United States Patent

Hill

[15] **3,641,885**

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[54] **AUTOMATIC DRAFTING USING PROJECTED RING OF LIGHT**

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[73] Assignee: **California Computer Products, Inc.**, Anaheim, Calif.

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[21] Appl. No.: **717,159**

[52] U.S. Cl. 95/1, 95/12, 355/20, 355/40, 355/67

[51] Int. Cl. G03b 11/00

[58] Field of Search....................355/71, 67, 20, 80, 81; 95/1, 95/12

[56] **References Cited**

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Assistant Examiner—Edna M. Bero
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[57] **ABSTRACT**

The disclosure concerns a photoexposure device used in automatic drafting and characterized as forming a movable ring of light at the photosensitive drafting surface, and wherein said ring may be formed by a central mask at the optical axis and an outer mask spaced therefrom to form an aperture ring, the central mask sized in relation to the aperture to substantially eliminate bleeding of light at the ring of light on the drafting surface and toward the edge of the ring, during line drawing.

5 Claims, 13 Drawing Figures

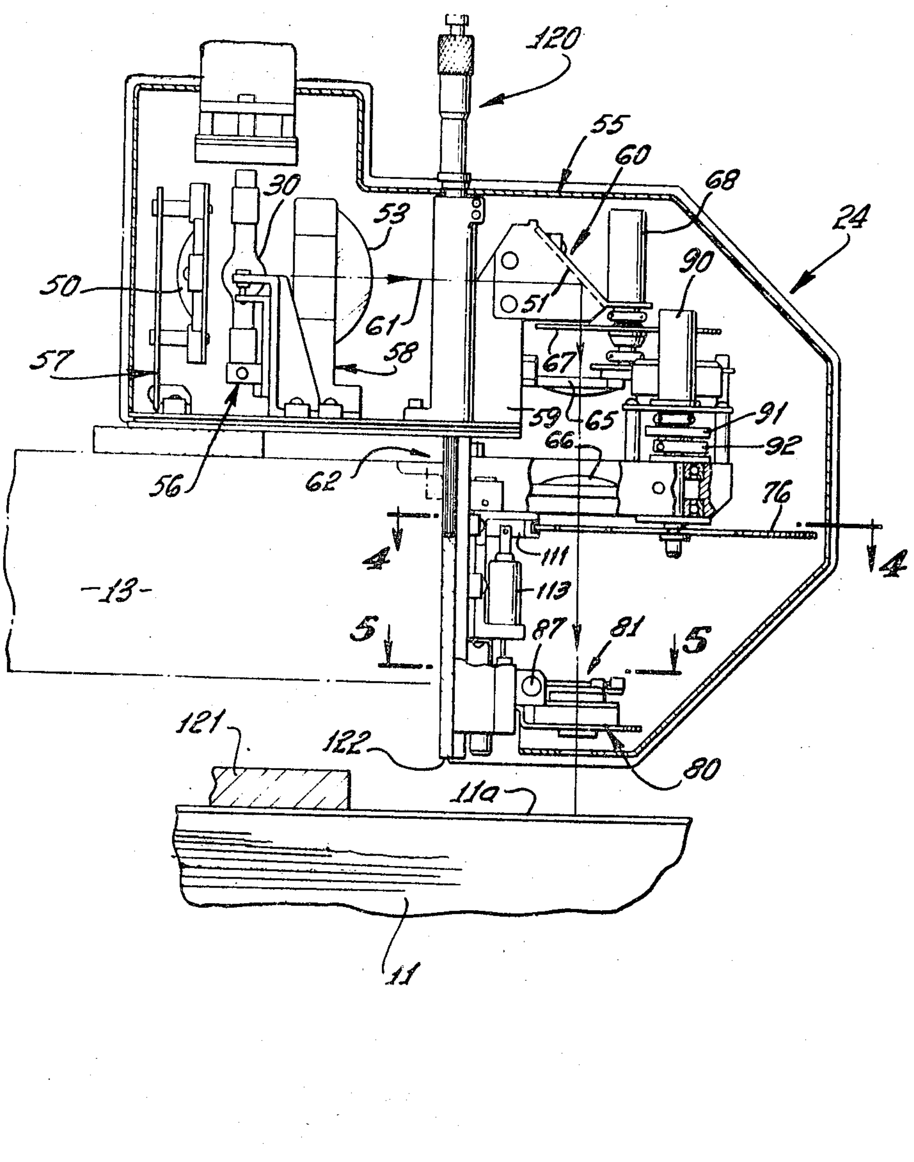

FIG. 1.

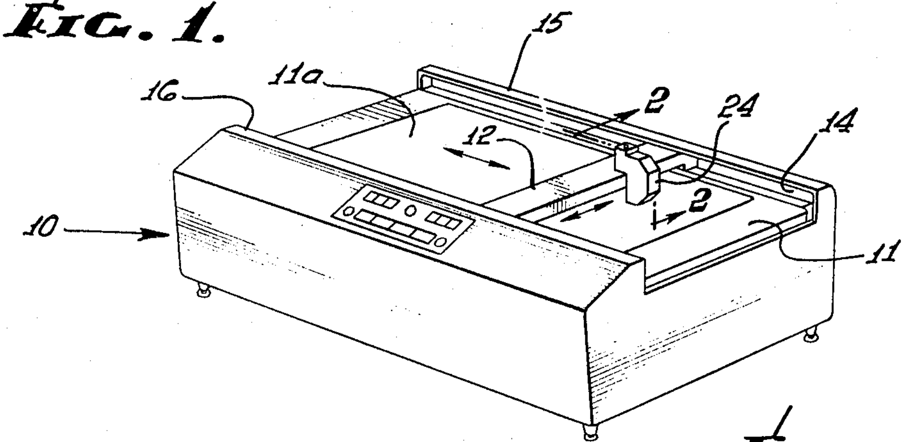

FIG. 12.

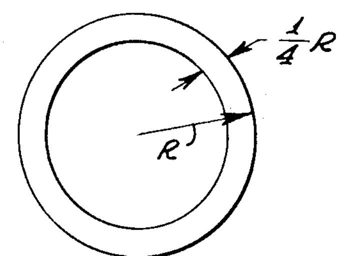

FIG. 2.

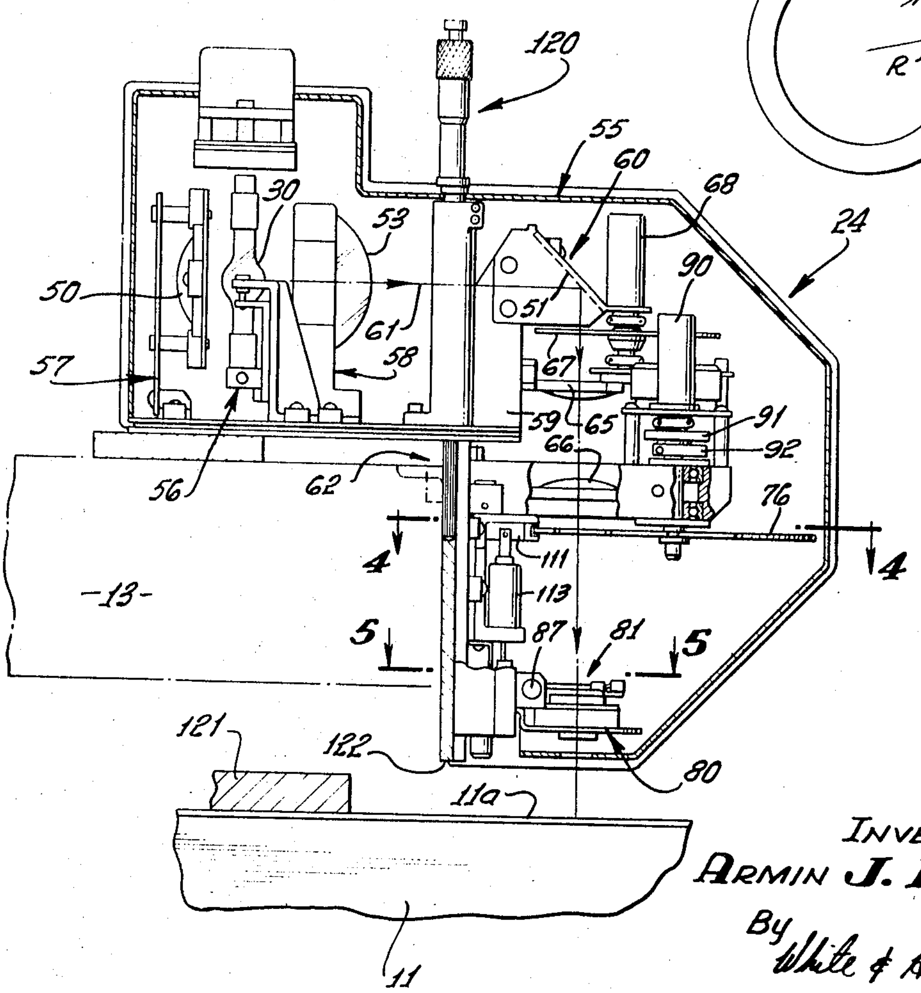

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FIG. 3.

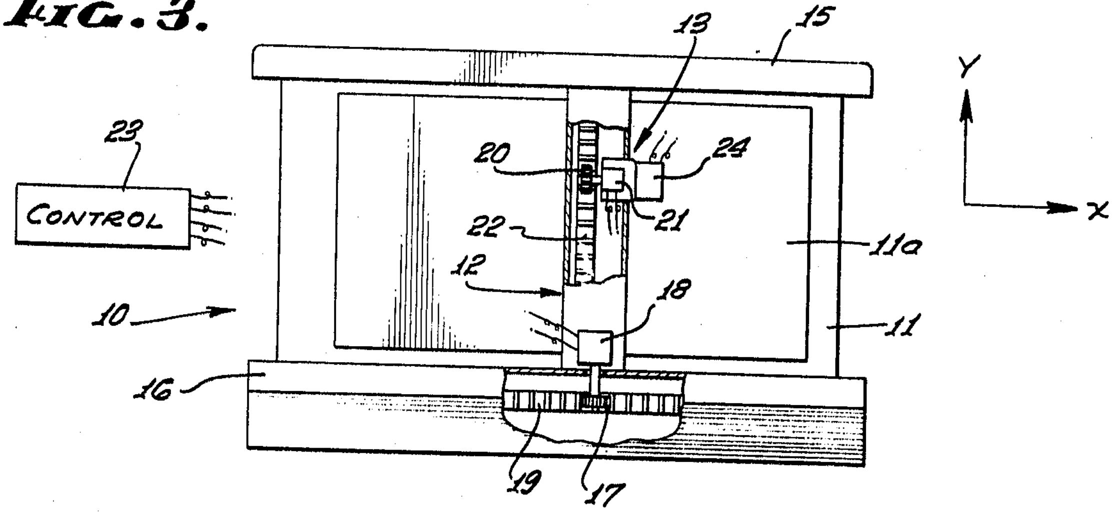

FIG. 4.

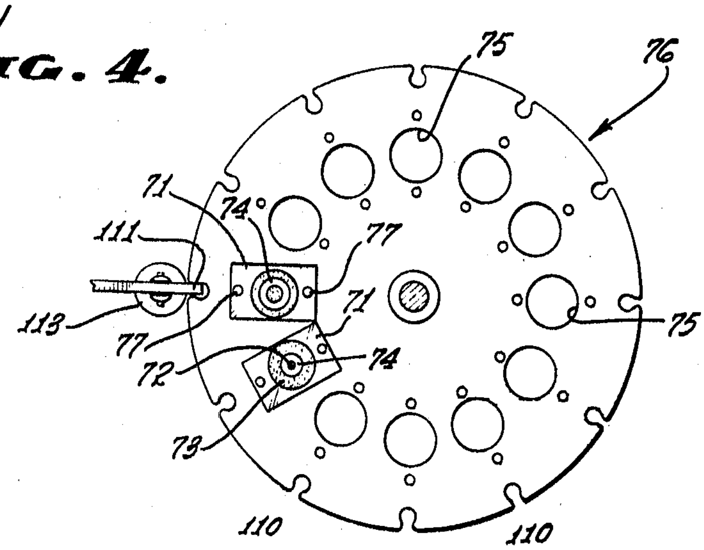

FIG. 5.

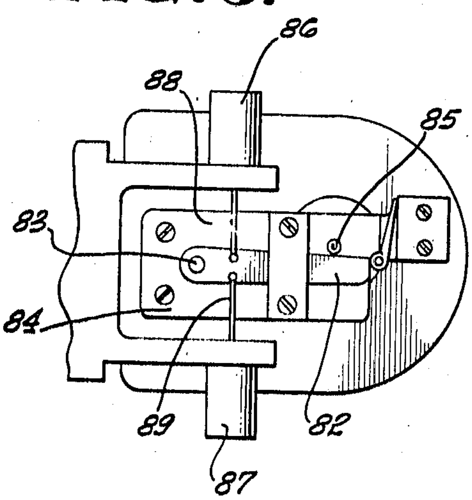

FIG. 6.

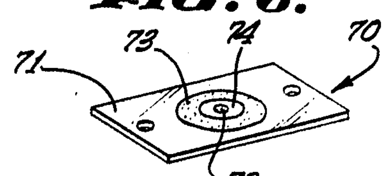

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FIG. 7.

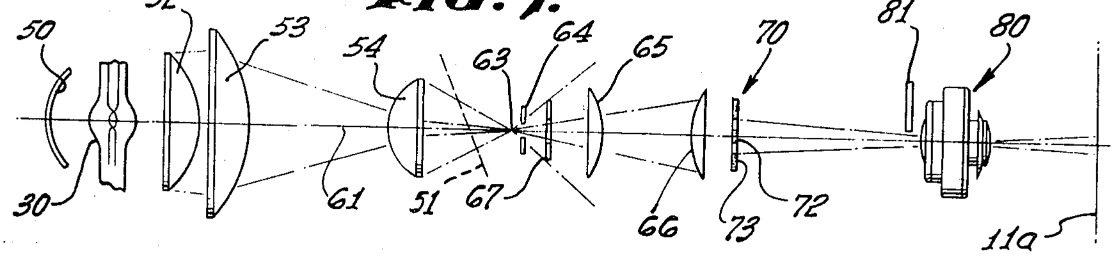


FIG. 13.

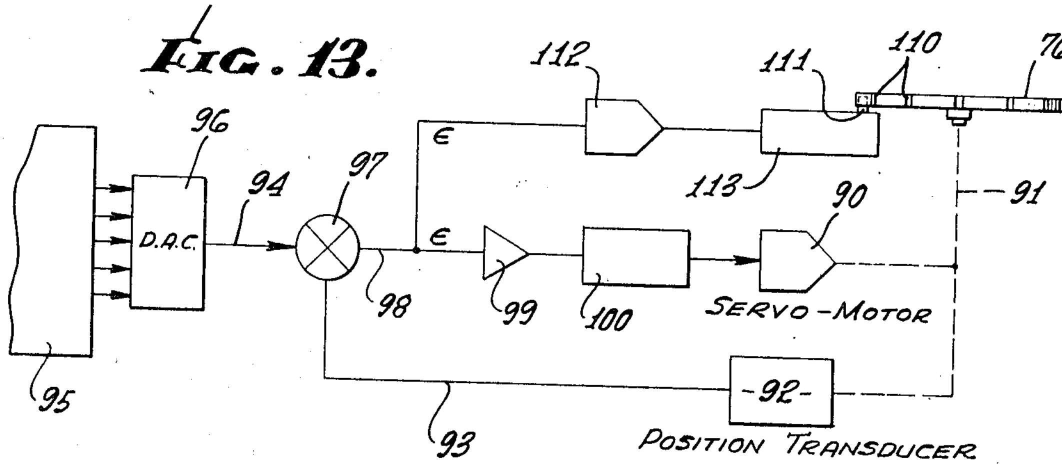


FIG. 8.

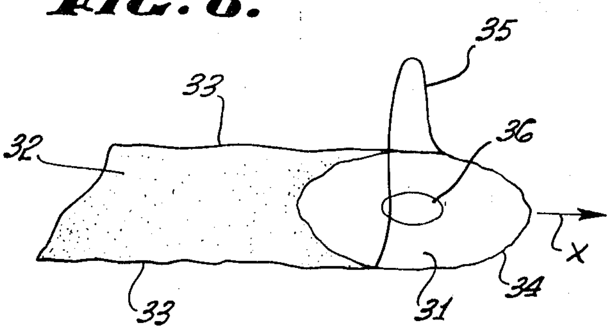


FIG. 9.

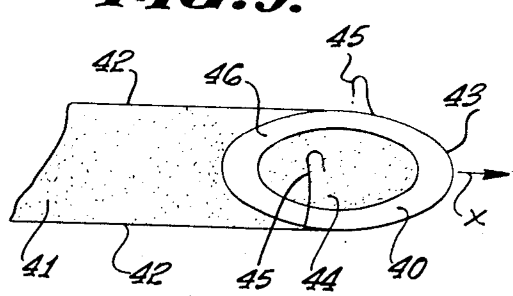


FIG. 10.

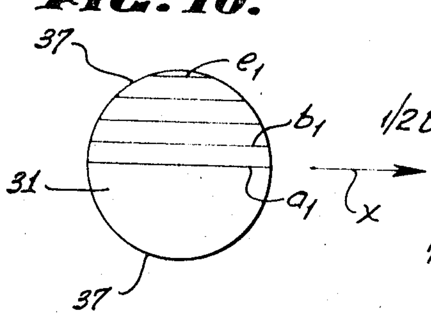
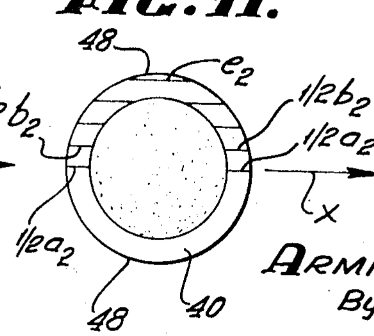


FIG. 11.



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AUTOMATIC DRAFTING USING PROJECTED RING OF LIGHT

BACKGROUND OF THE INVENTION

This invention relates generally to automatic drafting, and more particularly concerns improvements in photoexposure devices used in conjunction with carriages movable relatively over drafting surfaces.

The use of photoexposure devices in conjunction with movable carriages, as for example in automatic indicia marking machines, such as drafting apparatus, is well known. Such devices utilize the well-known technique of directing a narrow beam of light at a photosensitive surface to expose that surface in accordance with beam movement relative to the surface for forming indicia of various sorts, one example being lines.

A serious problem that exists in photoexposure indicia forming devices consists in nonuniform exposure at the plane of the photosensitive surface and during relative movement of the beam and that surface. For example, if a circular spot of light could be uniformly illuminated, and such a spot were moved relatively over the surface in a given direction, it would be found that surface increments over which the center of the spot moves would be exposed to the beam for a much longer time interval than surface increments over which only the edge portion of the spot moves.

Actually most optical systems will have a very sharp fall-off in illumination from center to edge of a circular spot (ideally this will vary as the fourth power of the cosine of the angle between the light ray and the optical axis). This effect, when combined with the aforementioned one, makes it impossible to expose a line with a moving spot with any acceptable degree of uniformity. The edges of the line will either be seriously underexposed or the center will be severely overexposed. In the former situation, the edges become ragged and uncertain; in the latter "bleeding" from the center to edge will again give an uncertain width to the effectively exposed portion of the line.

It is the intent of this invention to minimize this uncertainty. In this regard, the optical system is such that the center to edge ratio of illumination intensity is considerably less than that normally obtainable, and the gradient of illumination intensity near the edge is much sharper. Also incorporated in this invention is the concept that by using a suitable masking or other device the central illumination can be still further reduced so that an acceptably uniform exposure across the width of the line may be obtained, and the physical properties of the exposed area thus enhanced.

The need for this improvement becomes acute when it is desired to vary the degree of exposure of the surface to incident light as a function of the speed of movement of the spot over the surface, since the variation of exposure across the width of the line is independent of such speed, so that maintenance of proper exposure values at various speeds becomes increasingly difficult with higher speeds of travel.

SUMMARY OF THE INVENTION

It is a major object of the invention to overcome the above-described problems through the provision of automatic drafting apparatus in which a ring of light is projected for exposing a photosensitive drafting surface. Basically, the invention comprises a head adapted to overlie such a surface, the head being movable relative to and generally parallel to the surface; a source of light at the head; and means on the head to direct light from the source to form a ring of light at that surface during relative movement of the head and surface. As will be seen, the ring of light may be formed by mask structure in the light beam path, a mask being centered in that path to blank the center light, or the optical system itself may provide for substantial reduction of central light transmission; further, means may be provided to vary the overall size of the ring at the photosensitive surface, as will be described, in order to enable drawing lines of different widths, and the optical system is typically operable to transmit light through such different sized apertures in such manner that the illuminance of the outer edge of the ring of light in the plane of the light sensitive surface is essentially unchanged as the overall size of the apertures moved into the light path changes. For present purposes, "illuminance" is defined as the luminous flux incident upon a unit area.

It is another object of the invention to provide for projection of a ring of light so dimensioned as to achieve maximum illuminance with minimum differential exposure of areal increments of the photosensitive surface over which the light ring travels. As will be seen, this object is attained when the radial distance between the inner and outer circumferences of the ring of light is about one fourth the radius of the outer circumference of the ring. Finally, it is an object of the invention to enable use of an electric arc light source productive of a bright spot of light transmitted along an optical axis, with a mask located to mark out the bright spot of light.

These and other objects and advantages of the invention, as well as the details of illustrative embodiments, will be more fully understood from the following detailed description of the drawings, in which:

DRAWING DESCRIPTION

FIG. 1 is a perspective showing of an automatic drafting machine in which the invention may be embodied;

FIG. 2 is a vertical elevation, taken in section through a photoexposure device usable in the FIG. 1 machine;

FIG. 3 is a schematic showing of carriage actuation and movement;

FIG. 4 is a section taken on line 4—4 of FIG. 2;

FIG. 5 is a section taken on line 5—5 of FIG. 2;

FIG. 6 is a perspective view showing a mask arrangement;

FIG. 7 is an optical layout;

FIG. 8 is a perspective showing of differential exposure of a photosensitive surface to a moving light spot;

FIG. 9 is a perspective showing of exposure of a photosensitive surface to a moving light ring;

FIGS. 10 and 11 are plan views of a moving spot and ring of light;

FIG. 12 is a plan view of a ring of light of preferred proportioning; and

FIG. 13 is a block diagram of control apparatus for line width selection apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIGS. 1 and 3, the illustrated drafting table **10** includes a flat drafting area **11** on which a sheet **11*a*** is retained, as for example by vacuum applied from beneath. Carried on the table are a carriage **12** movable in the X-direction, and a carriage **13** movable in the Y-direction. Appropriate guides **14** for the X-carriage are located within the housing **15** and **16**, and suitable antifriction rollers may be provided to support the carriage in such guides. Similar guides and rollers may be provided for Y-carriage movement along the X-carriage, and in the Y-direction.

Referring now to FIG. 3, a pinion **17** driven by servomotor **18** is shown engaging a rack **19** within the housing **16**, for moving the X-carriage in the X-direction. Similarly, a pinion **20** driven by the servomotor **21** engages a rack **22** extending in the Y-direction. A control indicated at **23** in FIG. 3 controls operation of the motors to cause the head **24** in the carriage **13** to move in a precisely controlled manner over the drafting surface. In this regard, X–Y movement of an optical head over a marking or drafting surface is known, as for example is described in U.S. Pat. No. 3,120,577 to Young.

Control **23** may also embody circuitry to control operation of the head **24**, and the latter may be removably mounted on the carriage, with appropriate electrical connection made from the control to the mounted head.

In accordance with the invention, there is a source of light at the head, as for example the arc source **30** seen in FIGS. 1 and 7; further, means is provided in the head **24** to direct light from the source to form a ring of light at the photosensitive surface during relative movement of the head and that surface. In this regard, reference is made to FIGS. 8–12 in explanation of the differences is made of operation and result as between a "spot" of light as used in the prior art and a ring of light as provided by the present invention.

As seen in FIG. 8, a moving "spot" **31** of light produces an exposed line **32** having edges **33** which are not sharp but rather uneven or "fuzzy." This is caused by "bleeding" of light from the inner regions of the spot toward its circular edge **34** which is likewise not sharp, but rather "fuzzy." The light intensity increases toward the center of the spot, as indicated by the vertical intensity plot or graph **35** extending transversely over the spot. In particular, the arc light source produces a spot which is brightest at its center, as shown at **36**, and light from that center bleeds radially toward the edge of the spot, enhancing the lack of uniformity of the exposed line edges **33**. Furthermore, as seen in FIG. **10**, as the spot moves in the direction of arrow X, those portions of the photosensitive surface over which the center of the spot passes receive much more exposure than is received by those portions of the surface transversed by the outer portions **37** of the spot. This is made clear by comparison of the decreasing lengths of lines a_1–e_1 across the spot and corresponding to the varying degrees of exposure of surface increments under such lines. As a result, the surface increment under line a_1 is overexposed and increments under lines e_1 are underexposed.

As contrasted with the above, FIG. **9** shows light ring **40** producing an exposed line **41** having edges **42** which are sharp. Very little if any light bleeding toward the ring edge **43** occurs, due to the reduced light intensity in the area **44** within the ring. This is illustrated by the fall off at **45** of the light intensity plots **46** taken transversely across the ring. Such reduction in light intensity in area **44** may be effected by masking as will be described, or by the optical system itself. Furthermore, as seen in FIG. **11**, as the ring **40** moves in the X-direction, those portions of the photosensitive surface over which the center of the ring travels receive about the same exposure as received by those portions of the surface transversed by the outer portions **48** of the ring. This is made evident by comparison of the lengths of lines a_2–e_2 across the ring and corresponding to the varying degrees of exposure of surface increments under such lines. For example, the sum of the two lines ½a_2 and ½ a_2 is about equal to the length of line e_2. As a result, the surface increments that pass relatively under lines a_2 and e_2 are properly exposed and to about the same extent.

FIG. 12 illustrates a ring of light of preferred proportioning, with the radial dimension of the ring between inner and outer circumferences equal to about ¼R, where R is the overall radius of the outer circumference of the ring. This configuration provides for maximum illumination with minimum differential exposure of surface increments transversed by the ring and with maximum exposed line edge sharpeners.

Referring now to the optical system shown in FIGS. 2 and 7, light from the arc lamp source **30** is reflected by mirror **50** and passed to mirror **51** via first and second planoconvex condenser lens **52** and **53**, and a condenser trimmer lens **54**. These elements are enclosed within a housing **55** and suitably supported as at **56–60** as seen in FIG. **2**, the optical axis being designated at **61**. The housing is in turn supported on the carriage **13** that is movable in the Y-direction as described above. A removable tongue and groove vertical connection of the housing to the carriage indicated at **62** enables ready removal of the head **24** when desired. A micrometer-type height adjustment for the head **24** relative to the carriage is seen at **120**. A shim gage element **121** may be placed under the lower end of the micrometer tip **122**, and on the paper **11***a*, for assuring proper height adjustment.

From the mirror, the condensed light from the source is imaged at **63**, from which a trim aperture element **64** is offset. (Light is shown passing through the mirror **51** in FIG. **7**, for simplicity.) Passing beyond the element **64**, the light may, if desired, be subjected to modulation at control element **67**, by means of which the amount of light passing to planoconvex relay lenses **65** and **66** may be regulated, as for example in accordance with the movement or position of the light ring relative to the photosensitive surface indicated at **11***a*. In this regard, U.S. Pat. No. 3,316,348 to Hufnagel discloses such regulation as a function of speed, and U.S. Pat. No. 3,120,577 to Young disclosed the concept of such light modulation in a recording system involving X–Y movement. A suitable actuator for element **67** is indicated at **68**.

Leaving the lens **66**, the light is directed to fall on a mask **70** which obstructs passage of all the light excepting for a ring of predetermined size. As seen in FIGS. **4** and **6**, the mask may be defined by a transparent sheet or film **71** which is darkened centrally at **72** and concentrically at **73**, leaving only the transparent annular portion **74** to pass the ring of light. A series of such sheets configured to define light rings of different size may be mounted and centered over circularly spaced apertures **75** in a turret disc **76**, as by means of fasteners **77**, so that outer darkened regions **73** extend to the aperture boundaries. In this regard, the use of light masks and apertures arranged on movable supports is disclosed in U.S. Pat. No. 3,306,176 to Myers, and U.S. Pat. No. 3,292,485 to Mey. Further, should the optical system itself produce the light ring, the central mask **72** may be omitted.

After passing through the mask, the ring of light is transmitted to the objective lens unit at **80** for image projection on the photosensitive sheet **11***a*. A shutter mechanism **81** is located at the incident side of the objective lens for controlling light transmission in such manner that the ring of light is transmitted only during predetermined intervals, as during carriage movement, whereby overexposure of the photosensitive sheet may be avoided. The shutter illustrated in FIG. **5** includes a light blanking arm **82** pivoted at **83** to structure **84**, to move into and out of the light beam indicated at **85**. Solenoid actuators **86** and **87** are connected at **88** and **89** to the arm to pivot same into and out of the light beam path as commanded by the control **23**.

Referring to FIGS. 2,4 and 13, control means is provided to rotate the disc **76** to bring a selected mask into predetermined position in the path of the light beam. That control means may typically include an actuator such as servomotor **90** having drive connection to the turret disc **76** via coupling **91**. The control also includes sensing apparatus connected to sense the extent of such rotation of the disc and to effect stoppage of the servomotor in response to turret rotation to bring a selected size mask (or aperture in the case where masks are not used) into the light beam path. Typical of such sensing apparatus is a position transducer as for example a rotary potentiometer or encoder **92** indicated in FIGS. **2** and **13**. As the motor **90** rotates disc **76**, a corresponding analog signal is generated by the encoder for transmission at **93** for comparison with the mask selection command analog signal at **94**.

Mask selection digital signals are generated at **95** and converted at **96** to the analog signal **94**. Any difference between signals **93** and **94** is detected by the comparator **97** whose corresponding output error signal E is transmitted at **98** and via the operational amplifier **99** and power amplifier **100** to drive the servomotor **90** until the error signal is eliminated, at which time the selected mask has been brought into the light beam path, as described.

In addition, latching means is operable to block rotation of disc **76** during use of the projected ring of light for line drawing purposes. As seen in FIGS. 2,4 and 13, the latching means includes keeper slots **110** rotatable with the disc **76** and with angular spacing corresponding to the angular spacing of the various masks **70** on the disc. The latching means also includes a latch **111** controlled at **112** as by solenoid **113** to advance into a keeper slot when the error signal at **98** (and sensed by control **112**) has dropped to a low level indicating that the disc has brought a selected mask into predetermined position in the path of the light beam.

As mentioned previously, the optical system may be such that, in the absence of the mask, the center to edge ratio of illumination-intensity at the surface **11***a* is considerably less than that normally obtainable, and the gradient of illumination intensity near the edge is much sharper than normally obtainable. These effects may be produced through carefully balanced use of spherical aberration and the introduction of so-called "pincushion distortion."

I claim:

1. In a drafting machine, the combination comprising:

a head adapted to overlie a photosensitive surface, said head being moved relative to and generally parallel to said surface,

a source of light at the head,

and means on the head directing light from said source and forming a ring of light at said surface during said relative movement of the head and surface, the ring characterized in that the illumination intensity within the ring substantially exceeds the illumination intensity inside a circular zone formed inwardly of the ring and at the optical axis defined by the ring,

said means including a central mask at said axis and an outer mask spaced therefrom to define a ring-shaped aperture, said central mask sized in relation to said aperture to substantially eliminate bleeding of light at said surface toward the edge of the ring during said relative movement, said ring of light having an inner boundary defined by an inner circumference and an outer boundary defined by an outer circumference, the radial distance between said inner and outer circumferences being about one-fourth the radius of the outer circumference.

2. The combination of claim 1 including structure defining a series of ring shaped apertures selectively movable into the path of light from said source, said apertures having different overall sizes, said structure including, for each ring-shaped aperture, a central circular light mask and an outer light mask having an inner edge concentrically spaced from said central mask.

3. The combination of claim 2 including a rotary disc mounting said inner and outer masks at circularly spaced locations.

4. The combination of claim 1 wherein said source comprises an electric arc producing a bright spot of light transmitted along an optical axis, said central mask located to mask out said bright spot of light.

5. The combination of claim 1 wherein said last named means includes, in the light path between said source and said mask, condenser lens means for imaging said source, a light modulator and relay lens means; and, in the light path beyond said mask, a shutter and objective lens means.

* * * * *