United States Patent [19]

Webster

[11] **3,904,291**

[45] **Sept. 9, 1975**

[54] **PHOTOEXPOSURE MECHANISM AND CONTACT PRINTER THEREFOR**

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[73] Assignee: **The Gerber Scientific Instrument Company**, South Windsor, Conn.

[22] Filed: **Dec. 18, 1972**

[21] Appl. No.: **316,010**

[52] **U.S. Cl.** **355/19**; 355/40; 355/91; 355/95; 355/99; 354/4

[51] **Int. Cl.** **G03b 27/00**; G03B 27/02; G03b 27/32

[58] **Field of Search** 355/40, 19, 91, 97, 99, 355/78, 95; 354/4

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Primary Examiner—Richard M. Sheer

[57] **ABSTRACT**

A photographic artwork generating mechanism comprises a contact printer for exposing relatively large area images on a photosensitive surface in combination with another photoexposure device for drawing lines and/or for flashing small symbols on the photosensitive surface to complete the artwork by adding lines and other features to the image or images exposed by the contact printer. The contact printer may be operated either in a step and repeat manner or in a photo composition manner. In the step and repeat mode of operation, with each operation of the contact printer either a complete artwork or a complete artwork skeleton is exposed on the photosensitive surface. In the photo compose mode of operation, the contact printer is operated a number of times to compose a complete artwork or artwork skeleton from a number of exposures. In either mode of operation, when the contact printer is used to produce an incomplete artwork or skeleton, the artwork may be completed by using the second photoexposure device to add lines, small symbols and other features to the skeleton.

2 Claims, 31 Drawing Figures

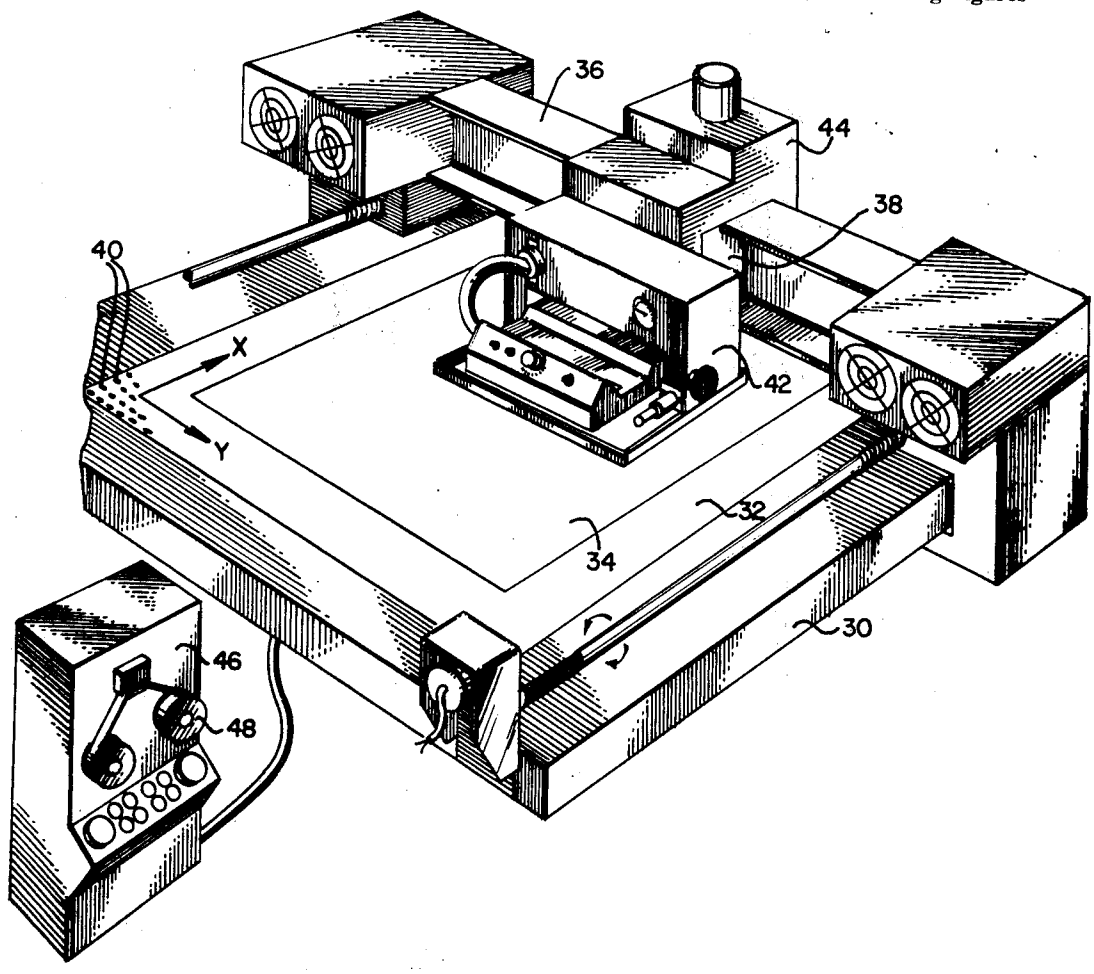


FIG. 1

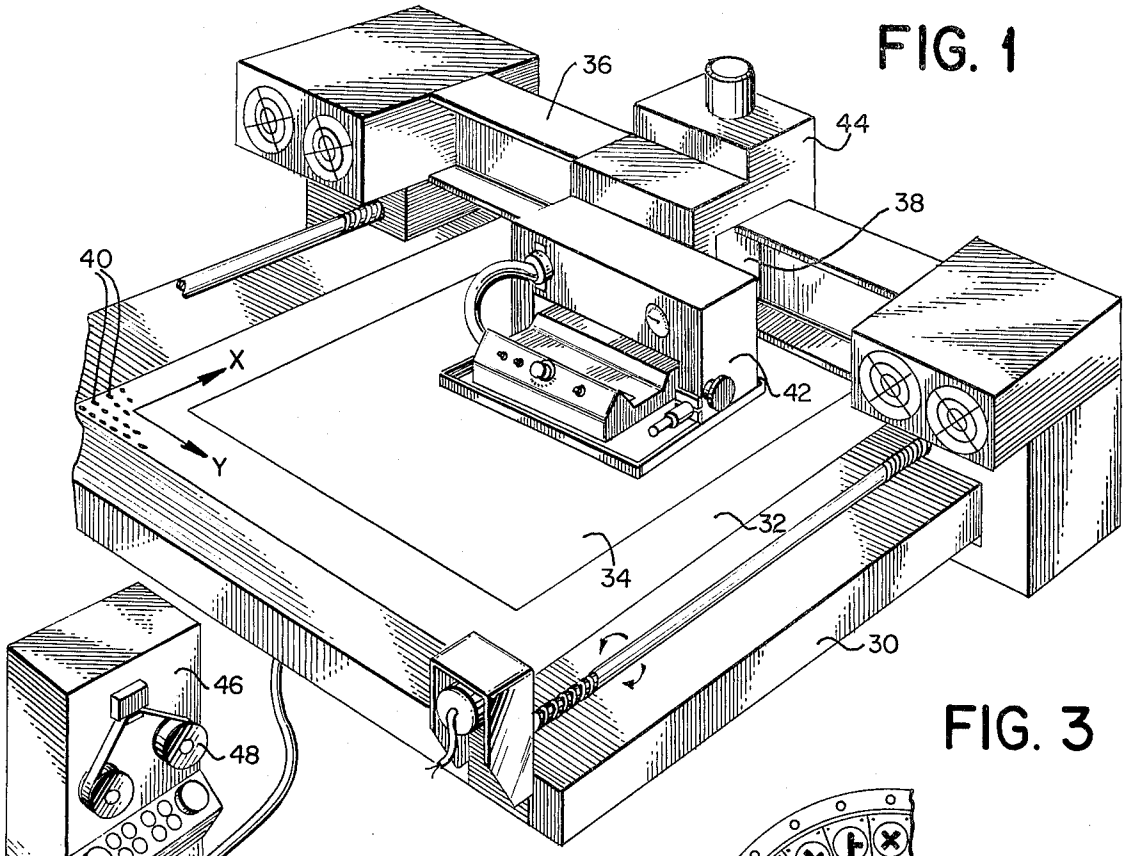


FIG. 3

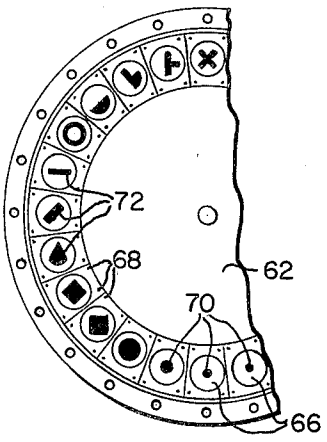


FIG. 2

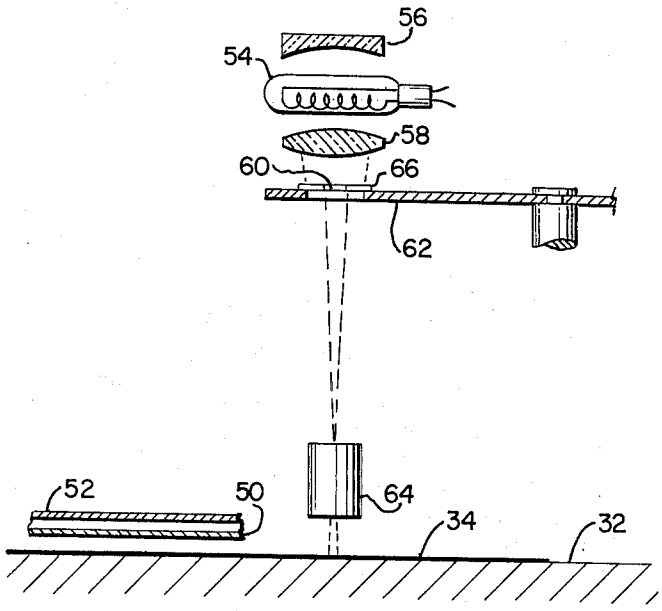
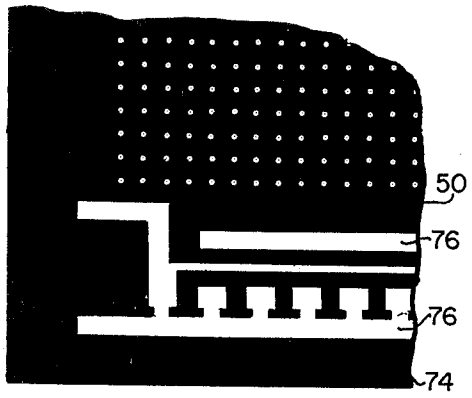


FIG. 4



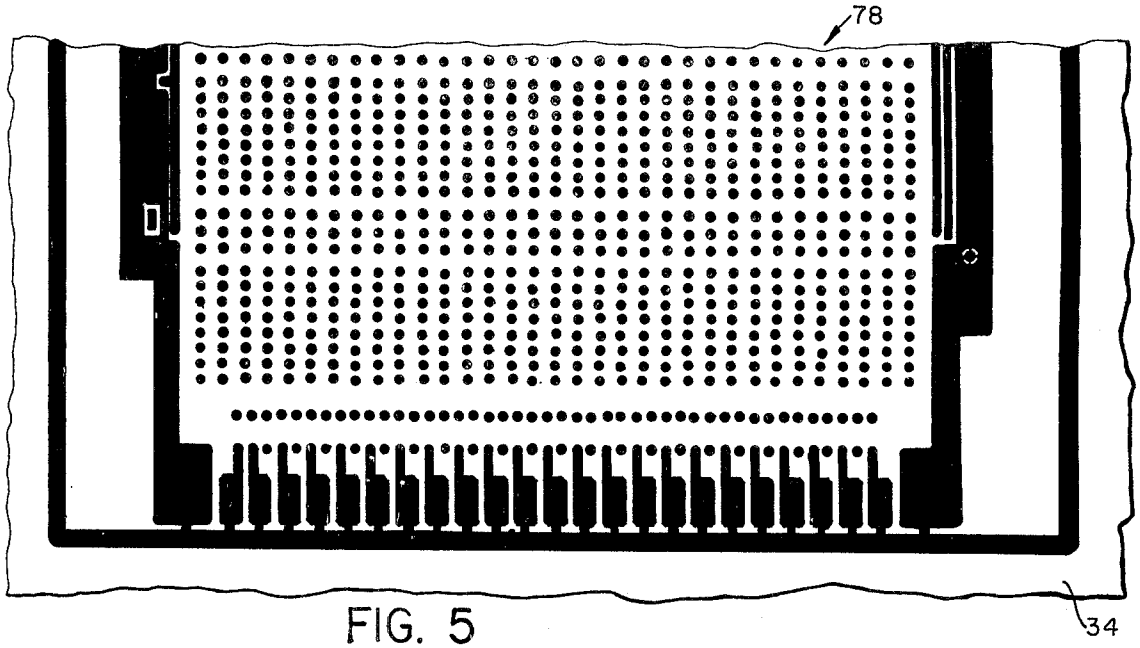


FIG. 5

FIG. 6

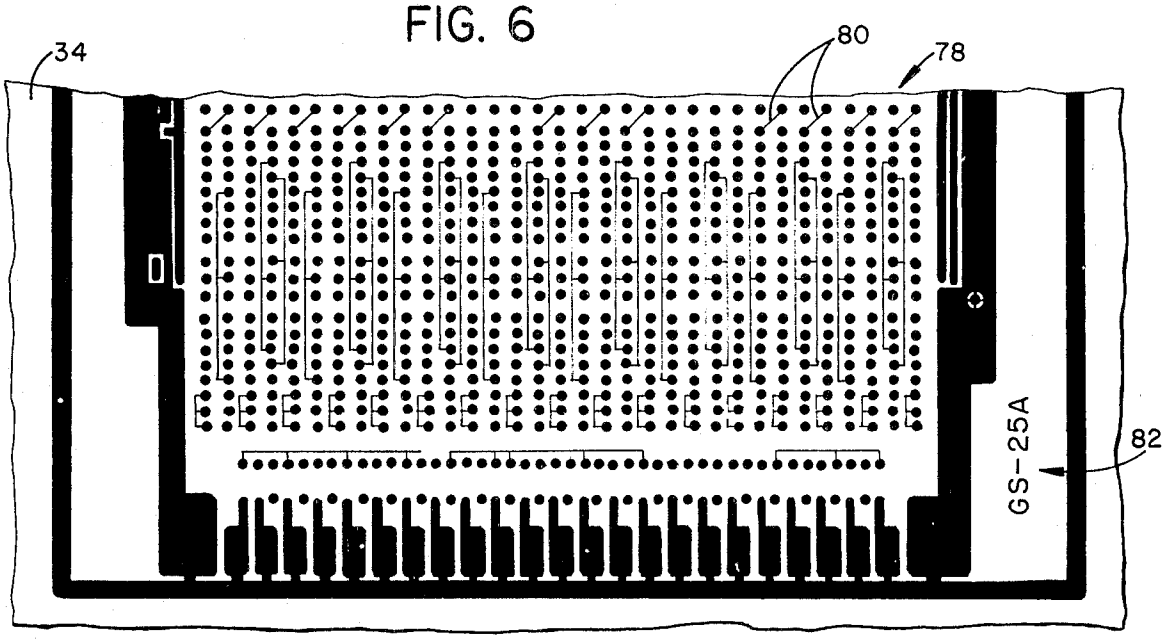
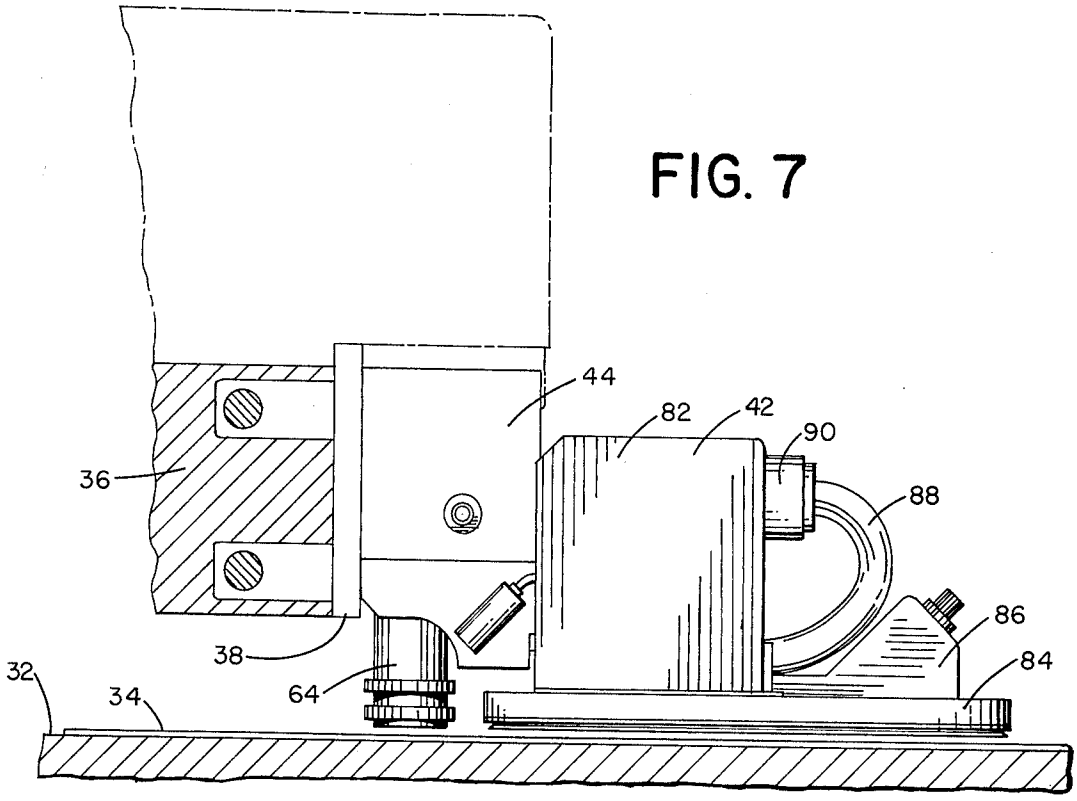


FIG. 7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82
42
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36
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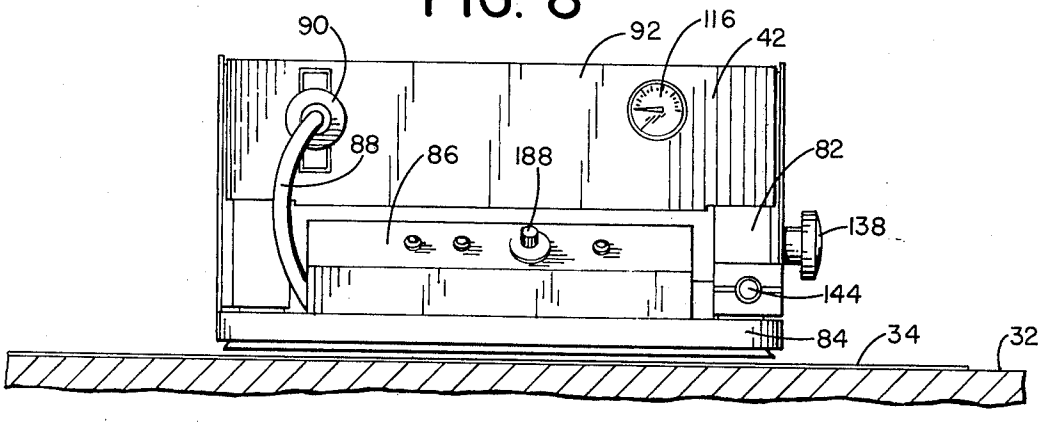
64
32
34

FIG. 8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84
34
32

FIG. 9

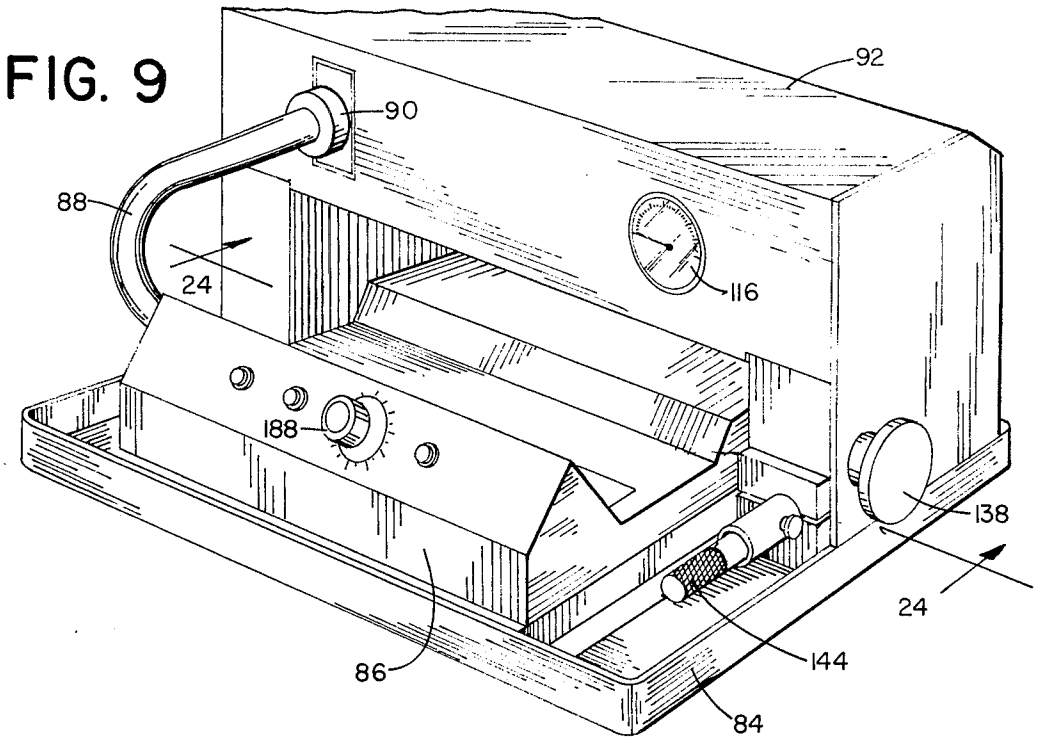
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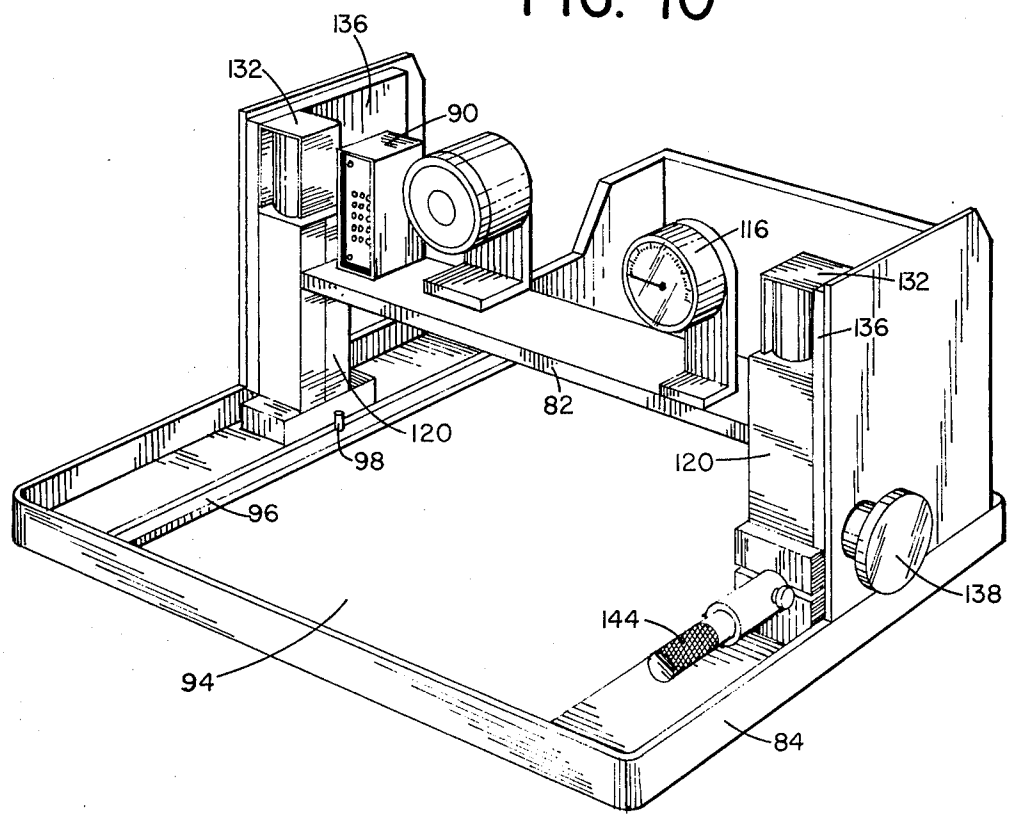
FIG. 10


136
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132
136
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96
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144
94
84

FIG. 11

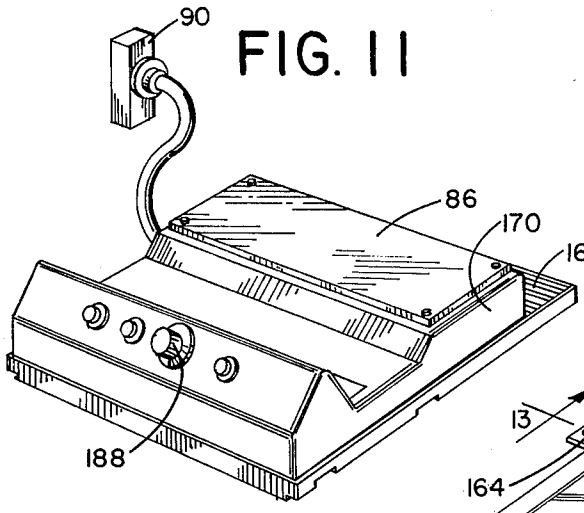


FIG. 12

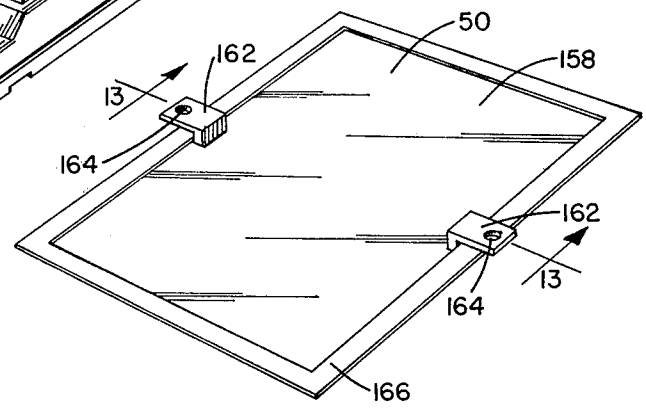


FIG. 13

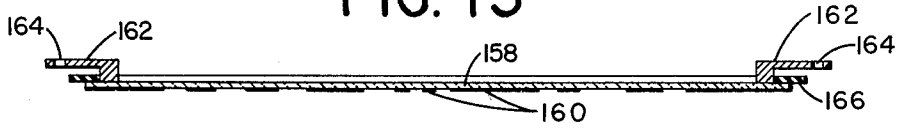
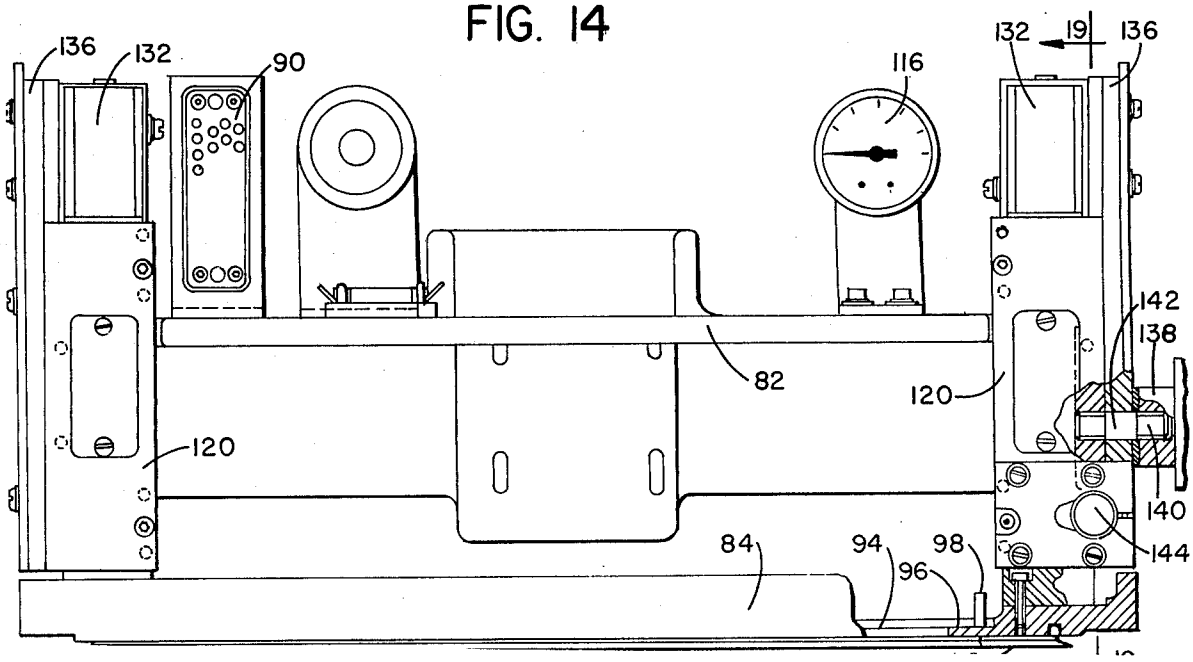


FIG. 14



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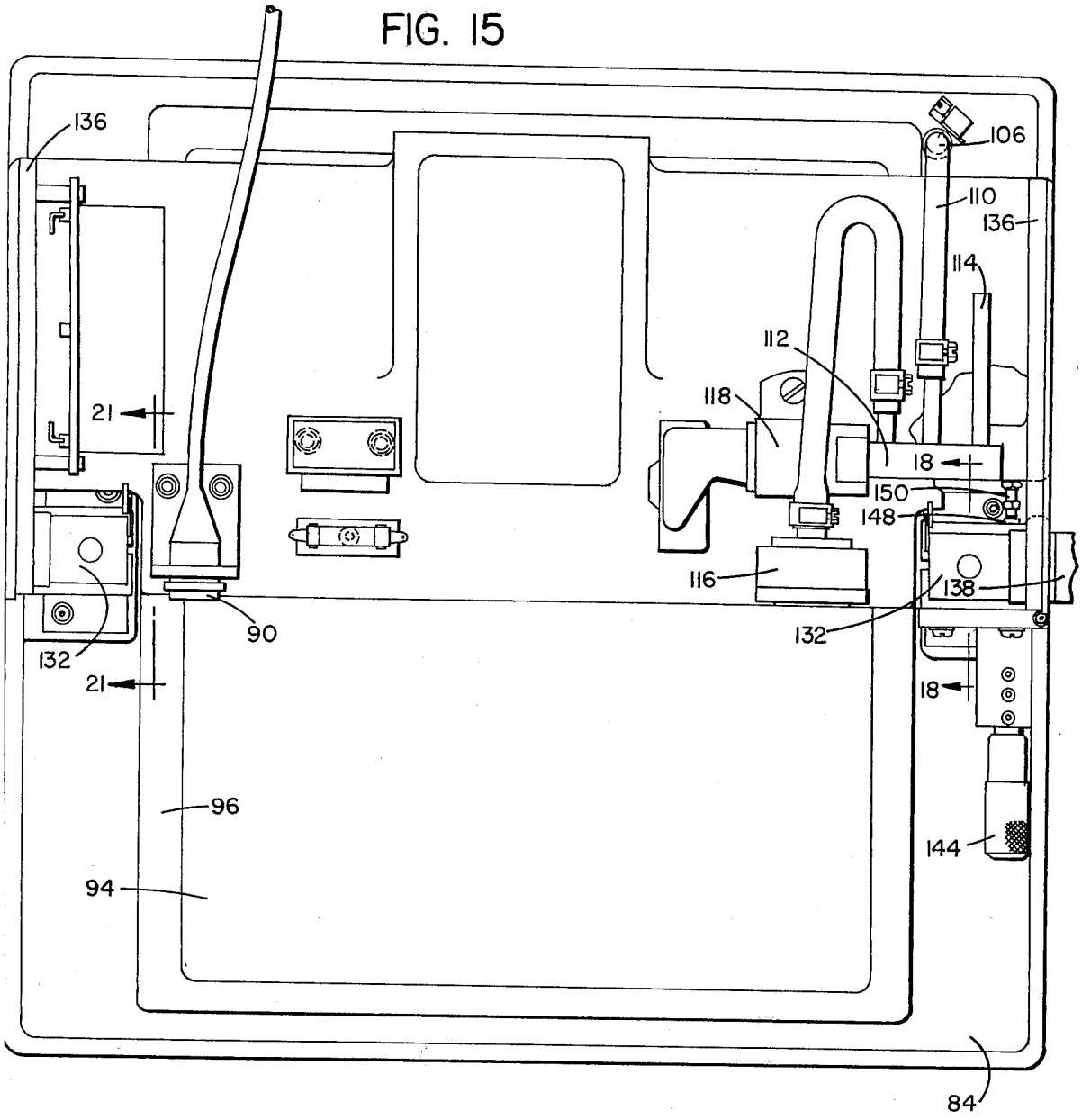

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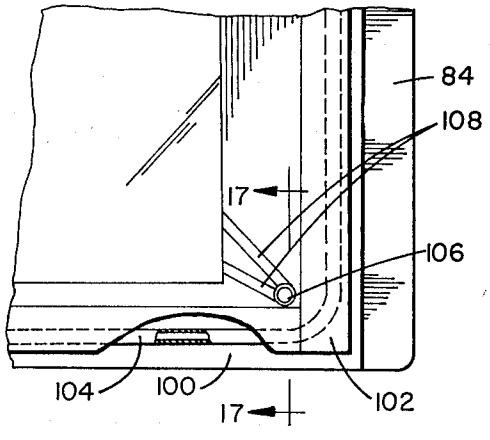
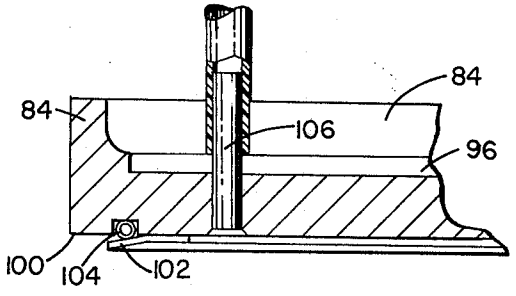


FIG. 17



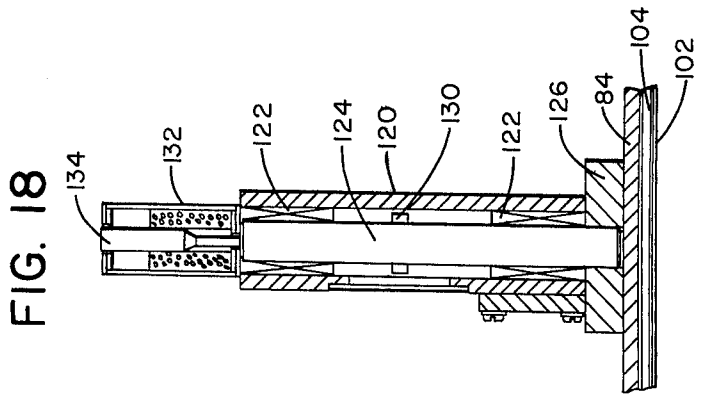


FIG. 18

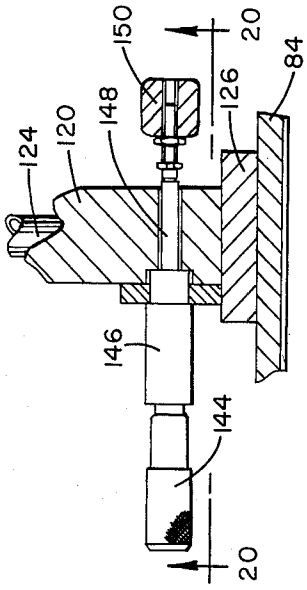


FIG. 19

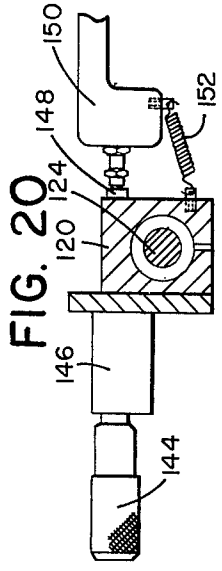
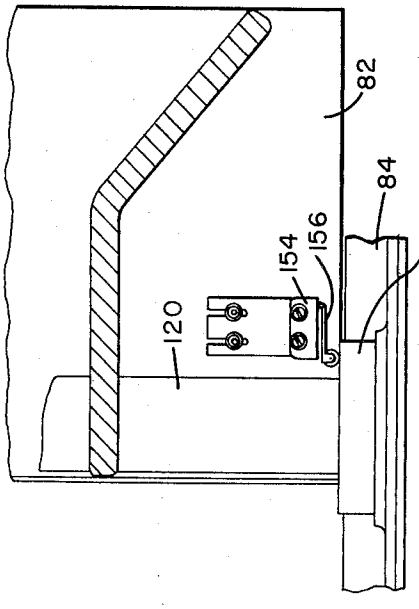


FIG. 20



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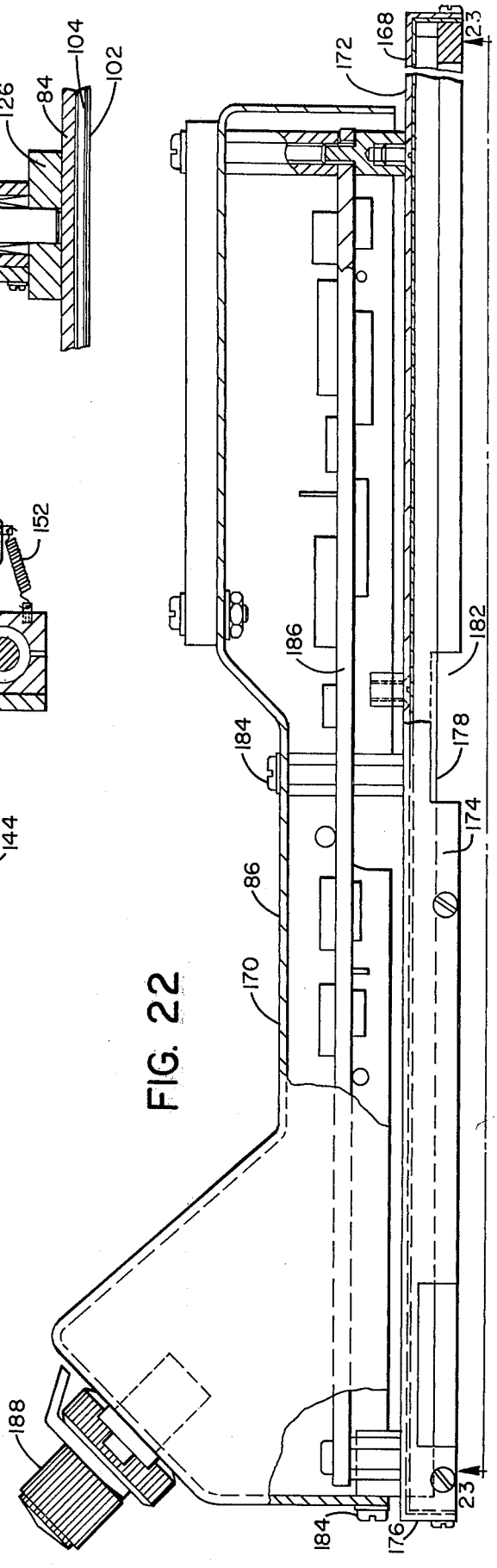


FIG. 22

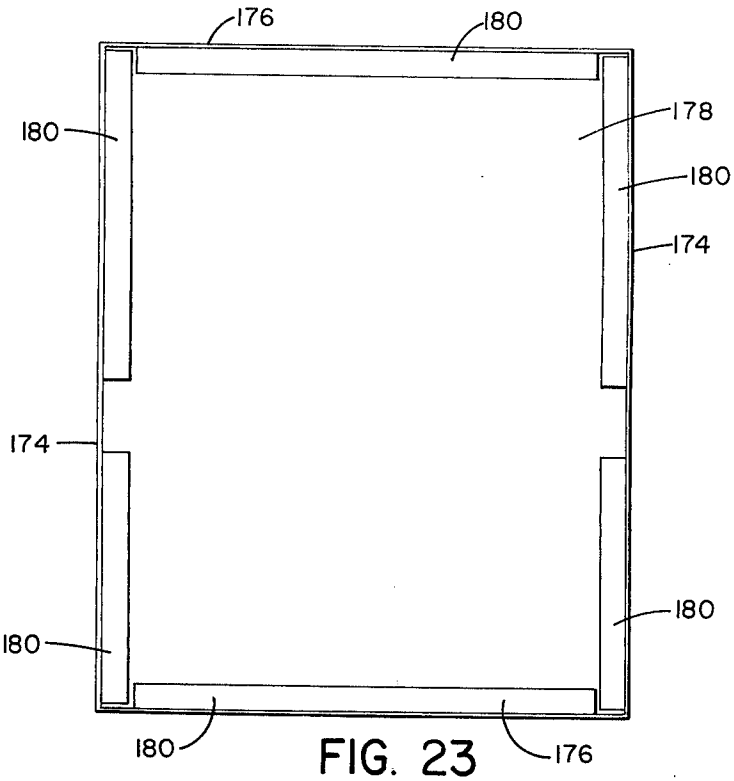


FIG. 23

FIG. 24

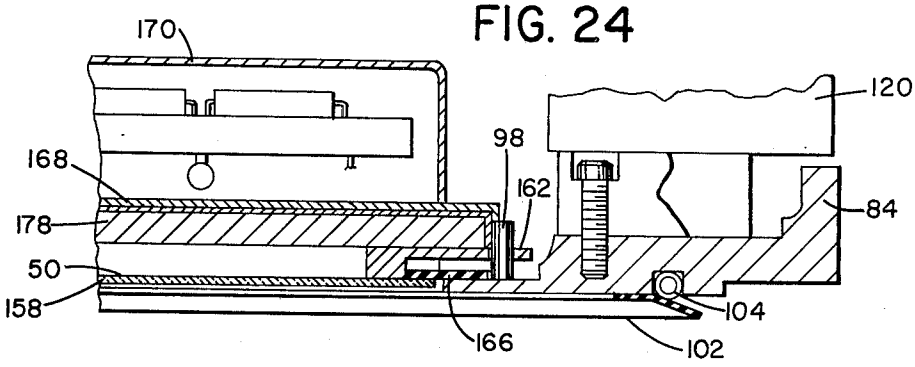
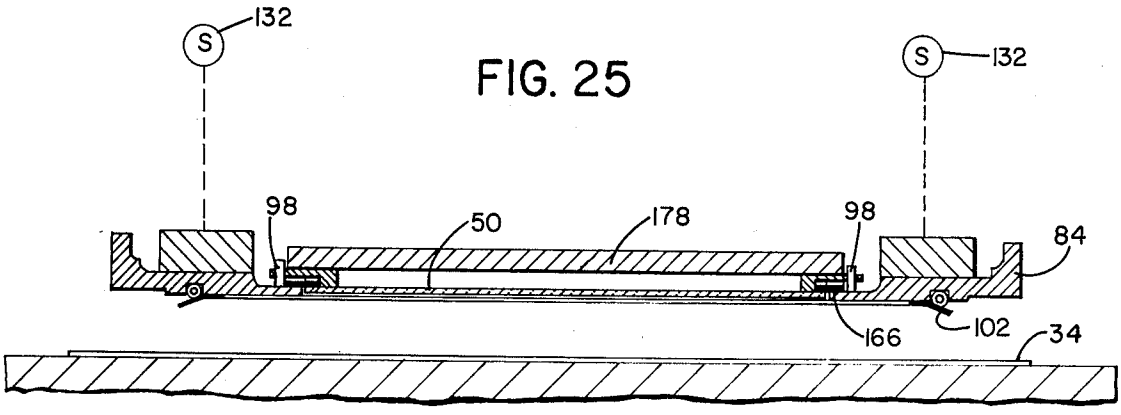


FIG. 25



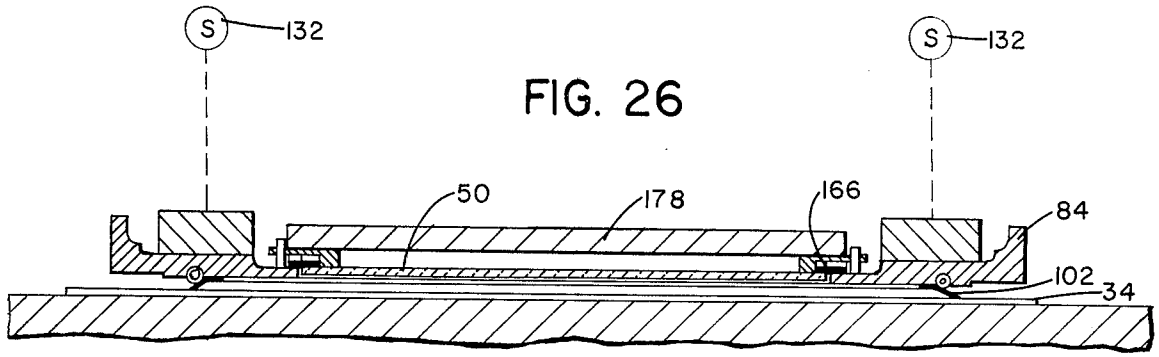


FIG. 26

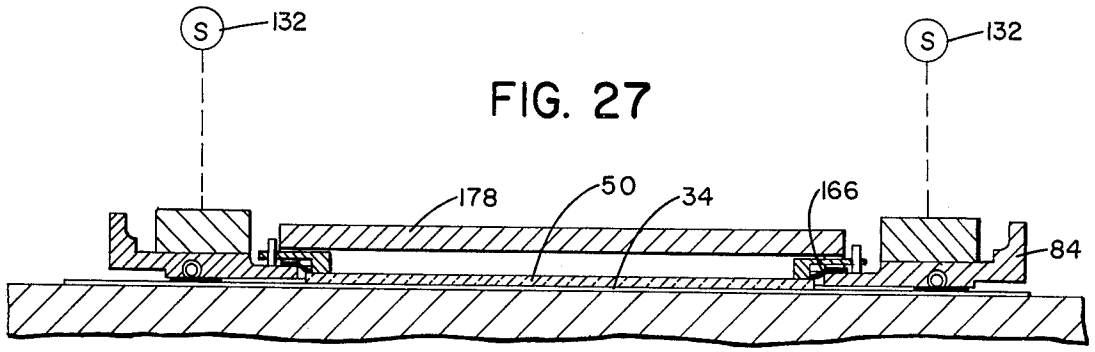


FIG. 27

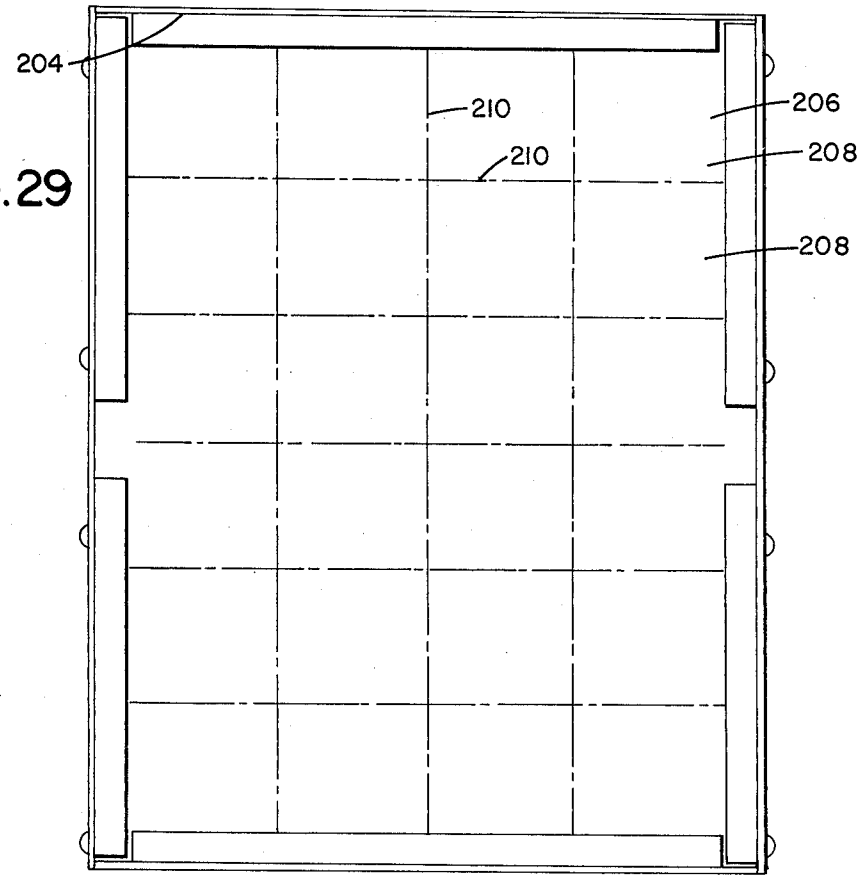
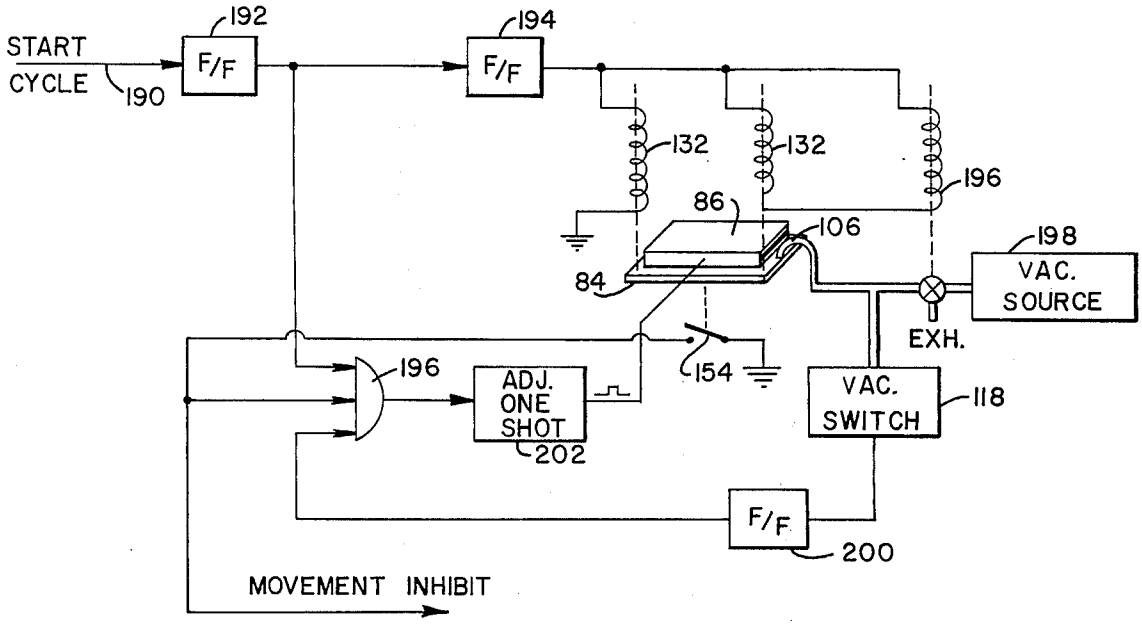


FIG. 29

FIG. 28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F/F
194
F/F
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132
196
86
106
198
VAC. SOURCE
84
EXH.
196
ADJ. ONE SHOT
202
154
VAC. SWITCH
118
F/F
200
MOVEMENT INHIBIT

FIG. 30

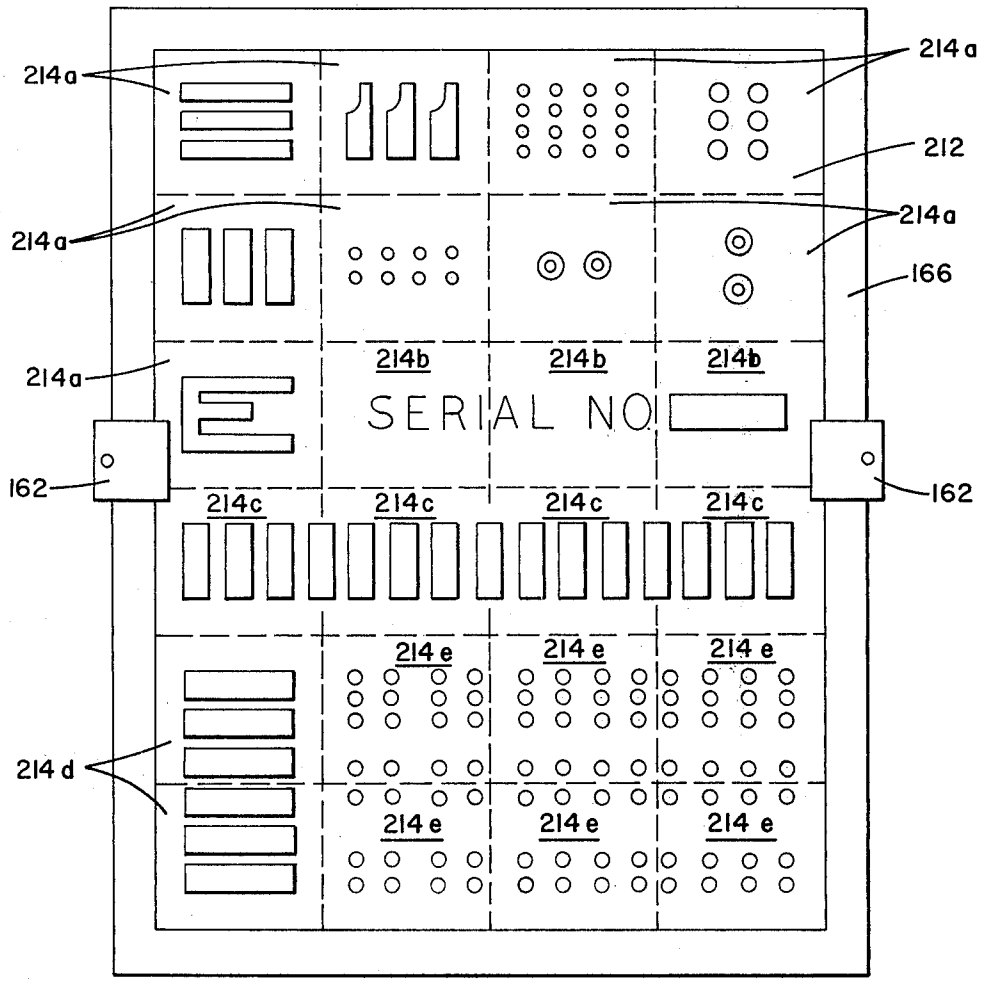
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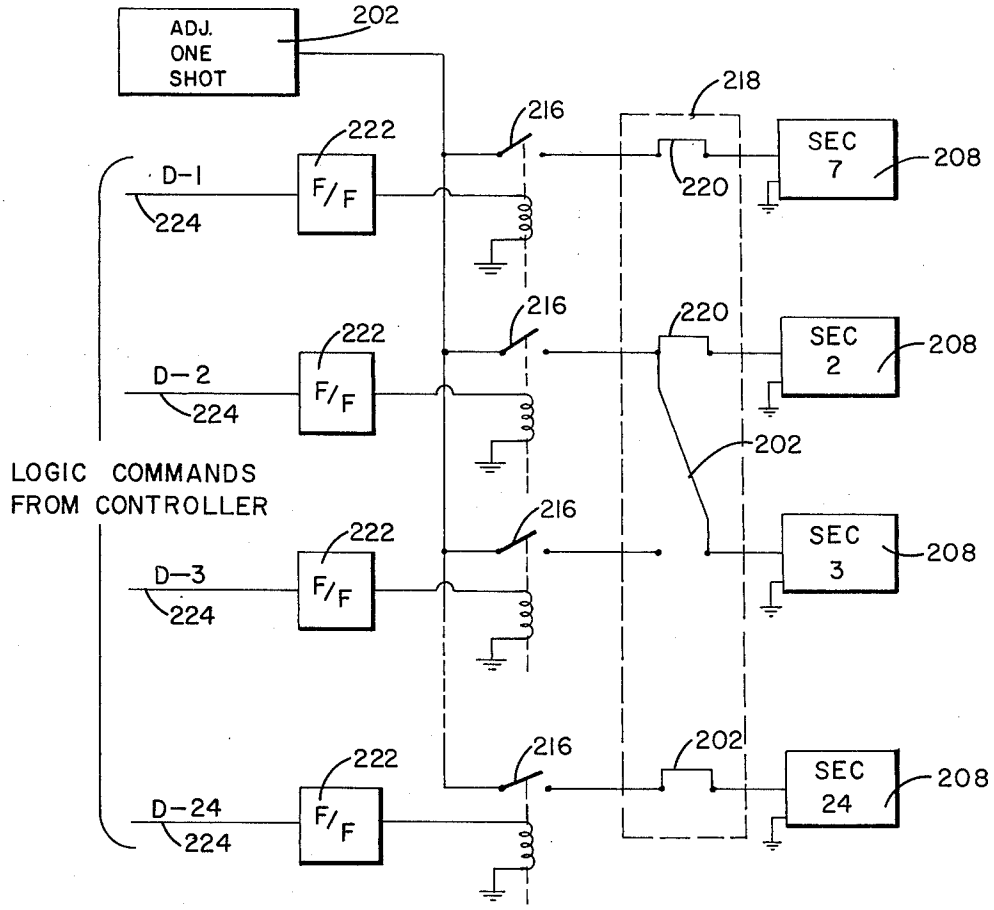
FIG. 31


ADJ.
ONE
SHOT
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222
D-1
F/F
224
SEC
7
208
220
216
220
D-2
222
F/F
224
SEC
2
208
202
LOGIC COMMANDS
FROM CONTROLLER
216
222
D-3
F/F
224
SEC
3
208
216
202
222
D-24
F/F
224
SEC
24
208

PHOTOEXPOSURE MECHANISM AND CONTACT PRINTER THEREFOR

BACKGROUND OF THE INVENTION

This invention relates to devices for exposing photosensitive surfaces to generate artworks thereon, and deals more particularly with such a device including both a contact printer for exposing a relatively large area of such photosensitive surface in one operation and another exposure device for drawing lines on the photosensitive surface and/or for exposing symbols of relatively small area.

The photoexposure mechanism of this invention is particularly useful in situations where it is desired to produce a relatively large number of identical or generally similar two-dimensional artworks. Such artworks may, for example, be masks of the type used in the manufacture of printed circuit boards and integrated circuit chips or in chemical milling and photo engraving processes. The mechanism of this invention includes a contact printer of improved construction which is movable over a photosensitive surface and operable with each operation of expose a relatively large area of the photosensitive surface. The exposure made with each operation of the contact printer may be such as to represent either a complete artwork or only a portion of an artwork which is subsequently completed by further exposure of the photosensitive surface. The contact printer includes a photo mask in the form of a plate which is held in direct contact with the photosensitive surface during a printing operation by a unique vacuum system which eliminates distortions of the photomask and photosensitive surface which otherwise might produce inaccuracies in the exposure.

In addition to being used by itself, the contact printer may also be used with a second photoexposure device, forming part of the mechanism of this invention, adapted to expose lines and other small symbols on the photosensitive surface. This permits the contact printer to be used to expose standard outlines, formats and repetitive patterns, and the other exposure device to be used to complete the artwork by adding lines and other small features to the image exposed by the contact printer. For example, in the manufacture of printed circuit boards, very often a number of different boards will use an identical basic format of contact fingers, bus lines and socket pads and will differ from one another only with regard to wiring lines drawn between these basic elements. Such wiring is sometimes referred to as "discretionary wiring" as it is wiring which is added to the basic or standard circuit board format, at the discretion of the designer, to convert the standard format into a specific circuit board configuration. Therefore, when producing circuit board masks of different specific configurations but of a standard format, the mechanism of this invention may have its contact printer equipped with a master photomask bearing the standard format so that with a single operation of the contact printer the entire basic format of the circuit board is exposed on the photosensitive surface. Then the second photoexposure device may be used to expose or draw-in the discretionary wiring. This avoids the need for drawing the entire circuit board configuration with the line drawing device or for providing the contact printer with a master photomask for each specific circuit board desired.

SUMMARY OF THE INVENTION

This invention resides in a mechanism for exposing artworks on photosensitive surfaces, which mechanism consists of a means for supporting a sheet of photosensitive material, a contact printing device, a second photoexposure device for exposing lines and small symbols, and a means for driving both the contact printing device and the second photoexposure device over the photosensitive surface to enable the contact printer to be brought into registry with selected areas of the photosensitive material and to enable the second photoexposure device to be moved along any desired line relative to the photosensitive material.

The invention also resides in the construction of the contact printer, especially the means included in such printer for holding the master photo mask thereof in direct contact with the photosensitive material during exposure. This construction includes a main frame, a base frame movable vertically relative to the main frame and having a relatively large opening parallel to the photosensitive material. The base frame opening is located adjacent the surface of the photosensitive material and receives a master photo mask in the form of a plate which is supported along its edges from the adjacent edges of the base frame by a gasket which pneumatically seals the plate to the base frame and resiliently supports the plate so as to allow it to move a small distance vertically relative to the base frame. The base frame includes a downwardly facing peripheral pneumatic seal gasket movable into and out of contact with the photosensitive material as the base frame is moved toward and away from such material, and a vacuum system is provided for introducing a vacuum into the space surrounded by the pneumatic seal gasket. The vacuum system and the means for moving the base frame are so controlled that in a printing operation the base frame is first moved downwardly to bring the pneumatic seal gasket into contact with the photosensitive surface, and then vacuum is applied to the space surrounded by the seal gasket to cause the base frame and the master plate to be urged by atmospheric pressure into direct contact with the photosensitive material. Another vacuum holddown system is used to hold the photosensitive material to its supporting surface.

The invention further resides in the utilization in the contact printer of an electro-luminescent panel as the light source for illuminating the associated photo mask, and in the photo mask being divided into a number of separate discrete areas and the electro-luminescent panel being divided into a similar arrangement of discrete areas, each of which overlies a corresponding respective one of said discrete areas of said photo mask, which are selectively energizable to enable the selective illumination of different areas of the photo mask.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing a photoexposure mechanism embodying this invention.

FIG. 2 is an illustration showing schematically the basic parts of the mechanism of FIG. 1.

FIG. 3 is a partial plan view of the aperture wheel of the line drawing and symbol flashing photoexposure device of the mechanism of FIG. 1.

FIG. 4 is a partial view of the master photo mask plate used in the contact printer of the mechanism of FIG. 1.

FIG. 5 is a view showing the image exposed on the photosensitive surface by operation of the contact printer of the mechanism of FIG. 1.

FIG. 6 is similar to FIG. 5 but shows a completed artwork made by adding lines, through the use of the line drawing device of the mechanism of FIG. 1, to the FIG. 5 skeletonal image.

FIG. 7 is a side elevational view of the contact printer and line drawing device of FIG. 1.

FIG. 8 is a front elevational view of the contact printing device of FIG. 1 with the light unit and top cover in place.

FIG. 9 is a perspective view of the contact printer of FIG. 1 with the top cover removed and with the light unit in place.

FIG. 10 is a perspective view similar to FIG. 9 but shows the light unit and master plate removed.

FIG. 11 is a perspective view showing the contact printer light unit by itself.

FIG. 12 is a perspective view showing the contact printer master plate by itself.

FIG. 13 is a vertical sectional view through the master plate taken on the line 13—13 of FIG. 12.

FIG. 14 is an enlarged front elevational view of the contact printer of the mechanism of FIG. 1 with the top cover, light unit and master plate removed and with certain parts being shown broken away to reveal the structure of other parts.

FIG. 15 is a plan view of the contact printer with the top cover, light unit and master plate removed.

FIG. 16 is an enlarged fragmentary view showing a portion of the base frame of the contact printer.

FIG. 17 is another enlarged fragmentary sectional view taken generally on the lines 17—17 of FIG. 16.

FIG. 18 is a sectional view taken on the line 18—18 of FIG. 15.

FIG. 19 is a sectional view taken on the line 19—19 of FIG. 14.

FIG. 20 is a sectional view taken on the line 20—20 of FIG. 14.

FIG. 21 is a sectional view taken on the line 21—21 of FIG. 15.

FIG. 22 is an enlarged view partly in vertical section and part in side elevation of the contact printer light unit.

FIG. 23 is a bottom view of the light unit of FIG. 22.

FIG. 24 is a vertical sectional view taken on the line 24—24 of FIG. 9.

FIGS. 25, 26 and 27 are illustrations, in the form of schematic vertical sectional views through the contact printer, showing the positions of the parts thereof at various stages of a printing operation.

FIG. 28 is a simplified schematic diagram illustrating the basic logic system for controlling the operation of the contact printer.

FIG. 29 is a bottom view of a light unit used in an alternate embodiment of this invention.

FIG. 30 is a plan view of a master plate designed for use with the light unit of FIG. 29.

FIG. 31 is a schematic diagram showing a modification of the logic system of FIG. 28 to adapt it for use with a multi-segment light unit such as shown in FIG. 29.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows in general a complete photoexposure mechanism embodying this invention. Referring to this figure, the mechanism there shown consists of a table 30 having a flat upwardly facing work surface 32 for supporting a sheet of photosensitive material 34. The photosensitive material may be of various different forms, but generally consists of a glass, plastic or paper sheet having a photosensitive film defining its upper surface. Supported for movement relative to the work surface 32 in the illustrated X coordinate direction is a main carriage 36 straddling the work surface 32, and mounted on the main carriage is a work carriage 38 movable relative to the main carriage in the illustrated Y coordinate direction. Therefore, by combined movement of the main carriage 36 in the X direction and movement of the work carriage in the Y direction the work carriage and the devices attached thereto may be moved to register with any point on the photosensitive material or to trace any desired line relative thereto.

The table 30, main carriage 36 and work carriage 38 are or may be parts of a conventional X-Y plotter of the type commonly used with pen or printing mechanisms attached to the work carriage for drawing graphics onto a sheet of paper or other material supported by the work surface. In any event, the table 30 preferably includes a vacuum holddown system for holding the sheet of photosensitive material 34 to the work surface. Such vacuum holddown systems are well known. In the illustrated case such a system is provided and consists of a large number of small openings 40, 40 passing through the material defining the work surface and connectible to a vacuum source. The work surface 32 is divided into a number of different sections to which the vacuum source may be selectively connected so that when the vacuum holddown system is in use only those openings 40, 40 covered by the sheet of photosensitive material may be connected to the vacuum source to prevent the loss of vacuum through uncovered openings. The vacuum drawn through the openings covered by the photosensitive material, of course, causes the photosensitive material to be pressed to the work surface by atmospheric pressure.

In accordance with this invention the mechanism of FIG. 1 further includes a contact printing photoexposure device 42, for exposing relatively large area images on the photosensitive material 34, and a second photoexposure device 44. The second device is operable to expose lines on the photosensitive material 34, to flash symbols of relatively small area onto the photosensitive material 34, or to both draw lines and flash small symbols. The contact printer 42 is of a unique construction as illustrated and described hereinafter in more detail. The second photoexposure device 44 may take various different forms but is preferably, and is taken herein to be, a device such as disclosed in U.S. Pat. No. 3,330,182 entitled "A Device for Exposing Discrete Portions of a Photosensitive Surface to a Variable Intensity Light Beam." The construction of the device 44 is discussed hereinafter only in a general manner and reference may be had to said U.S. Pat. No. 3,330,182 for a further understanding of its details. Completing the mechanism of FIG. 1 is a numerical controller 46, having a magnetic tape reader 48 as the input thereto, which automatically controls, in response to the input information supplied by the tape reader 48, the movement of the carriages 36 and 38 and the operation of the photoexposure devices 42 and 44.

FIG. 2 is a schematic view showing the basic parts of the contact printer 42 and of the second photoexposure device 44. Referring to this figure and considering first the contact printer 42, this device consists basically of a photomask 50 and a light source 52 for uniformly illuminating the photomask 50. The photomask is arranged parallel to and adjacent the sheet of photosensitive material 34 and between the material 34 and the light source so that when the light source is energized an image of the photomask is exposed on the photosensitive material. During such exposure or "printing" the photomask is held in direct contact with the photosensitive material as explained hereinafter. Within the broader aspects of this invention the photomask may take various different forms, but preferably and as shown hereinafter, it consists of a glass plate bearing an image formed by a layer of opaque material on its lower surface, the opaque layer being present at some areas of the bottom surface and absent from other areas of the bottom surface as needed to define the master image. Therefore, the master plate is in the form of a photographic transparency the image of which is defined by the opaque material.

The second photoexposure device 44 of FIG. 2 consists of a light source which may take various different forms but which is shown to consist of an incandescent lamp 54 and associated mirror 56. Light from the light source and mirror passes through a condensing lens 58 to uniformly illuminate one aperture 60 of an aperture wheel 62. A real image of the illuminated aperture 60 is projected onto the surface of the photosensitive material by a projecting lens system 64. A light spot is thereby created on the photosensitive material 34 and by moving the photoexposure device 44 relative to the photosensitive material, to accordingly move the projected light spot over the photosensitive material, a line may be generated or exposed on the photosensitive material as described in the aforesaid patent. The aperture wheel 62 contains a number of apertures any selected one of which may be brought into operative position in the path of the light rays from the light source to the projecting lens, and when the device is used for drawing lines the selected aperture is generally one defining a round image or some other image of relatively simple geometry to create a correspondingly shaped light spot. Also, the aperture wheel 62 may contain other apertures with images representing symbols to be exposed on the photosensitive material 34. When such a symbol is to be exposed, the appropriate aperture is brought into operative position while the device 44 is held either completely or relatively stationary relative to the photosensitive material and the light source is energized momentarily to briefly project a real image of the aperture onto the photosensitive surface. Alternatively, the light source may be continuously energized and a shutter which normally blocks the light path be operated to briefly unblock the light path and allow the image of the aperture to be projected onto the photosensitive surface. Regardless of which method is used to control the exposure, this general method of exposing small symbols onto the photosensitive surface is referred to herein as "symbol flashing."

FIG. 3 reveals in more detail the construction of the aperture wheel of the photoexposure device 44 and illustrates the differently shaped apertures used therein. As shown in this figure, the aperture wheel 62 carries a plurality of aperture plates 66, 66 arranged in an annular series around the outer marginal edge of the wheel and held to the wheel by a plurality of holders 68, 68. Each aperture plate 66 defines a single aperture. However, it should be understood that here the term "aperture" is used to refer to the light transmitting area of a particular aperture plate, and such aperture may actually consist of a number of separate light transmitting areas. For example, an aperture may be in the shape of a lower case letter *i* and consist of two transparent areas, one being the body of the letter and the other the dot. A number of the apertures, indicated at 70, 70, are of circular shape whereas the remaining apertures 72, 72 are of more complex shapes referred to for convenience as "symbols." The circular apertures 70, 70 are used when the device 44 is used in a line drawing manner. That is, when drawing lines one circular aperture 70 is brought into the operative position to cause a circular light spot to be projected onto the photosensitive surface. The various circular apertures are of different diameters so that by bringing different ones of such apertures into the operative position differently sized spots may be projected onto the photosensitive surface to generate lines of different width. The symbol apertures 72, 72 may vary widely in shape as required for the particular application to which the device 44 is put. For example, when the device is used in connection with the generation of printed circuit board photomasks, the symbol apertures 72, 72 may be in the shape of various contact fingers, pads or other shapes commonly found on printed circuit board masks. Also, some of the symbol apertures may be in the shape of alphabetical or numerical symbols to allow the exposure of numbers or letters onto the photosensitive surface through the symbol flashing process. The aperture plates 66, 66 of the aperture wheel 62 may, for example, either be in the form of thin metal plates wherein the apertures are formed by openings cut in the plates or may be in the form of photographic transparencies each consisting of a sheet of transparent material and a layer of opaque material, the aperture of each aperture plate being defined by the presence and absense of the opaque material over various portions of the transparent sheet.

FIG. 4 shows a portion of an exemplary master photomask used in the contact printer of this invention. The illustrated mask 50 is designed for use in connection with making printed circuit board photomasks and consists of opaque areas 74 and transparent areas 76. The design or shape of the transparent areas 76 is accordingly the image of the master photomask and is the image exposed on the photosensitive material when the contact printer is operated.

FIG. 5 shows a portion of an exemplary image exposed on a photosensitive surface through the use of the contact printer of this invention. In this particular case the image, which is indicated generally at 78, is an incomplete artwork and in particular is in the form of a basic format used by a series of different printed circuit board photomasks. Such incomplete artwork is sometimes herein referred to as a "skeletonal" artwork, and it is later completed by exposing additional lines or symbols on the photosensitive material through use of the second photoexposure device 42 of FIG. 1.

FIG. 6 shows a completed artwork as exposed on a photosensitive surface through the use of both the contact printer 42 and the second photoexposure device 44 of FIG. 1. Such completed artwork consists of

the skeletonal image **78** of FIG. **5** to which various lines, such as indicated at **80, 80,** have been added through the use of the second photoexposure device **44.** As mentioned previously, where the completed art-work is in the form of a photomask for manufacture of printed circuit boards the additional lines **80, 80** added to the skeletonal art-work or basic format **78** is usually referred to as discretionary wiring and is wiring which converts the basic format to a specific circuit board configuration. Therefore, by printing standard formats through the use of the contact printer **42** and by adding discretionary wiring with the line drawing photoexposure device **44** a large number of different circuit board configurations may be exposed without changing the master photomask of the contact printer and without drawing the entire circuit board configuration with the device **44.** In addition to merely drawing lines, the second photoexposure device **44** may also be used in the symbol flashing manner to expose symbols onto the photosensitive material to complete the artwork **78** of FIG. **5.** Such symbols may be of various sorts and shapes and may, for example, be alphabetical and numerical symbols, as indicated generally at **82** in FIG. **6,** used as to provide an identifying legend for the particular artwork in question. Of course, it will be understood that the contact printer need not necessarily be used in combination with a line drawing or symbol flashing device, and may instead be used by itself to expose complete artworks. To cause the contact printer to expose complete artworks it is of accessory only to provide it with a master photomask containing the image of a complete artwork. In either event, it will be noted that the sheet of photosensitive material **34** has an area considerably larger than the area thereof exposed by each operation of the contact printer. Therefore, the contact printer may be, and preferably is, operated in a step and repeat manner to expose a large number of identical images on the photosensitive material.

Reference is now made to FIGS. **7** to **28** for a more detailed description of the contact printing device **42** of FIG. **1.** Considering first FIGS. **7** and **8,** the contact printer **42** is there shown to be mounted to the work carriage **38** in front of the line drawing photoexposure device **44.** The basic components of the contact printer include a main frame **82,** a base frame **84,** and a light unit **86.** Another basic component is the master photomask **50,** not visible in FIGS. **7** and **8,** which underlies the light unit **86.** The main frame **82** is fixed relative to the work carriage **38** so as to be held at a fixed height above the work surface **32** and so as to be moved relative to the work surface and the sheet **34** of photosensitive material supported thereby by movement of the work carriage **38.** The base frame is generally rectangular in shape and is arranged generally parallel to the work surface **32.** FIGS. **7** and **8** show the base frame in a raised position and from this position it is movable downwardly toward the work surface **32,** as explained hereinafter, as part of the process of bringing the master photomask into printing contact with the surface of the photosensitive material. FIGS. **7** and **8** also show the light unit **86** in its normal operative position at which it rests on the base frame. The light unit **86** is readily removable from the base frame **84,** to allow access to and replacement of the associated master photomask, and is electrically connected to parts carried by the main frame **82** by a flexible multiconductor cable **88.** The cable **88** is permanently connected to the light unit **86** and releasably connected to the main frame **82** by a releasable connector **90.** A cover **92,** shown in FIG. **8,** normally covers the upper portion of the main frame.

As shown best in FIGS. **9** and **10,** the base frame **84** is generally rectangular in shape and includes a generally rectangular opening **94** arranged parallel to the plane of the work surface. The main frame is in the form of a bridge which straddles the opening **94** to provide a space for receiving the light unit **86.**

The construction of the base frame is best shown in detail in FIGS. **14** to **17.** Referring to these figures, the base frame adjacent the opening **94** has a horizontal upwardly facing shoulder **96** extending along and defining all four edges of the opening **94.** Located midway along the length of each of the two portions of the shoulder **96** extending along the side edges of the opening **94** is an upwardly extending guide pin **98,** shown in FIGS. **10** and **19.** The base frame has a generally planar downwardly facing bottom surface **100** and on this surface is an elongated gasket surrounding the opening **94** and adapted to engage the photosensitive material supported on the work surface to create a pneumatic seal between the base frame and the photosensitive material as the base frame is lowered toward the printing position. This gasket, as illustrated, consists of a strip **102** of flexible material having one edge cemented or otherwise attached to the bottom surface **100,** as shown in FIG. **17,** and a flexible tube **104** received in a groove in the base plate so as to resiliently hold the free edge of the strip **102** slightly spaced from the bottom surface **100.**

At the rear right-hand corner of the base frame **84,** as viewed in FIG. **15,** a vacuum tube **106** is connected to the base frame and communicates with the bottom surface **100** and grooves **108** in the bottom surface, see FIG. **16,** for introducing a vacuum to the space surrounded by the seal strip **102** for the purpose of holding the base frame and the master photomask in the printing position as explained in more detail hereinafter. The vacuum tube **106** is connected by a flexible conduit **110** to a manifold tube **112.** Also connected to the manifold tube is a supply tube **114,** a vacuum gauge **116** and a vacuum switch **118.** The supply tube **114** is connected to a suitable source of vacuum through a two-way solenoid operated valve, as hereinafter described, for controllably admitting or exhausting vacuum from the manifold tube **112.** The gauge **116** indicates the pressure existing in the manifold tube **112** and the switch **118** operates an associated set of contacts when the vacuum in the manifold tube **112** reaches a predetermined value.

Respectively associated with each of the two sides of the main frame **82** are two downwardly extending legs **120, 120** to which the base frame is attached. FIG. **14** shows both of the legs **120, 120** in elevation and FIG. **18** is a vertical section through one of the legs, the other leg being identical to that shown in FIG. **18.** As shown in FIG. **18,** each leg includes two vertically spaced bearings **122, 122** which slidably receive a cylindrical post **124.** The post **124,** at its bottom end, is fixed to the base frame **84** by being press fitted to a mounting pad **126** welded to the base frame **84.** Upward movement of the base frame **84** relative to the main frame **82** is limited by engagement of the lower ends of the legs **120, 120** with their associated mounting pads **126, 126.** The base frame is biased upwardly

toward this raised position by a helical spring **128** in each leg **120** surrounding the post **124,** the spring **128** being compressed between the lower bearing **122** and a collar **130** fixed to the post **124.** To move the base frame **84** downwardly from the raised position shown in FIG. **18** each leg **120** of the main frame has associated therewith a solenoid **132** including a plunger **134** having a downwardly facing end engaging the upper end of the associated post **124.** When the solenoid **132** is operated the plunger **134** is moved downwardly from the FIG. **18** position to accordingly push downwardly the post **124** and move downwardly the base frame **84.**

In addition to the base frame being movable vertically relative to the main frame by operation of the solenoids **132, 132,** it may also be rotated a small amount relative to the main frame about a vertical axis for the purpose of bringing the associated master photomask into accurate orientation relative to the X and Y axes of the work surface. That is, each master photomask consists of an image carried by a transparent plate and which image is fixed on the plate with respect to a set of reference X and Y axes also fixed relative to the plate. For proper operation of the contact printer the X and Y reference axes of the photomask plate should be exactly parallel with the X and Y axes of the work surface. Due to various small errors introduced during the making of a master photomask, when the master photomask is initially placed in the contact printer its reference axes may not precisely parallel the X and Y axes of the work surface. When the image of the master photomask is not properly angularly oriented relative to the axes of the work surface, it is said to be out of skew, and it is desirable to be able to adjust the base frame relative to the main frame to correct for this out-of-skew situation.

Referring to FIGS. **14** and **15,** the illustrated left-hand leg **120** is rigidly connected to the remainder of the main frame **82.** The right-hand leg **120,** however, is free to move a limited distance fore and aft relative to the remainder of the base frame. That is, as viewed in FIGS. **14** and **15,** the main frame **82** at each of its ends includes a vertical plate **136.** The left-hand leg **120** is permanently fixed to its plate **136.** The right-hand leg **120,** however, is slidable fore and aft relative to its plate **136.** Normally, the latter leg **120** is locked to its plate **136** by a knob **138.** The knob **138** has a stem **140** fixed thereto which passes loosely through a horizontally elongated slot **142** in the plate **136** into threaded engagement with the body of the leg **120.** When the knob **138** is tightened, the leg is clamped against the wall **136** and when the knob **138** is loosened the leg **120** is free to slide relative to the plate **136.** When the knob is loosened and the right-hand leg **120** is moved forwardly or rearwardly relative to the remainder of the main frame, the base frame **84** is rotated relative to the main frame about a vertical axis coinciding with the central axis of the post **124** of the left-hand leg **120.** That is, the left-hand post **124** rotates in its leg **120** and serves as a pivot member.

Means for adjustably positioning the right-hand leg **120** in the fore and aft direction to rotate the base frame relative to the main frame is shown best in FIGS. **19** and **20** and consists of a micrometer unit **144** having a barrel **146** fixed to the leg **120** and a spindle **148** extending through the leg **120** and engaging a stop **150** fixed to the remainder of the main frame. A tension spring **152** resiliently holds the free end of the spindle **148** in engagement with the stop **150.** Therefore, it will be appreciated that when the knob **140** is loosened operation of the micrometer unit **144** to advance or retract its spindle **148** will cause the right-hand leg **120** to be shifted rearwardly or forwardly relative to the remainder of the main frame and to thereby rotate the base frame about the axis of the post of the opposite leg **120.**

When the base frame is shifted sufficiently from its raised position toward its lowered position as to bring the base frame into contact with the sheet of photosensitive material supported by the work surface, it is desirable that no movement of the work carriage **38** be permitted. As part of a means for inhibiting movement of the work carriage when the base frame is in such lowered position, a limit switch **154,** as shown in FIG. **21,** is provided. This limit switch is mounted to the main frame **82** and has an operating arm **156** contacting an associated mounting pad **126** of the base frame **84.** The limit switch **154** has a set of contacts which are open when the operating arm **156** is in the position illustrated in FIG. **21** and which are closed after the base frame **84** is moved a predetermined distance downwardly from the FIG. **21** position.

As mentioned previously, the base frame **84** serves to receive and hold the master photomask **50** and the light unit **86.** The construction of the light unit **86** is best shown in FIGS. **11** and **22** and **23.** The construction of the photomask is shown in FIGS. **12** and **13** and the manner in which the light source **86** and photomask are normally assembled with the base frame is best shown in FIG. **24.** Considering first the photomask **50** of FIGS. **11** and **13,** this photomask consists of a plate **158** of glass having a layer of opaque material **160** on its bottom surface. The opaque material **160** does not entirely cover the bottom surface and instead defines a pattern of opaque and transparent areas which create the master image as discussed above in connection with FIG. **4.** The plate **158** is of a rectangular shape closely conforming to the rectangular shape of the opening **94** in the base frame so that when the master plate is placed in the base frame its edges are separated from the edges of the opening **94** by relatively small spaces. Fixed to each side of the plate **156,** as by cement, is an L-shaped guide member **162** having an opening **164** which slidably receives the associated guide pin **98** of the base frame. The two guide members **162, 162** and the two cooperating guide pins **98, 98,** therefore, accurately locate the plate **158** relative to the base frame while allowing the plate **150** to move a slight distance vertically relative to the base frame.

Around the four edges of the plate **158** is a sealing and supporting gasket in the form of a strip **166** of flexible resilient material. Along each edge of the plate **158** the strip **166** partly overlies and is cemented to the plate. The remainder of the strip extends outwardly beyond the plate and, when the plate **158** is in position on the base frame, the outwardly extending portion of the strip **166** engages the adjacent shoulder **96** of the base frame to vertically support the plate from the base frame. Additionally, the seal strip **166** of the plate **158** provides a pneumatic seal between the plate and the base frame and also because of its resilient or flexible nature allows the plate **158** to move a small distance vertically relative to the base frame.

Referring to FIGS. **11, 22** and **23,** the light unit **86** is of a rectangular shape and of a size similar to that of the

master photomask **50.** The unit is made up of a lower housing **168** and an upper housing **170** both made of sheet metal or other sheet material. The lower housing **168** is of an inverted cup shape and includes a flat rectangular upper wall **172** and, extending downwardly from the edges of the upper wall **172,** two side walls **174, 174** and two end walls **176, 176.** Contained within the bottom housing **168** is an electro-luminescent panel **178** which serves as the light source for illuminating the master photomask **50,** the panel **178** comprising the light source **52** illustrated in FIG. **4.** Below the electro-luminescent panel **178** are a number of marginal strips **180, 180** located adjacent the side walls **174, 174** and end walls **176, 176.** The strips **180, 180** are fixed to the housing **168** and serve to retain the electro-luminescent panel in place in the housing. When the light unit **86** is in place on the base frame of the contact printer, the strips **180, 180** rest on the seal strip **166** of the associated photomask and thereby support the electro-luminescent panel **178** a slight distance above the top surface of the photomask. As shown best in FIG. **22,** each side wall **174** of the bottom housing is notched midway along its length, as indicated at **182,** to accommodate the associated guide member **162** of the underlying photomask **50.**

The upper housing **170** of the light unit, as best illustrated in FIG. **22,** is also of a generally inverted cup shape and is fixed to the lower housing **168** by a number of fasteners **184, 184.** Within the top housing **170** is a circuit board **186** which provides the electrical control or logic circuitry associated with the light unit. As part of this control circuitry the light unit **86** includes a manually adjustable knob **188** by means of which the exposure time of the unit may be adjusted.

Having now described in some detail the construction of the contact printer **42** of FIG. **1,** its operation may be considered. For this purpose reference is made to FIGS. **25, 26** and **27** which show the basic parts of the contact printer in somewhat schematic form and show the relative positions of these parts during different phases of one operating cycle of the printer. FIG. **25** shows the contact printer in its non-printing condition wherein the base frame is in its fully raised position relative to the main frame. With the base frame in this position, the contact printer may be moved by the work carriage **38** to any desired position relative to the sheet of photosensitive material **34.** After the contact printer is brought into registry with a given area of the photosensitive surface which is to be exposed thereby, the work carriage **38** is held stationary and the solenoids **132, 132** are energized to move the base frame **84** downwardly relative to the main frame **82.** As the base frame moves downwardly the sealing gasket **102** on the lower face of the base frame eventually contacts the surface of the underlying photosensitive material and creates a pneumatic seal between the photosensitive material and the base frame. The position of the base frame at this point in the operation of the device is shown in FIG. **26.**

At the same time as the solenoids **132, 132** are energized the valve associated with the vacuum supply is operated to supply a vacuum to the vacuum tube **106** communicating with the bottom surface of the base plate. Therefore, after the gasket **102** contacts the photosensitive material the space between the photosensitive material and the master photomask is evacuated to create a pressure differential across the photomask and part of the base frame causing the photomask to be urged downwardly into direct contact with the surface of the photosensitive material and also drawing the base plate further downwardly toward the photosensitive material. This is the final or printing position of the photomask and is shown in FIG. **27.** From this figure, it should be noted that the photomask in the printing position is displaced slightly downwardly relative to the base frame from its normal position. That is, as the space below the photomask is evacuated the seal gasket **166** resiliently flexes to allow the photomask to move downwardly relative to the base frame into direct firm engagement with the surface of the photosensitive material. Thus, when the photomask is in direct printing contact with the photosensitive material, it is held in such condition solely by the atmospheric pressure exerted thereon and no substantial forces are exerted between the photomask and the remaining structure of the contact printer or work carriage which would tend to distort the photomask and cause inaccuracies in the exposure. With the photomask in the printing position shown in FIG. **27** the electro-luminescent panel of the light unit is energized for a predetermined time to illuminate the photomask and expose its image on the photosensitive material. After this exposure is complete, the vacuum is released and the base plate allowed to return to its normal raised position to enable the contact printer to be moved to a new area of the photosensitive material. Thereupon the above-described exposure process may be repeated.

FIG. **28** shows schematically the basic parts of a logic circuit used to control the operation of the previously described contact printer **42.** Referring to this figure, when the contact printer is to be operated to create an exposure, a start cycle signal is supplied on a line **190** to a flip-flop **192.** This sets the flip-flop **190** and supplies an output signal to another flip-flop **194** and to an AND gate **196.** The flip-flop **194** is thereupon set and provides an output signal which energizes the two solenoids **132, 132** to move the base frame **84** downwardly toward the printing position. It also operates a solenoid operated valve **196** in a line from a vacuum source **198** to the vacuum tube **106** to cause the vacuum source to be connected to the tube **106.** As the frame **84** reaches its lowered position the limit switch **154** is closed to supply an additional enabling signal to the AND gate **196** and also to provide an inhibit carriage movement signal which is supplied to the controller **46** of FIG. **1,** or other control instrumentality, to condition such controller or other control instrumentality to prevent movement of both the main carriage **36** and work carriage **38.** A short time after the base frame reaches its lowered position the vacuum source **198** will have evacuated the space between the photomask and the photosensitive surface to a given predetermined low pressure level at which the photomask will be firmly pressed against the photosensitive surface. At this predetermined low pressure level the vacuum switch **118** operates to set an associated flip-flop **200** to produce another enabling signal for the AND gate **196.** At this time with all input terminals of the AND gate **196** enabled, an output is produced from the latter gate causing the triggering of an adjustable one-shot, multivibrator **202,** the time duration of which is controlled by the control knob **188** of the light unit. A pulse of the desired time duration is accordingly sent to the light unit **86** to energize the electro-luminescent

panel for such time duration. Thereafter, clear signals are sent to the various flip-flops to return the device to its initial condition.

The electro-luminescent panel **178** of the light unit **86** is one having a single light emitting area coextensive with its entire face. That is, when the panel is energized, light is emitted from the entire downwardly facing surface thereof to illuminate the entire area of the underlying master photomask **50.** If desired, however, in an alternate embodiment of the contact printer of this invention the electro-luminescent panel of the light unit may be divided into a plurality of discrete separately energizable light emitting areas each overlying and registering with a respective one of a corresponding plurality of discrete areas of an associated photomask. Therefore, by energizing selected ones of the areas of the electro-luminescent panel, corresponding selected ones of the discrete areas of the photomask may be illuminated. Such arrangement makes possible the use of the contact printer, in a photo composition mode, to compose an artwork by exposing different portions of the artwork during a number of operations of the contact printer.

FIG. **29** shows a light unit **204** having a segmented electro-luminescent panel **206** adapting the contact printer previously described for use in photo composition work. The light unit **204** is essentially similar to the light unit **86** except for the replacement of the non-segmented electro-luminescent panel **178** of the unit **86** by the segmented panel **206.** Parts of the unit **204** which are identical to parts of the unit **86** have been given the same reference numerals as in the preceding figures and need not be redescribed. The panel **206** is divided into 24 separate segments or discrete areas **208, 208** as indicated by the broken dividing lines **210,** 210. Each segment **208** of the panel has its own pair of input leads, not shown, and by energizing the input leads of any one segment **208** such segment may be energized separately from the other segments. Of course, a number of segments may be simultaneously energized to simultaneously illuminate a corresponding number of discrete areas of the photomask.

FIG. **30** shows a representative master photomask divided into a number of discrete areas corresponding to the segments of the electro-luminescent panel **206** and intended for use therewith. Referring to FIG. **30,** the illustrated photomask is indicated at **212** and is divided into 24 separate discrete areas **214, 214** each of which underlies and registers with a respective one of the segments **208, 208** of the electro-luminescent panel when the light unit **204** and photomask **212** are in operative position on the base frame of the contact printer. Each discrete area **214** of the photomask is intended to be illuminated either by itself or in combination with several other areas of the photomask. For example, the nine areas marked **214***a*, 214*a* are intended to be illuminated separately and each contains a small image located entirely within its area. On the other hand, the three areas marked **214***b*, 214*b* are intended to be energized simultaneously and together define an image spread over parts of all three of the areas **214***b*, 214*b*. Likewise, the four areas marked **214***c*, 214*c* are intended to be illuminated simultaneously and together define a single image spread thereover. Similarly, the two areas **214***d*, 214*d* are intended to be illuminated simultaneously, and the six areas **214***e*, 214*e* are intended to be illuminated simultaneously.

The light unit of FIG. **29** and the photomask of the type shown in FIG. **30** may be used in the contact printer **42** of FIG. **1** in a photo composition mode to either create complete artworks entirely through the use of the contact printer or to complete only skeletonal artworks later completed through use of the second photoexposure device **44.**

FIG. **31** shows a modification of the control circuit of FIG. **28** used to adapt the FIG. **28** circuit to use with a segmented electro-luminescent panel and photomask such as shown by FIGS. **29** and **30.** Referring to FIG. **31,** the adjustable one-shot, multi-vibrator there illustrated is the same multi-vibrator **202** as shown in FIG. **28,** and the circuit used to trigger the multi-vibrator **202** is the same as that of FIG. **28** and is not repeated in FIG. **31.** However, instead of the output of the multi-vibrator **202** going directly to the electro-luminescent panel, as in FIG. **28,** the output, in the circuit of FIG. **31,** is connectible to the various segments or discrete areas **208, 208** of the panel **206** through a plurality of solenoid operated switches **216, 216** and a patch board **218.** The patch board **218** is or may be located in the upper housing of the light unit and includes an output terminal for energizing each lamp segment **208** and an input terminal from each switch **216.** By means of jumpers, such as indicated at **220, 220,** any switch **216** may be electrically connected to any one or more of the segments **208, 208** so as to energize such segments when the switch is closed, and such interconnections may be readily changed at will.

Each switch **216** is operated by an associated flip-flop **222** having an input line **224** from the controller **46.** Each time the contact printer is operated the controller supplies signals to one or more of the input lines **224,** 224 to set the associated flip-flop or flip-flops **222, 222** and to thereby close the associated switch or switches **216, 216.** Subsequently, when the adjustable one-shot, multi-vibrator **202** is triggered the output pulse therefrom is transmitted to each segment **208** associated with a closed switch **216** through a jumper **220** in the patch board **218** to illuminate such segment. Accordingly, it will be appreciated that by proper programming of the patch board **218** and of the signals supplied to the input lines **224, 224** from the computer, during each operation of the contact printer any selected one or more of the sections **208, 208** may be energized to thereby illuminate corresponding areas of the associated photomask.

I claim:

1. A mechanism for exposing an artwork on a photosensitive surface, said mechanism comprising means providing a work surface for supporting a sheet of material with a photosensitive surface, a contact printing device, a line drawing device, and means including automatic controller for moving both said contact printing device and said line drawing device in a plane parallel to said work surface to being said contact printing device into registry with selected areas of said photosensitive surface and to move said line drawing device along desired lines on said photosensitive surface, said contact printing device including means operable when said contact printing device is held stationary relative to said photosensitive surface for exposing a predetermined portion of an artwork on the area of said photosensitive surface registered therewith, said contact printing device further including a light source and a photomask arranged parallel to said work surface and

located between said work surface and said light source, said photomask being generally planar and being divided into a number of discrete areas, and said light source including means for illuminating selected ones of said discrete areas of said photomask, and said line drawing device including means for directing a spot of light onto said photosensitive surface as said line drawing device is moved relative to said photosensitive surface to cause the exposure of a line on said photosensitive surface.

2. A mechanism for exposing an artwork on a photosensitive surface, said mechanism comprising means providing a work surface for supporting a sheet of material with a photosensitive surface, a contact printing device, a line drawing device, and means for moving both said contact printing device and said line drawing device in a plane parallel to said work surface to bring said contact printing device into registry with selected areas of said photosensitive surface and to move said line drawing device along desired lines on said photosensitive surface, said contact printing device including means operable when said contact printing device is held stationary relative to said photosensitive surface for exposing a predetermined portion of an artwork on the area of said photosensitive surface registered therewith, and said line drawing device including means for directing a spot of light onto said photosensitive surface as said line drawing device is moved relative to said photosensitive surface to cause the exposure of a line on said photosensitive surface, said contact printing device including a photomask arranged parallel to said work surface and a light source in the form of an electro-luminescent panel, said photomask being located between said work surface and said electro-luminescent panel so that when said electro-luminescent panel is energized said photomask is illuminated thereby to expose an image of said photomask on the photosensitive surface of the sheet of material supported by said work surface, said photomask being generally planar and being divided into a number of discrete areas, said electro-luminescent panel being arranged in a plane parallel to said photomask and also being divided into a number of discrete areas each registering with a respective one of said discrete areas of said photomask, and means for selectively energizing said discrete areas of said electro-luminescent panel to selectively illuminate corresponding ones of said discrete areas of said photomask.

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