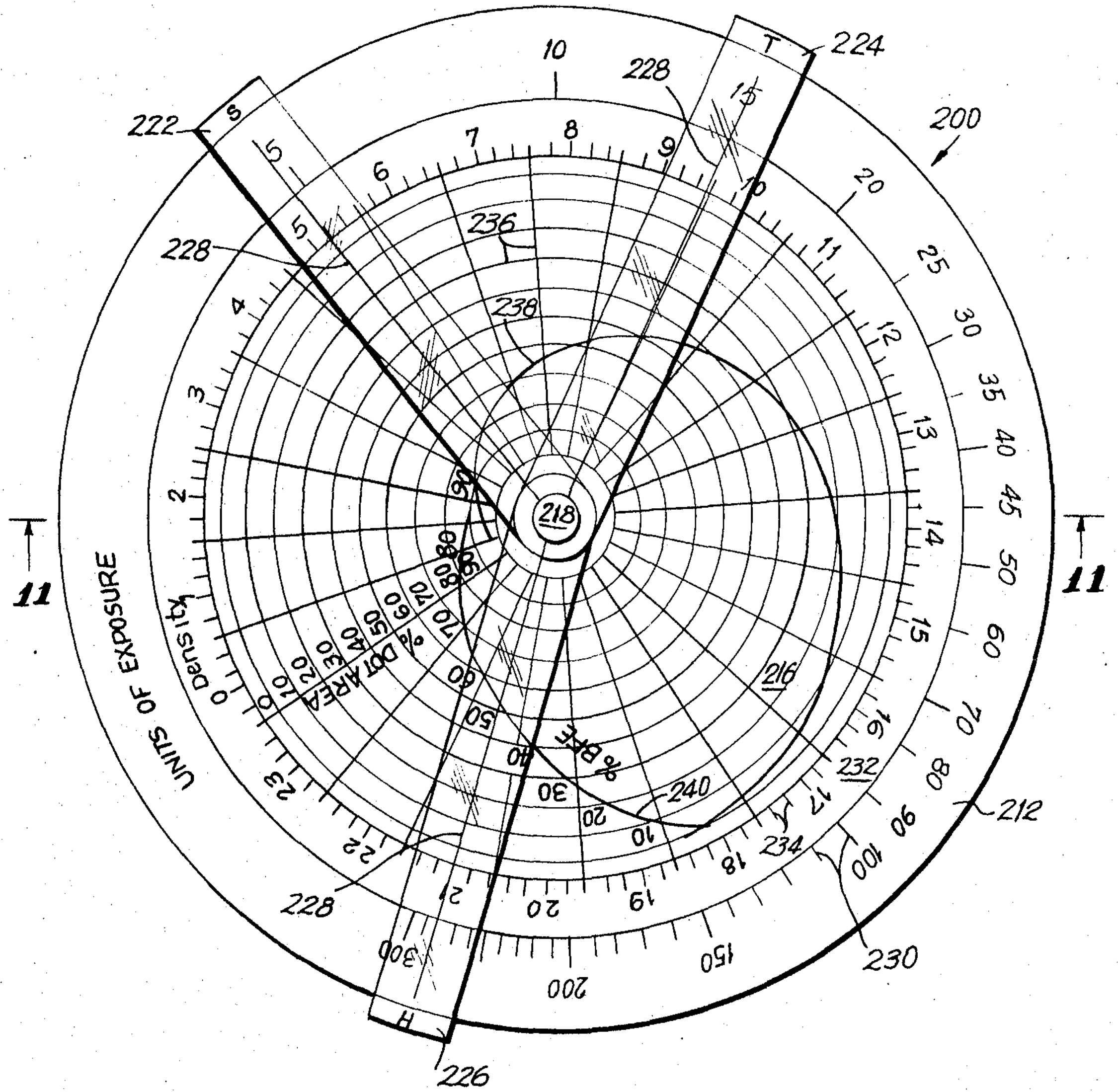

T
224
10
228
S
222
200
UNITS OF EXPOSURE
Density
% DOT AREA
% BFE
218
216
236
238
240
232
234
230
212
226
H
11
11

FIG. 10

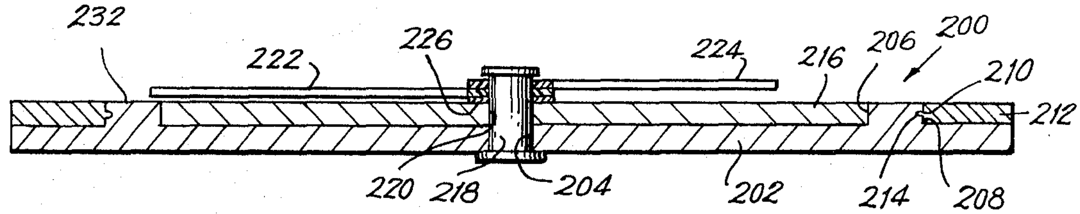

232
222
226
224
216
206
200
210
212
220
218
204
202
214
208

FIG. 11

APPARATUS FOR CALCULATING HALFTONE SCREEN EXPOSURES

BACKGROUND OF THE INVENTION

This invention is directed to the method and apparatus for calculating halftone screen exposures. In printing, the change from a continuous tone copy of a picture to an ink-printable image is achieved by means of a halftone screen. Said halftone screen changes continuous tone copy to dots of various sizes, the sizes of these dots being related to the tones of the original copy. When a press prints halftone dots, the ink transferred from all of the dots is essentially the same density, the change in printed values being the result of differences in dot area and therefore, ink amounts.

In halftone photography, using a halftone producing screen familiar to the art, it is common to find that the density range that can be reproduced by a halftone screen, referred to as the "screen range" or "basic range" of the lens-camera-screen system is generally between 1.0 and 1.40. The basic range is less than the tonal range of a large percentage of copy, generally referred to as the "copy range." Said copy range is generally defined as the difference between the highlights (light tones of a photo) and the shadows (the darkest areas) thereof. Density is expressed as the logarithm of opacity. In order to match the effective range of the lens-camera-screen system to the copy range, it is common to resort to supplemental exposures. One of these exposures is referred to as the "-bump exposure." The bump exposure is an exposure made with the image in place, but without the screen in order to improve the halftone reproduction of the high brightness areas of the image. The bump exposure shortens one end of the tone scale. The second supplementary exposure is referred to as the "flash exposure." The flash exposure is applied with the screen in place, but without the image to provide dots in the dark areas of the original image. The flash exposure extends the tone scale in the minimum brightness areas of the image and is usually expressed as percent basic flash exposure (%BFE). BFE is the basic flash exposure which by itself alone and in its entirety will produce minimum desired percent dot area. The % BFE actually used might correspond to the density value equal to the difference between screen and copy ranges, or even less if a bump exposure is also used.

An additional exposure utilized in direct screening is the undercolor removal (UCR) exposure which serves to remove the part of each color which contributes to the neutral or gray portions of the final printed product, said gray portions being replaced by the black printer.

Exposure control systems relating copy end-point densities to basic screen range, to permit the calculation of basic, flash and bump exposures suitable for a given piece of copy are well known in the art. These systems provide minimum area dots in shadows, but do not function to relate specific densities in the critical middle ranges to any specific printing area of the halftone. The reproduction characteristic between the extremes has heretofore been ignored. Further, in the halftone process, the tone reproduction characteristics of the entire photographic system, including lens, camera body and bellows, halftone screen, and photographic receptors varies from set-up to set-up so that the calculations for one set-up are not necessarily applicable to another set-up where at least one of the variables is changed. Uncontrolled reflections within the optical system normally referred to as "flare," will vary between different systems and affect image quality. Therefore, repetitive production of halftones of uniform and optimum quality requires accurate calculation of screen exposures for each set-up, and the maintaining of the conditions of the set-up.

By providing a method and apparatus which relates midtone density of copy to a specific dot size in the resulting halftone reproduction, it will be evident that this invention provides for controlling the supplementary exposures affecting the highlights and shadows while taking into account the properties, including flare, of the entire optical system.

SUMMARY OF THE INVENTION

In accordance with one embodiment of the invention, a slide-rule type computing apparatus for calculating halftone screen exposures is provided having a base and first and second slide members mounted in spaced relation for substantially parallel lateral displacement across said base. The region of said base intermediate said first and second slide members has a linear density scale inscribed thereon. The first slide member is adapted to receive a logarithmic units of exposure scale. The second slide member is adapted to receive a scale having orthogonal coordinates, the spacing of said coordinates along the axis of abscissa thereof being spaced to correspond with said density scale for receiving plots of percent dot area versus density. Three cursor members are slidably mounted on said base for lateral displacement across said base and slide members, each of said cursor members having a cursor line extending substantially normal to the axis of lateral displacement of said slide members and overlaying both said slide members and the region of said base therebetween.

Density versus percent dot area curves and a % BFE curve are empirically derived and inscribed on said orthogonal coordinates. A percent bump scale may also be empirically derived and applied either to the basic density scale or to the leftmost of said cursors. By manipulation of said first and second slide members and said cursors in accordance with the process more particularly described below, the various exposure values for both direct and indirect screening can be calculated.

Accordingly, it is an object of the invention to provide a method of calculating exposures which will permit the production of full color printed reproductions of originals by means of halftones, taking into consideration gray balance and the highlight, shadow and midpoint regions of said original. This applies to a halftone reproduction of either positive or negative originals.

A further object of the invention is to provide a method of calculating exposures for the production of halftones which coordinately determines flash, main and bump exposures.

Another object of this invention is to provide a slide-rule type computing apparatus which will permit the calculation of the various exposures necessary for the production of substantially optimum halftones.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification and drawings.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawing, in which:

FIG. 1 is a perspective view of one embodiment of the slide-rule type computing apparatus according to the invention;

FIG. 2 is a cross-sectional view taken along lines 2 — 2 of FIG. 1;

FIGS. 3 – 5 are front elevational views of the slide-rule type computing apparatus of FIG. 1 illustrating the use of said slide-rule type computing apparatus for indirect screening;

FIGS. 6 – 9 are front elevational views of said slide-rule type computing apparatus illustrating the use of said slide-rule type computing apparatus in direct screening;

FIG. 10 is a top plan view of a circular embodiment of the slide-rule type computer apparatus according to the invention; and

FIG. 11 is a cross-sectional view taken along lines 11—11 of FIG. 10.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2, a linear slide-rule type computing apparatus 10 is depicted particularly adapted for the calculation of halftone contact screen exposures. Said slide-rule computing apparatus consists of a base 12 having a small channel 14 and a large channel 16 formed in the front surface 17 thereof. Small channel 14 is formed with laterally extending grooves 18 in the side walls thereof, while similar laterally extending grooves 20 are formed in the side walls of large channel 16. Received within small channel 14 is a first slide member 22 formed with laterally extending flanges 24 which engage and ride in grooves 18. First slide member 22 is displaceable in the direction of arrows 26, as shown by the phantom lines 28. A notch 30 is formed in the rear wall of base 12 adjacent each edge of first slide member 22 to permit the easy gripping of said slide member when it is otherwise aligned with base 12.

Similarly, a second slide member 32 is received within large channel 16 and is formed with laterally extending flanges 34 which engage and ride in groove 20. Second slide member 32 is displaceable in the direction of arrows 36 as more particularly shown by phantom lines 38. A second pair of notches 40 is formed in the rear wall of base 12 adjacent the edge of large channel 16 to provide means for grasping said second slide member. A transparent overlay 42 is removably retained on a top surface of second slide member 32 by means of lengths of tape 44. A similar substantially opaque overlay 46 is mounted on small slide 22 by means of lengths of tape 48. A first cursor 50, second cursor 52 and third cursor 54 are slidably mounted on base 12. As best shown in FIG. 2, each of said cursors consists of a top slide block 56 engaging the top surface of base 12, a bottom block 58 supporting a leaf spring 61 in engagement with the bottom surface of said base, and a pair of cursor plates 60 and 62 supported on blocks 56 and 58 by rivets 63. At least cursor plates 60 are transparent. A cursor line 64 is inscribed on the cursor plate 60 of cursor 50, said cursor line extending substantially normally to the top surface of base 12, and overlying first and second slide members 22 and 32. Similarly, a cursor line 66 is inscribed on the cursor plate 60 of cursor 52 and a cursor line 68 is inscribed on the cursor plate 60 of cursor 54.

Overlay 46 mounted on slide member 22 has a logarithmic scale 70 inscribed thereon representative of units of exposure. The portion of the top surface 17 of base 12 intermediate small channel 14 and large channel 16 is inscribed with a linear scale 72 representative of density.

Transparent overlay 42 has a blank set of orthogonal coordinates 74 inscribed thereon. A legend for the ordinate axis of said coordinates is also inscribed on said overlay in terms of percent dot area. The spacing of the coordinate along the axis of abscissas corresponds to the unit spacing of the density scale 72. A set of orthogonal coordinates corresponding to coordinates 74 may also be inscribed directly on the top surface of second slide member 32, if desired. Further, while the embodiment of FIGS. 1 and 2 is a linear slide-rule type computing apparatus, a similar device could be formed by a circular slide-rule type computing apparatus, which would be provided with three corresponding radial cursors, and small and large annular slide members.

An example of such a circular slide-rule type computing apparatus is depicted in FIGS. 10 and 11. Circular slide-rule type computing apparatus 200 consists of a base 202 formed with a central aperture 204 therethrough. The upper surface of base 202 is formed with a central circular recess 206 and an annular peripheral recess 208. Peripheral recess 208 is formed with a circumferential groove 210 in the inner side wall thereof. Received within peripheral recess 208 is an annular first slide member 212 formed with a flange 214 which rides in groove 210 and serves to retain said annular first slide member within peripheral recess 208. First annular slide member 212 is rotatably displaceable about an axis defined by aperture 204 and base 202.

A second annular slide member 216 is received within central recess 206 and is also rotatably displaceable about an axis defined by aperture 204. A rivet passes through aperture 204 and base 202, through an aperture 220 in second annular slide member 216 and projects beyond the upper surface of said second annular slide member. Rotatably mounted on rivet 218 and retained in position relative to base 202 and second slide member 216 are a first S cursor 222, a second T cursor 224 and a third H cursor 226. Each of said cursors are transparent and bear a thin radially extending cursor line 228. In the embodiment of FIGS. 10 and 11, a logarithmic scale 230 is inscribed on the top surface of second annular slide member 212 representative of units of exposure. A portion 232 of the top surface of base 202 is inscribed with a linear scale 234 representative of density. The top surface of the second annular slide member 216 is inscribed with a normally blank set of orthogonal circular coordinates 236. A legend for the ordinate axis of said coordinates is also inscribed on said overlay in terms of percent dot area. The spacing of the coordinates along the axis of abscissas corresponds to the unit spacing of the density scale 234.

The method of utilizing slide-rule type computing apparatus 10 and 200 will be described by way of example, dealing first with an example of indirect screening, and then dealing with an example of direct screening. In indirect screening, one continuous tone negative is produced for each color component required to produce full color, for example, cyan, magenta and yellow, as well as the black, and a halftone positive is produced utilizing a halftone-producing screen. In the direct screening method, the process starts with a positive color transparency having a suitable filter and mask over it, a halftone negative for each of the required color components being produced by means of a halftone producing screen.

Dealing first with indirect screening, reference is had to FIGS. 3 – 5. Before use, the slide-rule device 10 according to the invention must be prepared by an empirical calibration method which specifically adapts the device to the system with which it is being utilized. The units of exposure scale is inscribed on an overlay 46 since the proportions of said scale will vary depending on the reciprocity factor of the system. Taking into consideration the reciprocity factor in selecting the units of exposure scale makes exposure results proportional to density. The reciprocity factor is determined empirically by comparing the value of the density of the original which produces a 50 percent dot in an exposure with screen only in "normal" time with the value of the original density which produces such a 50 percent dot in an exposure at twice "normal" time. A "-standard" units of exposure scale would be provided with the computer wherein the difference between said two densities would be, for example, 0.30. The ratio of the actual difference between said densities and the standard difference, "0.30," is the reciprocity factor. An exposure scale of the correct proportions can be made by photographic methods from the standard exposure scale utilizing a camera size set at said ratio.

The density scale, which as noted above is permanently inscribed on the surface 17 of base 12,was selected with equidistant marks approximately matching the anti-log of the exposure scale.

To calibrate the percent dot area versus density scale on orthogonal coordinates 74, the appropriate curve representative of this relationship for this particular set-up of the system including the screen is plotted on said coordinates. The data for said percent dot area versus density curve is obtained by making a screen only, no flash, no bump exposure of a gray scale against an average density background to produce a halftone. The percent dot area is measured at each density level of the gray scale by means of a densitometer. A dark field densitometer is preferably utilized to eliminate effect of dot fringe. If a conventional densitometer is used, calibration adjustments must be made in the resulting data. Greater accuracy is achieved if the percent dot area corresponding to each of the continuous-tone steps is obtained from the contact print on film, rather than from the soft-dot, camera negative. Curve 80 in FIG. 3 represents such a density versus percent dot area curve, referred to herein as the basic density curve. While this curve could be drawn directly on second slide member 32, the use of an overlay permits the slide-rule device 10 according to the invention to be used with a plurality of set-ups without the necessity of recalibration for each use. All that would be required would be the substitution of the appropriate overlay 42 associated with the set-up to be calibrated. Since the density measurements are made on a contact print on film, rather than on the camera film or plate, the percent dot area value utilized in deriving curve 80 would be the difference between the measured value (converted from density by a standard conversion chart) and 100 percent.

As applied to indirect screening, middle cursor 66 is identified as the T cursor and is generally representative of middle tone density. Left-most cursor 64 is identified as the S cursor representative of the shadow density and the right-most cursor 68 is identified as the H cursor and representative of the highlight density. The letters S, T and H are respectively removably inscribed on the corresponding plate 60 of the respective cursors. A curve representative of percent basic flash exposure (% BFE) versus time or exposure units is also applied to orthogonal coordinates 74. This curve can be obtained by trial exposures, although the data for such curve is available from the major film manufacturers, and a standard template of this curve may be provided. Referring again to FIG. 3, the % BFE curve is curve 82, which is applied to orthogonal coordinates 74 so that the 0% BFE point intersects the 0 percent dot area point on the density curve 80. The ordinate axis of the % BFE curve defines % BFE and may be indicated by a legend 86 for ease of reading. The unit spacing on the % BFE axis of the % BFE curve preferably corresponds to the unit scale on the percent dot area axis of coordinates 74. The abscissa of said % BFE scale is a density scale which need not be inscribed on the overlay.

In order to produce a scale for reading percent bump, it is necessary to plot a family of density curves corresponding to curve 80, but prepared at a plurality of main screen exposures plus percent bumps. Thus, separate exposures could be made for each of the two, four and eight percent bump conditions, said exposures being of a gray scale on a neutral background, as in the case of the preparation of curve 80. The family of percent bump density curves could be inscribed on a separate piece of graph paper having orthogonal coordinates corresponding to orthogonal coordinates 74, or they could be eraseably inscribed on overlay 42. Whatever approach is utilized, a single graph containing a family of density curves including the basic density curve 80 appears on a single set of orthogonal coordinates. The scale for percent bump is inscribed either on cursor line 64, the S cursor, or directly on density curve 80. This scale is derived by aligning said S cursor with the point on the basic density curve 80 corresponding to the maximum printable dot. This is usually located between 95 and 97 percent dot area. The percent bump scale is then produced by inscribing a short horizontal line 88 at the intersection of the S cursor and each of the percent bump density curves. Thus, the topmost of the horizontal lines **88** in FIG. **3** is representative of the intersection of the S cursor and the density curve corresponding to 6 percent bump. If the percent bump scale is to be inscribed on the density curve **80**, a short horizontal line would be inscribed on said density curve at the intersection of a horizontal line (parallel to the axis of abscissa of coordinates **74**) passing through the intersection of the S cursor aligned as above and each of the percent bump density curves. Inscribing the percent bump scale on cursor line **64** is the full equivalent of inscribing the percent bump scale on density curve **80**.

When all of the foregoing processes are completed, the slide-rule type device **10** is fully calibrated and ready for use in indirect screening. The first step in using device **10** is to set the first slide member **22**, which carries the units of exposure scale **70**. This setting is achieved by aligning the density value 1.0 on density scale **72** with the exposure index of the particular screen to be used. The exposure index is the number of exposure units required to produce a 50 percent dot at a selected reproducible degree of brightness on the film plane. This value is determined empirically and will remain substantially constant for a particular set-up, but generally varies between screens. In the example of FIG. **3**, the units of exposure are set to a magenta exposure index of 17.5, which value is aligned with 1.0 on the density scale.

To use the computer, it is necessary to determine what integrated halftone densities of highlight,midpoint and shadow are required in the finished product. This determination is made by the user based on eye response and the desired gray balance. Gray balance refers to the density relationship between the magenta, yellow and cyan exposures which will produce true gray tones.

Referring now to FIG. **3**, by way of example, the mid-point density was selected at 0.95, and second slide member **32** is displaced until the 50 percent dot area point on density curve **80** is aligned with T cursor **66**, as indicated by point **90** in FIG. **3**. The magenta main exposure is read at the intersection of the T cursor and the units of exposure scale when said T cursor and second slide member are so positioned. Thus, in the example of FIG. **3**, the main exposure is 16 exposure units. The highlight density was selected at a value of 1.6 and H cursor **68** is then moved into alignment with that value of density scale **72**. % BFE is read from the intersection of the H cursor and % BFE curve **82**. This point, at a value of 12 percent, is indicated at point **92**. Finally, the S cursor **64** is set at the shadow density of 0.35, and the percent bump is read on scale **88** on said S cursor. In the example of FIG. **3**, this value is 1.5 percent as indicated by the intersection of the S cursor **64** and the density curve **80** at point **94**.

The procedure is repeated for the yellow exposure index. In other words, the first slide member **22** is positioned relative to the density value 1.0 so that the exposure index associated with yellow is aligned therewith. Second slide member **32** is then aligned so that 50 percent dot position on the density scale is aligned with the T cursor and the midpoint density, shadow density and highlight density for yellow is read from the computer.

Reference is now made to FIG. **4** in connection with which the cyan exposures will be calculated. The device **10** of FIG. **4** is calibrated as indicated in connection with the discussion of FIG. 3. However, the process for using the computer varies in conjunction with the cyan exposure. The units of exposure scale is set as in the case of magenta and yellow exposures, in this case, cyan having an exposure index of 8.5. However, in the case of cyan, proper gray balance usually requires a midpoint dot value of between 60 and 65 percent, as opposed to the substantially 50 percent dot value of the magenta and yellow. It is noted that the midpoint dot value for magenta and yellow need not be 50 percent. The midpoint dot value on basic density curve **80** for any halftone is selected empirically by the user depending on the desired visual response to tone reproduction and/or gray value of the final product as determined by the ink-paper (substrate)-plate (printing surface) performance. Accordingly, the T cursor **66** is aligned with the desired midpoint density of 0.9 and the second slide member **32** is positioned so that the 62.5 percent dot area point on the density curve **80** is aligned with said T cursor, as indicated by point **96**. The main exposure is determined by then moving the T cursor into alignment with the 50 percent dot area point on density curve **80**, as indicated by phantom line **98**, intersecting density curve **80** at point **100** and then main exposure is read at the intersection of phantom line **98** and units of exposure scale **70**. The S cursor **64** is set at the shadow density and the percent bump will be indicated by the intersection of density curve **80** and scale **88** on said S cursor.

The highlight exposure is read in the usual manner except that the H cursor **68** is aligned with the highlight density, but the value on the % BFE curve **82** is read at the intersection of a point 0.05 density units to the left of said desired density value. In other words, the H cursor would be moved to the left, from the highlight density, 0.05 density units to the line indicated by phantom line **102** and % BFE would be read at the intersection of said phantom line and % BFE curve **82** as indicated by point **104**. If a K(black)exposure is to be made, the value for the K main exposure and for the K flash exposure may be calculated as illustrated in FIG. **5**. Again, the calibration of the device **10** remains unchanged but first slide member **22** is positioned so that the exposure index for K (black) is aligned with a density value of 1.0. Each of the S, T and H cursors are set at the desired shadow, mid-point and highlight densities, and the second slide member **32** is positioned so that the 50 percent dot area point on density curve **80** is aligned with the S cursor **64**. The latter setting is indicated at point **106**. The K main exposure is read at the intersection of the S cursor and the units of exposure scale **70**. The K flash exposure is read from the % BFE curve at the midpoint between the H and T cursors, as indicated by the intersection of phantom line **108** and % BFE curve **82** at point **109**. In this manner, all of the exposure values necessary for the production of a substantially optimum product are calculated, and through use of these values and through the maintenance of the set-up conditions, the reproduceability of the system is insured.

The circular slide rule embodiment of FIGS. **10** and **11** would be used in a similar manner. By way of example, a density versus percent dot area curve 238 has been drawn on the orthogonal coordinates 236 of second annular slide member 216. Also drawn on said coordinates is a % BFE curve 240.

Turning now to direct screening, the process utilizing slide-rule device 10 will be explained in connection with FIGS. 6 – 9. For direct screening, the slide-rule device is calibrated in an analogous manner, as will be noted below. First, the units of exposure scale is adjusted for reciprocity factor as described above. Then, as illustrated in FIG. 6, a no flash, no bump density curve 110 is plotted on orthogonal coordinates 74 and a % BFE curve 112 derived as discussed above is also applied to said orthogonal coordinates intersecting basic density curve 110 at 0 percent dot area (point 114). However, in addition to the basic density curve 110, an entire family of density curves is plotted on rectangular coordinates 74, each member of said family representing the density curve at the main exposure plus a specific % BFE. Thus, curves 116, 118, 120, 122, 124, 126 and 127 represent respectively the %BFE density curve for main plus 10, 20, 30, 40, 50, 60 and 70 % BFE. All of said density curves are derived in the manner described above.

Since we are now concerned with direct screening, the highlight and shadow areas are reversed so that, while the middle cursor line 66 is identified as the T cursor, the leftmost cursor line 64 is identified as the H or highlight cursor and the rightmost cursor 68 is identified as the S or shadow cursor. A scale 128 representative of percent bump is inscribed on the H cursor and is derived in the manner described above in connection with the percent bump scale on the S cursor for indirect screening.

The use of the slide-rule computing apparatus 10 according to the invention after calibration for direct screening starts with the setting of the units of exposure scale 72 is accordance with the exposure index for the particular screen. In the example of FIG. 6, which is directed to a magenta direct-screen separation, the exposure index is 58, which value is aligned with 1.0 on the density scale 72. The T cursor 66 is aligned with the desired midpoint density value, which value is determined either arbitrarily or through experiment. The determination is based on the midpoint value in terms of visual response and best reproduction of gray. A Munsell type evaluation of the printed results may be utilized to identify this midpoint value. The desired highlight density is the point at which a diffuse white highlight is produced, the H cursor being set at that value. In this case, the S cursor is set equidistant from the T cursor. In other words, the spacing between the H and T cursors equals the spacing between the T and the S cursors. Second slide member 32 is positioned so that the highlight end 130 of basic density curve 110 is aligned with the H cursor. The percent basic flash exposure is read at the intersection of the S cursor 68 and the % BFE curve 112, in this case, 40 % BFE. The main exposure for magenta is read by temporarily aligning the T cursor with the midpoint (in this case 50 percent) dot area point 132 on basic density curve 110 and reading the corresponding exposure value, as shown by phantom line 134.

For yellow, the units of exposure scale 72 is set for the yellow exposure index and the yellow main exposure is read by the T cursor 66 aligned with phantom line 134 in the manner described above.

The use of the computing device for calculating cyan exposures is illustrated in FIGS. 7 and 8. As an initial step, the units of exposure scale is displaced so that the exposure index for cyan is aligned with the 1.0 value on the density scale. The T cursor 66 is displaced from its original position shown by dashed line 136 to a new position, at which it intersects the density curve representative of the % BFE previously determined in conjunction with magenta at the point thereon substantially representative of 50 percent dot area, and which is also utilized for yellow. Thus, in FIG. 7, cursor 66 intersects curve 122 at point 138. The next step in the process is illustrated in FIG. 8, wherein it is seen that second slide member 32 is displaced to the left until the 37.5 percent dot area point on % BFE density curve 122 is aligned with T cursor 66. Thus, curve 122 intersects cursor 66 at point 140, the original position of basic density curve 110 and % BFE curve 112 being shown by dashed line 142. Percent bump for cyan is then read at the intersection of scale 128 on H cursor 64 and the basic density curve 110. In this case, a 3 percent bump is called for as indicated by the intersection of said H cursor and curve 110 (point 144). The main exposure for cyan is read by moving the T cursor into alignment with the 50 percent dot area point on the basic density curve 110. Note that the 50 percent dot area point for reading cyan, magenta and yellow main exposures is selected empirically as the desired midpoint for tone reproduction and gray balance. Similarly, the 37.5 percent dot area point in the selected % BFE density curve (curve 122 in example) with which T cursor 66 is aligned is determined empirically. The latter value is derived as the value less than the midpoint value by an amount substantially equal to the difference in percent dot area between cyan and either of magenta and yellow, cyan being generally larger. This measurement is illustrated by phantom line 146 which intersects curve 110 at point 148, the main exposure being read on units of exposure scale 70. The % BFE for cyan is determined by displacing the S cursor to the left 0.05 density units to alignment with phantom line 150, the value of % BFE being read at the intersection with curve 112, said intersection lying at point 152. The number of density units of displacement of said S cursor is selected for tone reproduction and gray balance of final product.

If a K (black) exposure is to be made, then the device 10 must be set so that the units of exposure scale 72 is positioned so that the K (black) exposure index is aligned with 1.0 on the density scale, as illustrated in FIG. 9. The second slide member 32 is then displaced so that the end 130 of basic density curve 110 is aligned with a vertical line corresponding to three-fourths of the distance between the T and H cursors, as measured from the H cursor, a line indicated by phantom line 154. The K main exposure is read by aligning the T cursor with the 50 percent dot area point on basic density curve 110, as indicated by phantom line 156 which intersects the basic density curve at point 158.

The K % BFE is read by identifying which of the family of main plus % BFE curves 116, 118, 120, 122, 124, 126, etc. intersects with the intersection of about the 20 percent dot area abscissa 160 and the S cursor

68. The % BFE which produced the intersected curve represents the K % BFE. In this case, curve 118 is intersected and the % BFE is 20.

Where UCR exposures are to be measured, the following procedure is followed. Referring first to FIG. 6, for magenta and yellow, the UCR exposure is read as % BFE at the intersection of the % BFE abscissa equal to the K flash exposure (20 percent) and the S cursor 68. This intersection is at point 164 and intersects curve 127, one of the family of % BFE density curves, the UCR exposure being the % BFE represented by curve 127. This value applies to both magenta and yellow.

Reference is had to FIG. 8, which depicts the reading of the cyan UCR exposure. This exposure is read as % BFE at the K flash minus 12.5 percent. Since the K flash, as determined above was 20 percent, the UCR exposure for cyan is read at the intersection of the 7.5 percent abscissa indicated by dashed line 166 and the S cursor 68. This intersection point 168 intersects curve 126 of the family of % BFE density curves, the UCR exposure being read as the % BFE associated therewith.

The above-described apparatus and method provides an integrated approach for the calculation of exposures for the production of halftones, both by the direct and indirect screening processes. The input information utilized describes the original copy in terms of photographic densities while the empirically derived information used in calibration describes the performance capabilities, and characteristic of the halftone reproduction set-up to produce a product to give dot size specifications. The input is compared with the output requirements to produce a read-out in terms of optimum exposure combinations of main, bump and flash exposures. Each exposure has the most effective control of a portion of the reproduction characteristic. Thus, the bump exposure is calculated (not estimated as in former practice) for its effect on the bright part of the copy image; the main exposure is calculated (and the calculation includes the additional exposure effects of the bump and flash exposures) for its effect on the selected midpoint; and the flash exposure is calculated (which includes any effects of the main and bump exposures) for its effect on the darkest part of the copy image. Accordingly, the apparatus and method according to the invention provides coordinated main, bump and flash exposures, with emphasis on the accurate placement of the midpoint densities.

The slide-rule type calculating device according to the invention is essentially an empirical analog of the halftoning process, and provides a means for adapting the method according to the invention for each individual halftone reproduction set-up. While the various slide members and cursors are manually manipulatable in the embodiment described in this application, said slide members and cursors could be automatically manipulated by suitable control devices where the slide-rule type computing apparatus according to the invention is mechanized. The manipulation of the various slide members and cursors could be effected automatically, in response to outputs of density sensing devices, or other input and control devices of the "-mechanized" device.

The method according to the invention could also be practiced by means of programmable analog and/or digital computers, in which case the calibration steps would be achieved by programming the computer to store the empirical data, while the calculation steps would be performed within the computer. Generally, such calculation steps would be performed without any physical manipulation of slide members and cursors, although the full equivalent of said manipulative steps would be performed electronically by the computer. Thus, a step such as aligning the magenta exposure index on the unit of exposure scale with the 1.0 value on the density scale could be achieved within a digital computer without physical displacement of a slide member or actual display of the scales by shifting one of the scales in registers or memory. Similarly, the equivalent of positioning a cursor and reading a scale in accordance with the alignment thereof could also be performed electronically by a digital computer.

While the foregoing examples are for four-color process work, the same method is applicable to single or multi-color halftone reproductions or interpretations, such as duotones or "tritones" (three non-process colors). The actual initial settings used in the method and apparatus according to the invention such as highlight, midpoint and shadow densities and midpoint percent dot area on the basic density curve, are determined empirically by the user in each case to produce the desired results.

It will thus be seen that the objects set forth above, and those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A slide-rule type computing apparatus for calculating halftone screen exposures comprising a base; first and second slide members mounted in spaced relation for substantially parallel lateral displacement across said base, the region of said base intermediate said first and second slide members having a linear density scale inscribed thereon; said first slide member being adapted to receive a logarithmic units of exposure scale, said second slide member being adapted to receive a scale having orthogonal coordinates, the spacing of the coordinates along the axis of abscissa thereof substantially corresponding with the units of said density scale for receiving plots of percent dot area versus density; and three cursor members slidably mounted on said base for lateral displacement across said base and slide members, each of said cursor members having a cursor line extending substantially normal to the axis of lateral displacement of said slide members and overlaying both said slide members and the region of said base therebetween.

2. A slide-rule type computing apparatus as recited in claim 1, including an overlay dimensioned and adapted for removable mounting on said first slide member and having said logarithmic units of exposure scale inscribed thereon.

3. A slide-rule type computing apparatus as recited in claim 1, including an overlay dimensioned and adapted for removable mounting on said second slide member, said second slide member overlay having said orthogonal coordinates inscribed thereon.

4. A slide-rule type computing apparatus as recited in claim 3, wherein said second slide member overlay is inscribed with a scale defining the ordinate axis of said orthogonal coordinates,said scale extending linearly between 0 and 100 and being representative of percent dot area.

5. A slide-rule type computing apparatus as recited in claim 1, wherein said orthogonal coordinates have a density curve of percent dot area versus density and a % BFE curve inscribed thereon, with the point of 0 percent dot area on said density curve substantially the point of 0% BFE on said % BFE curve.

6. A slide-rule type computing apparatus as recited in claim 5, wherein a percent bump scale is inscribed on the one of said cursor members on the left when said scales are viewed.

7. A slide-rule type computing apparatus as recited in claim 5, wherein said second slide member has a family of density curves inscribed on the orthogonal coordinates thereof, a first of said family of density curves representing a main exposure-no flash condition, each of the other of said density curves representing main exposure plus a particular value of % BFE.

8. A slide-rule type computing apparatus as recited in claim 1, wherein said slide rule is linear.

9. A slide-rule type computing apparatus as recited in claim 1, wherein said first and second slide members extend linearly.

10. A slide-rule type computing apparatus as recited in claim 1, wherein said first and second slide members are annular shaped, said cursor members being pivotably mounted at the axis of rotation of said slide members, said cursor lines extending radially from said axis.

11. A method for calculating halftone contact screen exposures on a slide-rule type computing apparatus having a base, first and second slide members mounted in spaced relation for substantially parallel lateral displacement relative to said base, the region of said base intermediate said slide members having a linear density scale inscribed thereon, said first slide member being adapted to have a logarithmic units of exposure scale positioned thereon, said second slide member being adapted to have a scale having orthogonal coordinates positioned thereon, the spacing along the axis of abscissa of said coordinates substantially corresponding to the units of said density scale; and first, second and third cursor members slideably mounted on said base for lateral displacement relative thereto, each of said cursor members having a cursor line inscribed thereon extending normally to the axis of lateral displacement of said slide members and overlaying said slide members and the region of said base therebetween, which comprises the step of calibrating said slide-rule type computing apparatus including inscribing on said orthogonal coordinates a basic density curve plot of percent dot area versus density of original for the set-up to be used; and inscribing on said orthogonal coordinates a % BFE curve, the 0 percent dot area point on said basic density curve and the 0% BFE point on said % BFE curve being in substantial coincidence.

12. The method of claim 11, wherein said calibration step further includes the step of empirically deriving the data for said plot of percent dot area versus density of original by measuring percent dot area on a halftone print of a screen-only exposure of a gray scale.

13. The method of claim 11, wherein said calibration step further includes inscribing a family of plots of percent dot area versus density of original on said orthogonal coordinates, each of the plots in said family being representative of a main exposure plus a percent bump exposure of predetermined value; positioning the cursor member on the left when said scales are viewed to align said left-most cursor line with the point on said basic density curve corresponding to the maximum printable dot; and inscribing a percent bump scale on said left-most cursor line corresponding to the intersection between said cursor line with each of said family of percent bump density curves, the value of percent bump on each point of said percent bump scale being equal to the added percent bump of the intersecting percent bump density curve; and identifying said left-most cursor lines as the S cursor, the middle cursor line as the T cursor and the right-most cursor line as the H cursor, whereby said calculating apparatus is prepared for use in indirect screening.

14. The method of claim 13, including the further step of calculating the magenta exposures comprising:

a. aligning the magenta exposure index on said units of exposure scale with the 1.0 value of said density scale by displacing said first slide member;
b. aligning said H, T and S cursors with the highlight, midpoint and shadow densities on said density scale by displacing each of said cursor members;
c. aligning the percent dot area point on said basic density curve which substantially corresponds to the desired magenta midpoint for tone reproduction and gray balance with said T cursor by displacing said second slide member;
d. reading the magenta main exposure on said units of exposure scale at the intersection thereof with said T cursor;
e. reading the magenta flash exposure as the % BFE at the intersection of said % BFE curve and said H cursor; and
f. reading the magenta bump exposure as the percent bump at the intersection of said percent bump scale on said S cursor and said basic density curve.

15. The method of claim 14, wherein the percent dot area value on said basic density curve aligned with said T cursor is about 50 percent.

16. The method of claim 13, including the further step of calculating the yellow exposures comprising:

a. aligning the yellow exposure index on said units of exposure scale with the 1.0 value of said density scale by displacing said first slide member;
b. aligning said H, T and S cursors with the highlight, midpoint and shadow densities on said density scale by displacing each of said cursor members;
c. aligning the percent dot area point on said basic density curve substantially corresponds to the desired yellow midpoint for tone reproduction and gray balance with said T cursor by displacing said second slide member;
d. reading the yellow main exposure on said units of exposure scale at the intersection thereof with said T cursor;

e. reading the yellow flash exposure as the % BFE at the intersection of said % BFE curve and said H cursor; and

f. reading the yellow bump exposure as the percent bump at the intersection of said percent bump scale on said S cursor and said basic density curve.

17. The method of claim **16**, wherein the percent dot area value on said basic density curve aligned with said T cursor is about 50 percent.

18. The method of claim **13**, including the step of calculating the cyan exposures comprising:

a. aligning the cyan exposure index on the units of exposure scale with the 1.0 value of said density scale by displacing said first slide member;

b. aligning said H, T and S cursors with the highlight, midpoint and shadow densities on said density scale by displacing each of said cursor members;

c. aligning the percent dot area point on said basic density curve which substantially corresponds to the desired cyan midpoint for tone reproduction and gray balance with said T cursor by displacing said second slide member;

d. reading the cyan main exposure at a point on said units of exposure scale substantially aligned with an axis extending parallel to said T cursor and passing through a point substantially corresponding to 50 percent dot area on said density curve;

e. reading the cyan flash exposure as the % BFE at the intersection of said % BFE curve and an axis extending substantially parallel to said H cursor and aligned with a point on said density scale a number of density units selected for tone reproduction and gray balance less than the point on said scale with which said H cursor is aligned; and

f. reading the cyan bump exposure as the percent bump at the intersection of said percent bump scale on said S cursor and said basic density curve.

19. The method of claim **18**, wherein the number of density units less than the point on said density scale with which said H cursor is aligned is about 0.05.

20. The method of claim **18**, wherein the percent dot area value on said basic density curve aligned with said T cursor lies within the range between 60 and 65 percent dot area.

21. The method of claim **20**, wherein the percent dot area value on said basic density curve aligned with said T cursor is about 62.5 percent.

22. The method of claim **13**, including the further step of calculating halftone exposures comprising:

a. aligning exposure index for the set up on said units of exposure scale with the 1.0 value of said density scale by displacing said first slide member;

b. aligning said H, T and S cursors with the highlight, midpoint and shadow densities on said density scale by displacing each of said cursor members;

c. aligning the percent dot area point on said basic density curve which substantially corresponds to the desired midpoint for tone reproduction any/or gray balance with said T cursor by displacing said second slide member;

d. reading the main exposure on said units of exposure scale at the intersection thereof with said T cursor;

e. reading the flash exposure as the % BFE at the intersection of said % BFE curve and said H cursor; and

f. reading the bump exposure as the percent bump at the intersection of said percent bump scale on said S cursor and said basic density curve.

23. The method of claim **11**, including the step of calculating the K (black) exposures comprising:

a. aligning the K (black) exposure index on said units of exposure scale with the 1.0 value on said density scale by displacing said first slide member;

b. aligning said H, T and S cursors with the highlight, midpoint and shadow densities on said density scale by displacing each of said cursor members;

c. aligning the percent dot area point on said basic density curve which substantially corresponds to the desired K (black) midpoint for tone reproduction and gray balance with said S cursor;

d. reading the K (black) main exposure on said units of exposure scale at the intersection thereof with said S cursor; and

e. reading the K (black) flash exposure as the % BFE at the intersection of an axis extending substantially parallel to said T cursor about midway between said H and T cursors, and said % BFE curve.

24. The method of claim **23**, wherein the percent dot area value on said basic density curve aligned with said S cursor is about 50 percent.

25. The method of claim **11**, including the further step of forming said units of exposure scale as a proportion of a standard units of exposure scale, said proportion being equal to the reciprocity factor of said set-up.

26. The method of claim **11**, wherein the left-most of said cursor lines when viewing said scales is identified as the H cursor, the middle cursor line is identified as the T cursor, and the right-most cursor line is identified as the S cursor; and including the further step of inscribing on said orthogonal coordinates a family of % BFE density curves for the set-up to be used defined by plots of percent dot area versus density of original, each of said plots representing the combination of a main exposure and one of a selected plurality of % BFE exposures and being identified by the value of the % BFE thereof, so that said slide-rule type calculating apparatus is adapted for calculating exposure values for direct screening.

27. The method of claim **26**, including the further step of calculating magenta exposures comprising:

a. aligning the magenta exposure index on said units of exposure scale with the 1.0 value on said density scale by displacing said first slide member;

b. aligning said H and T cursors with the respective highlight and midpoint densities on said density scale by displacing the corresponding cursor members;

c. aligning said S cursor so that the distance between said H and T cursors substantially equals the distance between said T and S cursors;

d. aligning said basic density curve so that the highlight end thereof substantially touches said H cursor;

e. reading the magenta flash exposure as % BFE at the intersection of said S cursor and said % BFE curve or at the intersection of said S cursor and the point substantially representative of 0% dot area on one of said family of %BFE density curves; and

f. reading the magenta main exposure on the units of exposure scale at a point thereon intersecting an axis extending substantially parallel to said T cursor and passing through the percent dot area point on said basic density curve substantially corresponding to the desired magenta midpoint for tone reproduction and gray balance.

28. The method of claim 27, wherein the percent dot area value on said basic density curve intersecting said axis extending substantially parallel to said T cursor is about 50 percent.

29. The method of claim 27, and including the further step of reading the magenta UCR exposure at the intersection of said S cursor and the abscissa of said orthogonal coordinates equal to the K(black)flash exposure in % BFE, as the % BFE associated with the one of the family of % BFE curves passing through said intersection.

30. The method of claim 27, wherein the percent dot area value on said basic density curve intersecting said axis extending substantially parallel to said T cursor is about 50 percent.

31. The method of claim 26, and including the further step of calculating yellow exposures comprising:

a. aligning the yellow exposure index on said units of exposure scale with the 1.0 value on said density scale by displacing said first slide member;

b. aligning said H and T cursors with the respective highlight and midpoint densities on said density scale by displacing the corresponding cursor members;

c. aligning said S cursor so that the distance between said H and T cursors substantially equals the distance between said T and S cursors;

d. aligning said basic density curve so that the highlight end thereof touches said H cursor;

e. reading the yellow flash exposure at the intersection of said S cursor and said % BFE curve or at the intersection of said S cursor and the 0 percent dot area on one of said family of % BFE density curves, as % BFE; and

f. reading the yellow main exposure on the units of exposure scale at a point thereon intersecting an axis extending substantially parallel to said T cursor and passing through the percent dot area point on said basic density curve substantially corresponding to the desired yellow midpoint for tone reproduction and gray balance.

32. The method of claim 31, and including the further step of reading the yellow UCR exposure at the intersection of said S cursor and the abscissa on said orthogonal coordinates equal to the K (black)flash exposure in % BFE, as the % BFE associated with the one of the family of % BFE curves passing through said intersection.

33. The method of claim 26, including the further step of calculating halftone exposures comprising:

a. aligning the exposure index for the set-up on said units of exposure scale with the 1.0 value on said density scale by displacing said first slide member;

b. aligning said H and T cursors with the respective highlight and midpoint densities on said density scale by displacing the corresponding cursor members;

c. aligning said S cursor so that the distance between said H and T cursors substantially equals the distance between said T and S cursors;

d. aligning said basic density curve so that the highlight end thereof substantially touches said H cursor;

e. reading the flash exposure as % BFE at the intersection of said S cursor and said % BFE curve or at the intersection of said S cursor and the point substantially representative of 0% dot area on one of said family of % BFE density curves; and

f. reading the main exposure on the units of exposure scale at a point thereon intersecting an axis extending substantially parallel to said T cursor and passing through the percent dot area point on said basic density curve substantially corresponding to the desired midpoint for tone reproduction and/or gray balance.

34. The method of claim 26, wherein said calibration step further includes inscribing a family of plots of percent dot area versus density of original on said orthogonal coordinates, each of the plots in said family being representative of a main exposure plus a percent bump exposure of predetermined value; aligning the H cursor with the point on said basic density curve corresponding to maximum printable dot; and inscribing a scale on said H cursor corresponding to the intersection between said cursor and each of said family of percent bump density curves, the value of percent bump on each point of said scale being equal to the added percent bump of the intersecting percent bump density curve.

35. The method of claim 34, and including the further step of calculating cyan exposures comprising:

a. aligning the cyan exposure index on said units of exposure scale with the 1.0 value on said density scale by displacing said first slide member;

b. aligning said H and T cursors with the respective highlight and midpoint densities on said density scale by displacing the corresponding cursor members;

c. aligning said S cursor so that the distance between said H and T cursors substantially equals the distance between said T and S cursors;

d. aligning said basic density curve so that the highlight end thereof touches said H cursor;

e. aligning said T cursor with the percent dot area point on the selected one of said % BFE density curves associated with the % BFE for magenta or yellow which corresponds to the desired magenta or yellow midpoint for tone reproduction and gray balance, by displacing the corresponding cursor member;

f. aligning the percent dot area point on said selected % BFE density curve which corresponds to the cyan midpoint for tone reproduction and gray balance with said T cursor by displacing said second slide member;

g. reading the cyan main exposure at the intersection of said units of exposure scale and an axis extending substantially parallel to said T cursor and passing through the point on said basic density curve substantially representative of 50 percent dot area;

h. reading the cyan bump exposure at the intersection of said percent bump scale on said H cursor and said basic density curve as percent bump; and

i. reading the cyan flash exposure as % BFE at the intersection of an axis extending substantially parallel to said S cursor and aligned with a point on said density scale a number of density units selected for tone reproduction and gray balance less than the point on said scale with which said S cursor is aligned, with either said % BFE curve or the 0 percent dot area point on one of said family of % BFE density curves.

36. The method of claim **35**, wherein the number of density units less than the point on said density scale with which said S cursor is aligned is about 0.05.

37. The method of claim **35**, wherein the percent dot area point on said selected % BFE density curve with which said T cursor is aligned by displacing the corresponding cursor member is about 50 percent.

38. The method of claim **37**, wherein the percent dot area point on said selected % BFE density curve with which said T cursor is aligned by displacing said second slide member is about 37.5 percent.

39. The method of claim **35**, and including the further step of reading cyan UCR exposure at the intersection of said S cursor with the abscissa on said orthogonal coordinates equal to the K (black) flash exposure in % BFE minus 12.5 percent, as the %BFE associated with the one of said family of % BFE curves passing through said intersection.

40. The method of claim **34**, and including the further step of calculating halftone exposures for a second color correlated to a first color comprising:

a. aligning the second color exposure index on said units of exposure scale with the 1.0 value on said density scale by displacing said first slide member;

b. aligning said H and T cursors with the respective highlight and midpoint densities on said density scale by displacing the corresponding cursor members;

c. aligning said S cursor so that the distance between said H and T cursors substantially equals the distance between said T and S cursors;

d. aligning said basic density curve so that the highlight end thereof touches said H cursor;

e. aligning said T cursor with the percent dot area point on the selected one of said % BFE density curves associated with the % BFE for said first color which corresponds to the desired first color midpoint for tone reproduction and/or gray balance, by displacing the corresponding cursor member;

f. aligning the percent dot area point on said selected % BFE density curve which corresponds to the second color midpoint for tone reproduction and/or gray balance with said T cursor by displacing said second slide member;

g. reading the second color main exposure at the intersection of said units of exposure scale and an axis extending substantially parallel to said T cursor and passing through the point on said basic density curve substantially representative of 50 percent dot area;

h. reading the second color bump exposure at the intersection of said percent bump scale on said H cursor and said basic density curve as percent bump; and

i. reading the second color flash exposure as % BFE at the intersection of an axis extending substantially parallel to said S cursor and aligned with a point on said density scale a number of density units selected for tone reproduction and/or gray balance less than the point on said scale with which said S cursor is aligned, with either said % BFE curve or the 0 percent dot area point on one of said family of % BFE density curves.

41. The method of claim **26**, including the further step of calculating K (black) exposures comprising:

a. aligning the K (black) exposure index on said units of exposure scale with the 1.0 value on said density scale by displacing said first slide member;

b. aligning said H and T cursors with the respective highlight and midpoint densities on said density scale by displacing the corresponding cursor members;

c. aligning said S cursor so that the distance between said H and T cursors substantially equals the distance between said T and S cursors;

d. aligning the highlight end of said basic density curve with an axis extending substantially parallel to said T cursor and positioned at a point spaced from said H cursor a distance equal to about three-fourths of the distance between said H and T cursors;

e. reading the K (black) main exposure on said units of exposure scale at its intersection with an axis extending substantially parallel to said T cursor and intersecting a percent dot area point on said basic density curve which substantially corresponds to the desired K(black) midpoint for tone reproduction and gray value;

f. reading the K (black) flash exposure at the intersection of said S cursor with about the 20 percent dot area abscissa on said orthogonal coordinates, as the % BFE associated with the one of said family of % BFE density curves crossing said intersection.

42. The method of claim **41**, wherein said percent dot area point on said basic density curve corresponding to the desired K (black) midpoint is about 50 percent.

43. The method of claim **26**, including the further step of forming said units of exposure scale as a proportion of a standard units of exposure scale, said proportion being equal to the reciprocity factor of said set-up.

44. A method of calculating halftone screen exposures on a calculating device having a logarithmic units of exposure scale positionable for selective alignment with a linear density scale and having a set of orthogonal coordinates positionable for selective alignment with said density scale, the units along the axis of abscissa of said coordinates substantially corresponding to the units of said density scale, which comprises the step of calibrating said computing apparatus including applying on said orthogonal coordinates a basic density curve plot of percent dot area versus density of original for the set-up to be used; and applying to said orthogonal coordinates a % BFE curve, the 0 percent dot area point on said basic density curve and the 0% BFE point on said % BFE curve being in substantial coincidence.

45. The method of claim **44**, wherein said calibration step further includes the step of empirically deriving the data for said plot of percent dot area versus density of original by measuring percent dot area on a halftone print of a screen-only exposure of a gray scale.

46. The method of claim 45, including the further step of calculating the halftone exposures comprising:

a. positioning said units of exposure scale so that the exposure index for the set-up is aligned with the 1.0 value on said density scale;
b. positioning said orthogonal coordinates so that the percent dot area point on said basic density curve which substantially corresponds to the desired midpoint for tone reproduction and/or gray balance is aligned with the midpoint density on said density scale;
c. reading the magenta main exposure on said units of exposure scale at the intersection thereof with an axis extending substantially parallel to said axis of ordinates and passing through said point on said basic density curve substantially corresponding to said desired midpoint;
d. reading the flash exposure as the % BFE at the intersection of said % BFE curve with an axis extending substantially parallel to said axis of ordinates and passing through the highlight density on said density scale;and
e. reading the bump exposure as the percent bump on said percent bump scale at the intersection of an axis extending parallel to said axis of ordinates and passing through the shadow density on said density scale,with said basic density curve.

47. The method of claim 44, wherein said calibration step further includes applying a percent bump scale to said orthogonal coordinates along an axis extending parallel to the axis of ordinates thereof, the value of percent bump on each point of said percent bump scale being determined from the intersection of an axis extending substantially parallel to the axis of ordinates of said orthogonal coordinates and passing through the point on said basic density curve corresponding to the maximum printable dot, with each of a family of plots of percent dot area versus density of original on said orthogonal coordinates, each of the plots in said family being representative of a main exposure plus a percent bump exposure of predetermined value, the predetermined value associated with each intersecting curve of said family determining the value on said percent bump scale, whereby said calculating device is prepared for use in indirect screening.

48. The method of claim 47, including the further step of calculating the magenta exposures comprising:

a. positioning said units of exposure scale so that the magenta exposure index is aligned with the 1.0 value on said density scale;
b. positioning said orthogonal coordinates so that the percent dot area point on said basic density curve which substantially corresponds to the desired magenta midpoint for tone reproduction and gray balance is aligned with the midpoint density on said density scale;
c. reading the magenta main exposure on said units of exposure scale at the intersection thereof with an axis extending substantially parallel to said axis of ordinates and passing through said point on said basic density curve substantially corresponding to said magenta midpoint;
d. reading the magenta flash exposure as the % BFE at the intersection of said % BFE curve with an axis extending substantially parallel to said axis of ordinates and passing through the highlight density on said density scale; and
e. reading the magenta bump exposure as the percent bump on said percent bump scale at the intersection of an axis extending parallel to said axis of ordinates and passing through the shadow density on said density scale,with said basic density curve.

49. The method of claim 48, wherein the percent dot area value in said basic density curve aligned with said midpoint on said density scale is about 50 percent.

50. The method of claim 47, including the further step of calculating the yellow exposures comprising:

a. positioning said units of exposure scale so that the yellow exposure index is aligned with the 1.0 value on said density scale;
b. positioning said orthogonal coordinates so that the percent dot area point on said basic density curve which substantially corresponds to the desired yellow midpoint for tone reproduction and gray balance is aligned with the midpoint density on said density scale;
c. reading the yellow main exposure on said units of exposure scale at the intersection thereof with an axis extending substantially parallel to said axis of ordinates and passing through said point on said basic density curve substantially corresponding to said yellow midpoint;
d. reading the yellow flash exposure as the % BFE at the intersection of said % BFE curve with an axis extending substantially parallel to said axis of ordinates and passing through the highlight density on said density scale; and
e. reading the yellow bump exposure as the percent bump on said percent bump scale at the intersection of an axis extending parallel to said axis of ordinates and passing through the shadow density on said density scale, with said basic density curve.

51. The method of claim 50, wherein the percent dot area value on said basic density curve aligned with said midpoint on said density scale is about 50 percent.

52. The method of claim 47, including the step of calculating the cyan exposures comprising:

a. positioning said units of exposure scale so that the cyan exposure index is aligned with the 1.0 value on said density scale;
b. positioning said orthogonal coordinates so that the percent dot area point on said density curve which substantially corresponds to the desired cyan midpoint for tone reproduction and gray balance is aligned with the midpoint density on said density scale;
c. reading the cyan main exposure on said units of exposure scale at the intersection thereof with an axis extending substantially parallel to said axis of ordinates and passing through the point on said basic density curve substantially corresponding to said cyan midpoint;
d. reading the cyan flash exposure as the % BFE at the intersection of said % BFE curve with an axis extending substantially parallel to said axis of ordinates and the point on said density scale a number of density units selected for tone

reproduction and gray balance less than the hightlight density; and

e. reading the cyan bump exposure as the percent bump on said percent bump scale at the intersection of an axis extending parallel to said axis of ordinates and passing through the shadow density on said density scale,with said basic density curve.

53. The method of claim **52**, wherein the number of density units less than the highlight density is about 0.05.

54. The method of claim **52**, wherein the percent dot area value on said density curve aligned with the midpoint density on said density scale lies within the range between 60 and 65 percent dot area.

55. The method of claim **54**, wherein the percent dot area value on said basic density curve aligned with said midpoint density is about 62.5 percent.

56. The method of claim **44**, including the step of calculating the K (black) exposure comprising:

a. positioning said units of exposure scale so that the K (black) exposure index is aligned with the 1.0 value on said density scale;

b. positioning said orthogonal coordinates so that the percent dot area point on said basic density curve which substantially corresponds to the desired K (black) midpoint for tone reproduction and gray balance is aligned with the shadow density on said density scale;

c. reading the K (black) main exposure on said units of exposure scale at the intersection thereof with an axis extending substantially parallel to said axis of ordinates and passing through said shadow density on said density scale; and

d. reading the K (black) flash exposure as the % BFE at the intersection of of said % BFE curve with an axis extending substantially parallel to said axis of ordinates and passing through a point on said density scale about midway between said highlight and midpoint densities.

57. The method of claim **56**, wherein the percent dot area point on said basic density curve aligned with said shadow density is about 50 percent.

58. The method of claim **44**, including the further step of forming said units of exposure scale as a proportion of a standard units of exposure scale, said proportion being equal to the reciprocity factor of said set-up.

59. The method of claim **44**, including the further step of applying on said orthogonal coordinates a family of % BFE density curves for the set-up to be used defined by plots of percent dot area versus density of original, each of said plots representing the combination of a main exposure and one of a selected plurality of % BFE exposures and being identified by the value of the % BFE thereof, so that said calculating device is adapted for calculating exposure values for direct screening.

60. The method of claim **59**, including the further step of calculating magenta exposures comprising:

a. positioning said units of exposure scale so that the magenta exposure index is aligned with the 1.0 value on said density scale;

b. positioning said orthogonal coordinates so that the highlight end of said basic density curve is substantially aligned with the highlight density on said density scale;

c. reading the magenta flash exposure as % BFE at the intersection of an axis extending substantially parallel to said axis of ordinates and aligned with a point on said density scale of a value higher than said midpoint density by an amount substantially equal to the difference in densities between said highlight and midpoint densities, with the % BFE curve or with a point substantially representative of 0 percent dot area on one of said family of % BFE density curves; and

d. reading the magenta main exposure on the units of exposure scale at a point thereon intersecting an axis extending substantially parallel to said axis of ordinates and passing through a percent dot area point on said density curve which substantially corresponds to the desired magenta midpoint for tone reproduction and gray balance.

61. The method of claim **60**, wherein the percent dot area value on said basic density curve intersecting said axis extending substantially parallel to said axis of ordinates is about 50 percent.

62. The method of claim **60**, and including the further step of reading the magenta UCR exposure at the intersection of said axis extending substantially parallel to said axis of ordinates and passing through a point on said density scale of a value higher than said midpoint density by an amount equal to the difference between said midpoint density and said highlight density, with the abscissa of said orthogonal coordinates equal to the K (black) flash exposure in % BFE, as the % BFE associated with the one of the family of % BFE curves passing through said intersection.

63. The method of claim **60**, and including the further step of reading the yellow UCR exposure at the intersection of said axis extending substantially parallel to said axis of ordinates and passing through a point on said density scale of a value higher than said midpoint density by an amount equal to the difference between said midpoint density and said highlight density, with the abscissa of said orthogonal coordinates equal to the K (black) flash exposure in % BFE, as the % BFE associated with the one of the family of % BFE curves passing through said intersection.

64. The method of claim **59**, and including the further step of calculating yellow exposures comprising:

a. positioning said units of exposure scale so that the yellow exposure index is aligned with the 1.0 value on said density scale;

b. positioning said orthogonal coordinates so that the highlight end of said basic density curve is substantially aligned with the highlight density on said density scale;

c. reading the yellow flash exposure as % BFE at the intersection of an axis extending substantially parallel to said axis of ordinates and aligned with a point on said density scale of a value higher than said midpoint density by an amount substantially equal to the difference in densities between said highlight and midpoint densities, with the % BFE curve, or with a point substantially representative of 0 percent dot area on one of said family of %BFE density curves; and

d. reading the yellow main exposure on the units of exposure scale at a point thereon intersecting an axis extending substantially parallel to said axis of ordinates and passing through a percent dot area point on said density curve which substantially corresponds to the desired magenta midpoint for tone reproduction and gray balance.

65. The method of claim 64, wherein the percent dot area value on said basic density curve intersecting said axis extending substantially parallel to said axis of ordinates is about 50 percent.

66. The method of claim 59, including the further step of calculating halftone exposures comprising:

a. positioning said units of exposure scale so that the exposure index for the set-up is aligned with the 1.0 value on said density curve;

b. positioning said orthogonal coordinates so that the highlight end of said basic density curve is substantially aligned with the highlight density on said density scale;

c. reading the flash exposure as % BFE at the intersection of an axis extending substantially parallel to said axis of ordinates and aligned with a point on said density scale of a value higher than said midpoint density by an amount substantially equal to the difference in densities between said highlight and midpoint densities, with the % BFE curve or with a point substantially representative of 0 percent dot area on one of said family of % BFE density curves; and

d. reading the main exposure on the units of exposure scale at a point thereon intersecting an axis extending substantially parallel to said axis of ordinates and passing through a percent dot area point on said density curve which substantially corresponds to the desired midpoint for tone reproduction and/or gray balance.

67. The method of claim 59, wherein said calibration step further includes applying a percent bump scale to said orthogonal coordinates along an axis extending parallel to the axis of ordinates thereof, the value of percent bump on each point of said percent bump scale being determined from the intersection of an axis extending substantially parallel to the axis of ordinates of said orthogonal coordinates and passing through the point on said basic density curve corresponding to the maximum printable dot, with each of a family of plots of percent dot area versus density of original on said orthogonal coordinates, each of the plots in said family being representative of a main exposure plus a percent bump exposure of predetermined value, the predetermined value associated with each intersecting curve of said family determining the value on said percent bump scale.

68. The method of claim 67, and including the further step of calculating cyan exposures comprising:

a. positioning said units of exposure scale so that the cyan exposure index is aligned with the 1.0 value on said density scale;

b. positioning said orthogonal coordinates so that the point substantially representative of the highlight end thereof is aligned with the highlight density on said density scale;

c. repositioning said orthogonal coordinates so that the percent dot area point on the selected one of said %BFE density curves associated with the % BFE for magenta or yellow which substantially corresponds to the desired cyan midpoint for tone reproduction and gray balance is aligned with an axis extending substantially parallel to said axis of ordinates and passing through the percent dot area point on said said selected one of said % BFE density curves which substantially correspond to the desired magenta or yellow midpoint for tone reproduction and gray balance when said orthogonal coordinates were first positioned;

d. reading the cyan main exposure at the intersection of said units of exposure scale and an axis extending substantially parallel to said axis of ordinates and passing through a point on said basic density curve substantially representative of 50 percent dot area;

e. reading the cyan bump exposure as the percent bump on said percent bump scale at the intersection of an axis extending parallel to said axis of ordinates and passing through the highlight density on said density scale, with said basic density curve; and

f. reading the cyan flash exposure as % BFE at the intersection of an axis extending substantially parallel to said axis of ordinates and passing through a point on said density scale of a value higher than the midpoint density by an amount equal to the difference between said midpoint density and the highlight density less a number of density units selected for tone reproduction gray balance, with either said % BFE curve or the 0 percent dot area point on one of said family of % BFE density curves.

69. The method of claim 68, wherein the number of density units less than the difference between said midpoint and highlight densities is about 0.05.

70. The method of claim 68, wherein the percent dot area point on said selected % BFE density curve substantially corresponding to the desired magenta or yellow midpoint is about 50 percent.

71. The method of claim 70, wherein the percent dot area point on said selected % BFE density curve substantially corresponding to the desired cyan midpoint is about 37.5 percent.

72. The method of claim 68, and including the further step of reading cyan UCR exposure at the intersection of an axis extending substantially parallel to said axis of ordinates and passing through a point on said density scale of a value higher than said midpoint density by an amount equal to the difference between said midpoint density and said highlight density, with the abscissa on said orthogonal coordinates equal to the K (black) flash exposure in % BFE minus 12.5 percent, as the % BFE associated with the one of said family of % BFE curves passing through said intersection.

73. The method of claim 67, and including the further step of calculating halftone exposures for a second color correlated to a first color comprising:

a. positioning said units of exposure scale so that the second color exposure index is aligned with the 1.0 value on said density scale;

b. positioning said orthogonal coordinates so that the point substantially representative of the highlight end thereof is aligned with the highlight density on said density scale;

c. repositioning said orthogonal coordinates so that the percent dot area point on the selected one of said % BFE density curves associated with the % BFE for said first color which substantially corresponds to the desired second color midpoint for tone reproduction and/or gray balance is aligned with an axis extending substantially parallel to said axis of ordinates and passing through the percent dot area point on said selected one of said % BFE density curves which substantially corresponds to the desired first color midpoint for tone reproduction and/or gray balance when said orthogonal coordinates were first positioned;

d. reading the second color main exposure at the intersection of said units of exposure scale and an axis extending substantially parallel to said axis of ordinates and passing through a point on said basic density curve substantially representative of 50 percent dot area;

e. reading the second color bump exposure as the percent bump on said percent bump scale at the intersection of an axis extending parallel to said axis of ordinates and passing through the highlight density on said density scale, with said basic density curve; and

f. reading the second color flash exposure as % BFE at the intersection of an axis extending substantially parallel to said axis of ordinates and passing through a point on said density scale of a value higher than the midpoint density by an amount equal to the difference between said midpoint density and the highlight density less a number of density units selected for tone reproduction and/or gray balance, with either said % BFE curve or the 0 percent dot area point on one of said family of % BFE density curves, as % BFE.

74. The method of claim **59**, including the further step of calculating K (black) exposures comprising:

a. positioning said units of exposure scale so that the K (black) exposure index is aligned with the 1.0 value on said density scale;

b. positioning said orthogonal coordinates so that the highlight end of said basic density curve is substantially aligned with a point on said density scale of a value above the highlight density by an amount equal to about three-fourths of the difference between the midpoint density and said highlight density;

c. reading the K (black) main exposure on said units of exposure scale at its intersection with an axis extending substantially parallel to said axis of ordinates and intersecting a percent dot area point on said basic density scale which substantially corresponds to the desired K (black) midpoint for tone reproduction and gray balance; and

d. reading the K (black) flash exposure at the intersection of an axis extending substantially parallel to said axis of ordinates and passing through a point on said density scale of a value above said midpoint density by an amount equal to the difference between said midpoint density and said highlight density, with about the 20 percent dot area abscissa on said orthogonal coordinates, as the % BFE associated with one of said family of % BFE density curves crossing said intersection.

75. The method of claim **74**, wherein the percent dot area point on said basic density curve corresponding to the K (black) midpoint is about 50 percent.

76. The method of claim **59**, including the further step of forming said units of exposure scale as a proportion of a standard units of exposure scale, said proportion being equal to the reciprocity factor of said set-up.

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