United States Patent

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[54] AUTOMATIC DRAWING MACHINE

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[52] **U.S. Cl.** **95/12**

[51] **Int. Cl.** **G03b 29/00**

[58] **Field of Search** 95/12

[56] **References Cited**

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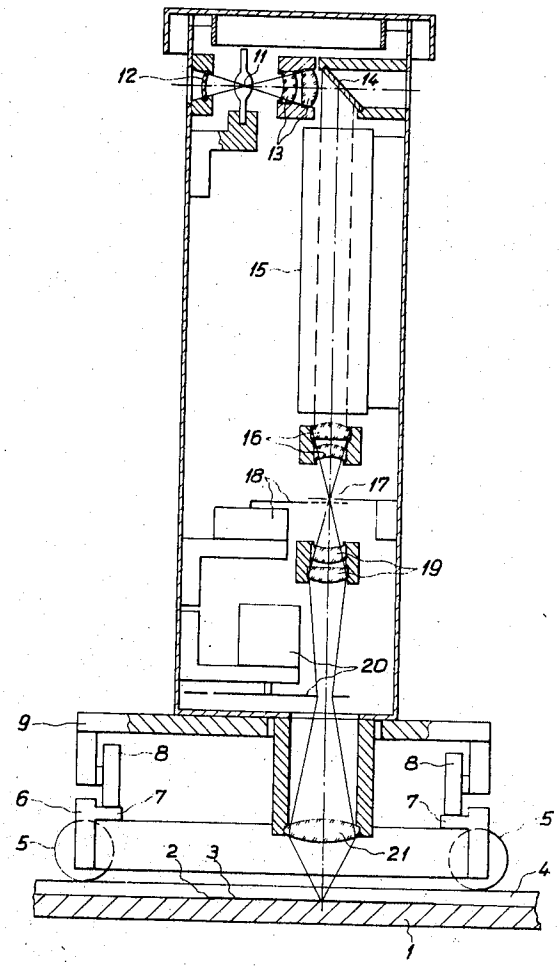
[57] **ABSTRACT**

Photo-optical drawing apparatus has a head which projects a movable beam of light on a drawing board. The beam of light is projected through a diaphragm and onto the drawing board. The intensity of the light striking the drawing board is controlled by a shutter, the transparency of which varies with the molecular structure in one of its light-conductive elements.

15 Claims, 5 Drawing Figures



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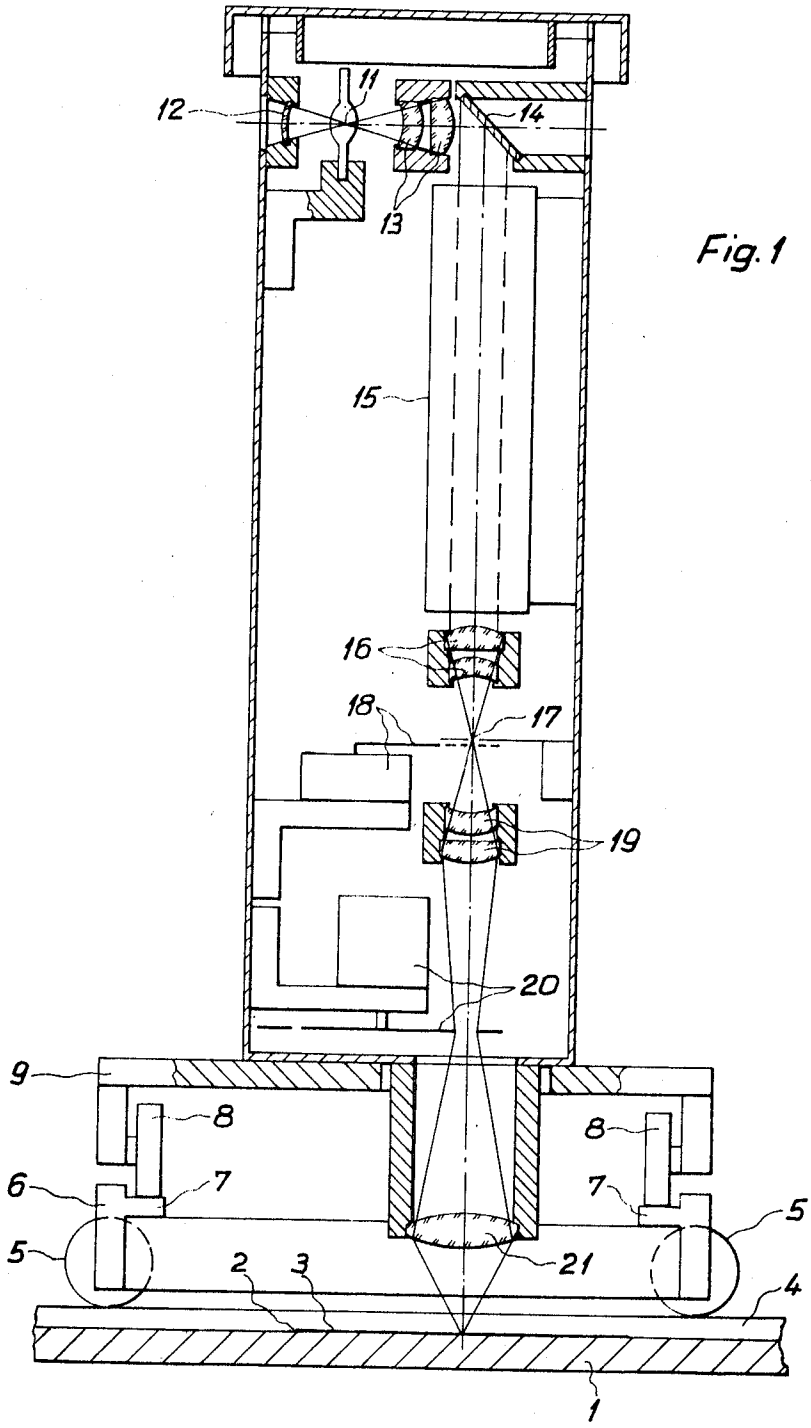

Fig. 1

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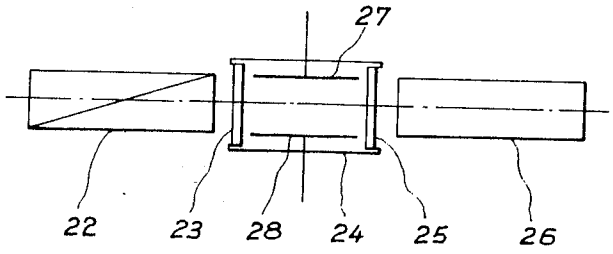

Fig. 2

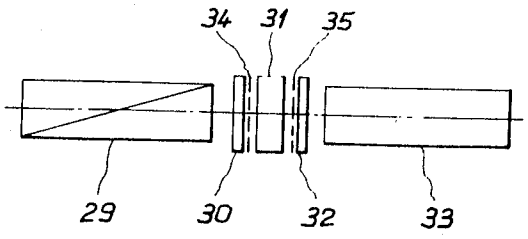

Fig. 3

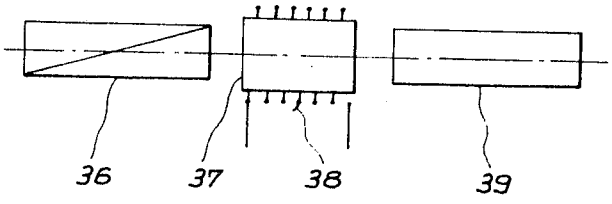

Fig. 4

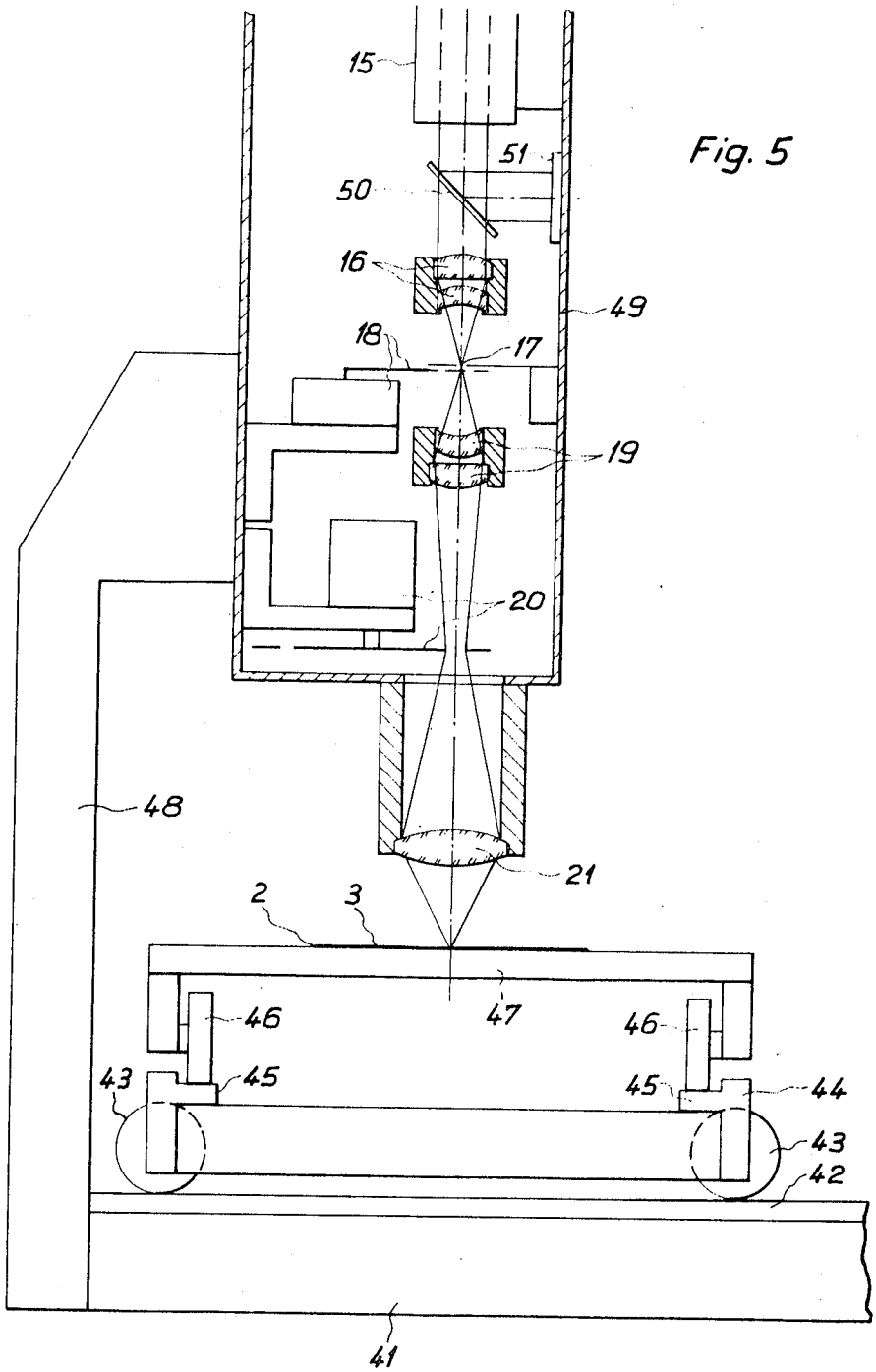

Fig. 5

AUTOMATIC DRAWING MACHINE

The present invention relates to photo-optical drawing heads for use in automatic drawing machines.

In known automatic drawing machines, lines or figures are plotted photographically on a photosensitive layer provided on an emulsion carrier in the form of a film, a glass or metal plate, or a sheet of paper which may be secured as by clamping or laid in position, on the drawing board of the drawing machine. The known drawing machines are provided with a photo-optical drawing head, which is displaceable relative to the drawing board in the direction of the co-ordinates of a rectangular, oblique-angled or polar coordinate system, and which is provided with a photographic projection system comprising a light source, a condenser system, a generally electromagnetically operated shutter, a diaphragm or mask, and an image-reproducing system. The illuminating light is focused by the condenser system at the aperture of the diaphragm or mask, the image of the aperture of the diaphragm or mask being reproduced by the image-reproducing system on the photosensitive layer. As the drawing head moves relatively to the drawing board, the image of the diaphragm or mask moves over the photosensitive layer thus producing thereon the required line or figure. The controlled elements of an automatic drawing machine of this kind, that is to say the drawing head or the drawing board, the light source, the shutter and the diaphragm or mask receive their control impulses from a storage medium, for example a punched tape, a punched card or a magnetic tape. These elements are logically combined and operate accordingly.

The operation of such automatic photo-optical drawing machines, particularly those required to operate with substantial acceleration, at substantial maximum speeds and with comparatively short starting and slowing-down distances, involves certain difficulties affecting the quality of the drawing to be produced. Where a shutter operated by electromagnetic or electromotive means is used, a magnetic field has to be built up or the inertia of the rotor of the motor has to be overcome and the shutter blades have to be accelerated before the shutter is actually opened. During the period required for this, the optical axis of the drawing head or its track point on the photosensitive layer has already moved a determined distance before the photosensitive layer commences to be exposed to the pencil of light with the result that the beginning of the line is protracted in the direction of drawing. The same but in the opposite sense occurs at the end of the line to be drawn. Theoretically it would be possible to delay the starting of the electric motors producing the displacement of the drawing head relative to the drawing board in the directions of the two coordinates, so that they do not start to rotate before the shutter is open. Such delay has, however, to be adjusted to the friction in the gears of the drawing machine and to the time lag of the shutter, that is to say to factors which are not absolutely constant, so that in this way no substantial improvement of the results is obtained. Thus, for example, when an excessive delay is adjusted or when the friction in the gears of the drawing machine increases, for example due to thermal reasons, or when the response time lag of the shutter is shortened the line produced will have a thick beginning. Deviations from these variable factors in the opposite sense result in a protracted beginning of the line. Even with optimum adjustment of the delay, the thickness of the beginnings and ends of the lines and the positions thereof are detrimentally affected by inconstant friction and response time lags.

In order to obtain lines of required thickness and photographic density, the light intensity of the image of the light source in the aperture of the diaphragm or mask has to have a determined relationship to the effective drawing speed. The effective drawing speed and the effective light intensity never correspond perfectly owing to the relatively substantial inertia of the mechanical system in general, particularly during acceleration and deceleration periods, irrespective of whether the control device of the drawing machine controls the speeds of the movements of the drawing head relative to the drawing board in the directions of both co-ordinates, so that an effective drawing speed results, or whether the effective drawing speed is predetermined and the movements in the directions of the two coordinates are calculated therefrom and controlled accordingly. This results in differences in the thickness and photographic density of the lines, such differences taking a periodic or aperiodic course according to the attenuation of the total system.

The invention seeks to eliminate the disadvantages of the known automatic, photo-optical drawing machines, or at least to reduce such disadvantages to a substantial extent. The fundamental properties of the mechanical parts of drawing machines of this kind cannot be changed, but is has been found that the disadvantageous combined effects of the frictions in the gears of the drawing machine, the inertia of the light-density control hitherto effected by displacement of a wedge filter provided in the paths of the rays of the beam of rays emitted by the light source, and the response time lag of the shutter may be eliminated wholly, or at least for the most part, by other means.

According to the present invention there is provided a photo-optical drawing head for use in automatic drawing machines, the head having a drawing board associated therewith, the head and board being movable relative to one another to effect a drawing on a photosensitive layer mounted on the board by means of light emitted from a source in the head, the relative movement and the intensity of the light source being controlled by control signals of a storage medium or computer, the drawing head having a condenser system to focus light from the source at an apertured diaphragm or mask, a shutter having a movable opaque member, and an image-reproducing system by which an image of the apertured diaphragm or mask is reproduced on the photosensitive layer, and in which a molecular shutter is arranged in the path of light emitted by the source to control the intensity of the light beam. A second shutter operated by electromagnetic means is provided to interrupt the small amounts of light which pass through the electro-optical or magneto-optical shutter when there is no relative movement between the drawing head and the drawing board.

For convenience of the ensuring discussion, the term molecular shutter has been adopted to describe devices which have light transmissability characteristics which vary according to the molecular structure of a light transmitting element. This encompasses the electro-optical and magneto-optical devices found in Class 350, subclasses 150 and 151 as well as devices such as those described in U.S. Pat. Nos. 3,328,110, 3,238,843 and 3,247,765 which do not employ light-polarizing elements but do change their light transmissability in response to changes on a molecular level rather than a gross mechanical level. Such devices are found in Class 350, subclass 160. Molecular changes, as used herein, include but are not limited to changes in crystalline structure, ionization or orientation of microscopic particles in the light-transmitting element.

In photo-optical drawing heads of this construction the inertias of the shutter and of the brightness control are considerably reduced due to the substantially inertialess operation of the molecular shutter. While in the known automatic drawing machines provided with a photo-optical drawing head, the electric motors producing the movements of the drawing head relative to the drawing board, the shutter and the brightness control have hitherto been switched on substantially simultaneously, it is possible with the drawing head according to the invention, for the shutter and the brightness control, which two elements are combined in the electro-optical or magneto-optical shutter, to be opened by suitable switching means with corresponding indicating devices only when the movements of the drawing head relative to the drawing board actually commence. The harmful influences of the friction in the guide tracks between the drawing head and the drawing board may thus be considerably reduced.

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

FIG. 1 shows part of an automatic drawing machine provided with a photo-optical drawing head;

FIG. 2 shows an electro-optical shutter of Kerr-cell construction for the drawing head of the drawing machine;

FIG. 3 shows an electro-optical shutter of ammonium-dihydrophosphate or potassium-dihydrophosphate cell construction for the drawing head of the drawing machine;

FIG. 4 shows a Faraday shutter for the drawing head of the drawing machine, and

FIG. 5 shows part of a second embodiment of an automatic drawing machine.

In FIG. 1, a drawing board 1 carries an emulsion carrier 2, for example a glass or metal plate, a film, or a sheet of paper carrying a photosensitive layer 3 which may be clamped, placed loosely, or fixed securely in position. Two rails 4 extending in the direction of one co-ordinate of a co-ordinate system are secured to the drawing board 1. The rails support rollers 5 of a carriage 6 which is thus movable across the drawing board 1 in the direction of that one co-ordinate. The carriage 6 carries two rails 7 extending in the direction of the other co-ordinate of the co-ordinate system, and which support rollers 8 rotatably mounted on a base plate 9 of a photo-optical drawing head of the drawing machine. The drawing head may thus be moved on the carriage 6 across the drawing board 1 of the drawing machine in the direction of the second co-ordinate of the co-ordinate system. The carriage 6 and the drawing head are respectively provided with a reversible driving motor, the driving motors receiving control impulses from a storage medium, for example a punched tape, a punched card, a magnetic tape or a computer. This known construction does not constitute a subject matter of the invention and thus does not require to be described in detail.

A light source 11 is mounted securely on the drawing head of the automatic drawing machine. A concave reflector 12 is located at one side of the light source and a first auxiliary condenser lens system 13 is located at the opposite side of the source 11. The condenser produces an image of the source 11 and an image reflected from the reflector 12 at infinity. A cold-light mirror 14 is situated behind the condenser remote from the light source to reflect the shortwave part and a small residue of the longwave light of the beam of substantially parallel rays of light emitted by the auxiliary condenser 13 to a molecular shutter 15. The molecular shutter 15 is, in the direction of its optical axis, followed by a second auxiliary condenser lens system 16, an apertured diaphragm 17, a shutter 18 operated by electromotive or electromagnetic means, a main condenser lens system 19, a further apertured diaphragm or mask 20 and an optical image-reproducing system 21 with focusing device, the latter reproducing the image of the aperture of the apertured diaphragm or mask 20 on the photosensitive layer 3 of the emulsion carrier 2. All of the parts referred to are mounted on and moved together with the drawing head.

The drawing head operates as follows.

The light source 11 and the image thereof reflected by the concave reflector 12 are together reproduced at infinity by the first auxiliary condenser 13. The beam of substantially parallel light rays transmitted by the auxiliary condenser 13 is incident upon cold-light mirror 14 which, for a short time, reflects the shortwave light and a small residue of the longwave light into the molecular shutter 15, whereas a greater part of the long-wave-length heating light passes through the cold-light mirror 14 and is radiated outside the head. In this way an undesirable heating of sensitive parts of the drawing head and of the drawing machine is avoided. The light passing through the shutter 15 falls upon the second auxiliary condenser 16 which forms a true image of the light source 11 and of the image reflected by the concave mirror 12 at the aperture of the apertured diaphragm 17. When the shutter 18 is in the open position, the illuminating light is focused by the main condenser 19 on the aperture of the apertured diaphragm or mask 20 and the final image is reproduced on the photosensitive layer 3 by the focusable optical image-reproducing system 21.

When the automatic drawing machine is inoperative, the shutter 15 and the shutter 18 provided in series therewith are closed. In the closed position, the molecular shutter 15 has very little transmitting power, and any light passing through it is intercepted by the closed shutter 18 so that no light at all can pass to the photosensitive layer 3. When a line is to be drawn, the shutter 18 is opened first by a control device of the automatic drawing machine. The intensity of the light passing through the shutter 15, which is still in its closed position, is, however, insufficient to be able to effect a blacking of the photosensitive layer 3 within a few seconds. The movements of the drawing head in the directions of the coordinates can thus commence with a delay of about 0.5 to 1.0 sec. Upon movement of the drawing head in the direction of the coordinates, the control device or the drawing machine immediately transmits to the molecular shutter 15 a control signal corresponding to the required drawing speed with resultant inertialess increase in the light transmission thereof. The light then issuing from the illuminated aperture of the diaphragm 17 is focused by the main condenser 19 so that the aperture of the apertured diaphragm or mask 20 is illuminated with an intensity sufficient to ensure reproduction of the image thereof on the photosensitive layer 3 by the correspondingly focused optical image-reproducing system 21, so that upon movement of the drawing head and thus of the image of the apertured diaphragm or mask the required line is produced on the photosensitive layer at that moment. As the line is drawn, the light intensity of the image of the apertured diaphragm or mask on the photosensitive layer 3 is adjusted by the shutter 15 according to the drawing speed. When the drawing of a line is complete, the shutter 18 is closed about 0.5 to 1.0 sec. after the closing of the molecular shutter 15, which takes place simultaneously with the termination of the movements of the drawing heads in the directions of the coordinates.

Molecular shutters such as electro-optical shutters and the magneto-optically utilizing Faraday shutters of various constructions are, of course, known. FIG. 2 shows, by way of example, an electro-optical shutter comprising a Kerr-cell. Light emitted by a light source enters a polarizer 22. The plane-polarizer light then passes through a glass cover 23 into a cylindrical container 24 filled with nitrobenzene or chloroform and leaves the container 24 through a second glass cover 25 to enter an analyzer 26 turned through an angle of 90° relative to the polarizer 22. Electrodes 27 and 28 mounted within the container 24 enable an electrostatic stress to be applied to the nitrobenzene or chloroform. The light plane polarized in polarizer 22, except for a small residue, is extinguished in the analyzer 26 when no voltage is applied across the electrodes 27 and 28. Application of voltage is applied across the electrodes 27 and 28. Application of voltage to the electrodes 27, 28 results in an electric field being produced in the container 24, the electric field being effective to rotate the plane of polarization of the light passing through the nitrobenzene or chloroform. The transmitting power of the Kerr-cell increases according to the voltage applied and according to the resultant rotation of the polarization plane of the light passing through.

An ammonium-dihydrophosphate or potassium-dihydrophosphate cell is illustrated in FIG. 3, in which the light emitted by a light source enters a polarizer 29 and then passes through a glass plate 30 into an ammonium-dihydrophosphate or potassium-dihydrophosphate crystal 31. The light then passes through a second glass plate 32 into the analyzer 33. In this case, the electric field which acts upon the ammonium-dihydrophosphate or potassium-dihydrophosphate crystals 31 and rotates the plane of polarization of the light is produced by electrodes 34 and 35.

The Faraday shutter comprising a polarizer 36, a glass body 37 carrying a magnetic coil 38, and an analyzer 39, illustrated in FIG. 4, operates analogously.

In certain cases, particularly where the light source of the optical drawing head is operated at a high voltage and/or at a

high current intensity, and in which a drawing head of larger dimensions has to be provided, it is desirable for the photo-optical drawing head to be secured in position on the chassis of the automatic drawing machine and for the drawing board to be mounted so as to be displaceable of the chassis of the drawing machine in the directions of the coordinates of the coordinate system. An automatic drawing machine of this kind, which is provided with a photo-optical drawing head similar to that hereinbefore described but of a modified construction, is partially and diagrammatically illustrated in FIG. 5. Two rails 42 extend in the direction of one coordinate of the coordinate system and are secured to a platform 41 of the chassis of the drawing machine. Rollers 43 of a carriage 44 run on the rails 42. Two rails 45 extend in the direction of the other coordinate of the coordinate system and are secured to the carriage 44. A drawing board 47 of the drawing machine is mounted on rollers 46 which are displaceable along the rails 45. The platform 41 of the chassis of the drawing machine is secured to a column 48, the upper part of which supports a housing 49 containing the photo-optical drawing head.

The main parts of the modified construction illustrated in FIG. 5, only part of which is shown, correspond to those of the construction illustrated in FIG. 1. Corresponding parts in FIGS. 1 and 5 are provided with identical reference numerals. Thus 15 denotes the molecular shutter, 16 the second auxiliary condenser, 17 the first apertured diaphragm, 18 the shutter operated by electromotive or electromagnetic means, 19 the main condenser, 20 the second apertured diaphragm or mask, and 21 the focusable image-reproducing optical system. The image-reproducing optical system 21 reproduces the image of the aperture of the apertured diaphragm or mask 20 on the photosensitive layer 3 of the emulsion carrier 2 which may be secured in position as by clamping or simply laid upon the drawing board 47. The above-mentioned parts operate in the same manner as the corresponding parts in FIG. 1. In the drawing machine illustrated in FIG. 5, the relative movements between the drawing board 47 and the stationary photo-optical drawing head in the directions of the two coordinates system are, however, produced by displacement of the carriage 44 in the direction of one coordinate and by displacement of the drawing board 47 on carriage 44 in the direction of the other coordinate.

In the photo-optical drawing head illustrated in FIG. 5, a partially reflecting mirror 50, for example an infrared mirror, is provided between the electro-optical or magneto-optical shutter 15 and before the shutter 18. Conveniently this mirror 50 is arranged between the shutter 15 and the second auxiliary condenser 16. The mirror 50 reflects the longwave part of the light issuing from the electro-optical or magneto-optical shutter 15 to a photoelectric cell 51 and allows the short-wave part of the light, that is the photographically effective part thereof, to pass to the second auxiliary condenser 16. This enables control of the transmission of the electro-optical or magneto-optical shutter 15 by a closed control circuit, in that the photoelectric cell 51 is coupled back to the electro-optical or magneto-optical shutter 15.

As illustrated in FIGS. 1 and 5, the apertured diaphragm or mask 20 is advantageously provided in the form of a rotary diaphragm mounted on the shaft of an adjusting device which received its control impulses from the control device of the drawing machine. The rotary diaphragm is provided with a number of diaphragm apertures of various diameters provided at intervals around the circumference of a circle. The apertured diaphragm is adjusted by the adjusting device, so that the particular aperture of the diaphragm, the image of which aperture results in a line of the desired thickness being produced on the photosensitive layer 3, is moved to the operating position.

I claim:

1. An automatic drawing machine having a drawing board and a photo-optical drawing head, the head and board being laterally movable relative to one another, control means for controlling said relative movement and the intensity of light emitted by said head and falling on the board, a light source, a diaphragm having opaque and transparent portions, means for projecting a beam of light from said light source through said diaphragm and onto the drawing board, said projection means including a projection lens system for projecting an image of at least a portion of the diaphragm on the drawing board, a first electro-optical or magneto-optical shutter means in the path of said beam of light for controlling the intensity thereof, a second shutter in the path of said beam of light, and electromagnetic means for operating the second shutter.

2. Apparatus according to claim 1 having a first auxiliary condenser lens means in the light beam to create a first portion of the beam with parallel rays of light, said first shutter being located in the first portion of the beam.

3. Apparatus according to claim 1 having a partially reflecting mirror disposed obliquely in the light beam between the first shutter and the diaphragm to direct the beam into two paths, one of the paths being directed toward the diaphragm, a photoelectric cell located in the other path and coupled to the portion of the control means which changes the molecular structure of the light-conductive element in the first shutter.

4. Apparatus according to claim 3 wherein the partially reflecting mirror is an infrared mirror oriented to transmit shortwave portions of the light beam along the one path toward the diaphragm and to reflect longwave portions of the light beam along the other path toward the photoelectric cell.

5. Apparatus according to claim 1 having a first auxiliary condenser lens means in the light beam to create a first portion of the beam with parallel rays of light, said first portion of the beam passing through the first shutter, and a second auxiliary condenser lens means in the beam to produce a true image of the light source substantially in the plane of said second shutter.

6. Apparatus according to claim 1 having an auxiliary condenser lens means in the beam to create a true image of the light source substantially in the plane of said second shutter.

7. Apparatus according to claim 1 wherein said control means includes means for opening said second shutter prior to commencement of relative movement between the drawing head and the drawing board.

8. Apparatus according to claim 7 having an auxiliary condenser lens means in the beam to create a true image of the light source substantially in the plane of said second shutter.

9. Apparatus according to claim 8 having another auxiliary condenser lens means in the light beam to create a first portion of the beam with parallel rays of light, said first shutter being located in the first portion of the beam.

10. Apparatus according to claim 9 having a partially reflecting mirror disposed obliquely in the light beam between the first shutter and the diaphragm to direct the beam into two paths, one of the paths being directed toward the diaphragm, a photoelectric cell located across the other path and coupled to the control means to vary the intensity of the field within the first shutter.

11. Apparatus according to claim 10 wherein the partially reflecting mirror is an infrared mirror oriented to transmit shortwave portions of the light beam along the one path toward the diaphragm and to reflect longwave portions of the light beam along the other path toward the photoelectric cell.

12. An automatic drawing machine having a drawing board and a photo-optical drawing head, the head and board being laterally movable relative to one another, control means for controlling said relative movement and the intensity of light emitted by said head and falling on the board, a light source, a diaphragm having opaque and transparent portions, means for projecting a beam of light from said light source through said diaphragm and onto the drawing board, said projection means including a projection lens system for projecting an image of at least a portion of the diaphragm on the drawing board, a first shutter having light transmissability characteristics which vary according to the molecular structure within a light-conductive element thereof, means operatively connected to the control means for changing the molecular structure within the

light-conductive element to vary the light transmissability of the first shutter, a second shutter for interrupting the beam of light, said second shutter having opaque portions movable to and from a position interrupting said beam, said control means including means for opening said second shutter prior to commencement of relative movement between the drawing head and the drawing board.

13. Apparatus according to claim 12 wherein the first shutter is an electro-optical shutter.

14. Apparatus according to claim 12 wherein the first shutter is a magneto-optical shutter.

15. Apparatus according to claim 12 having electromagnetic means for moving the opaque portions of the second shutter.

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