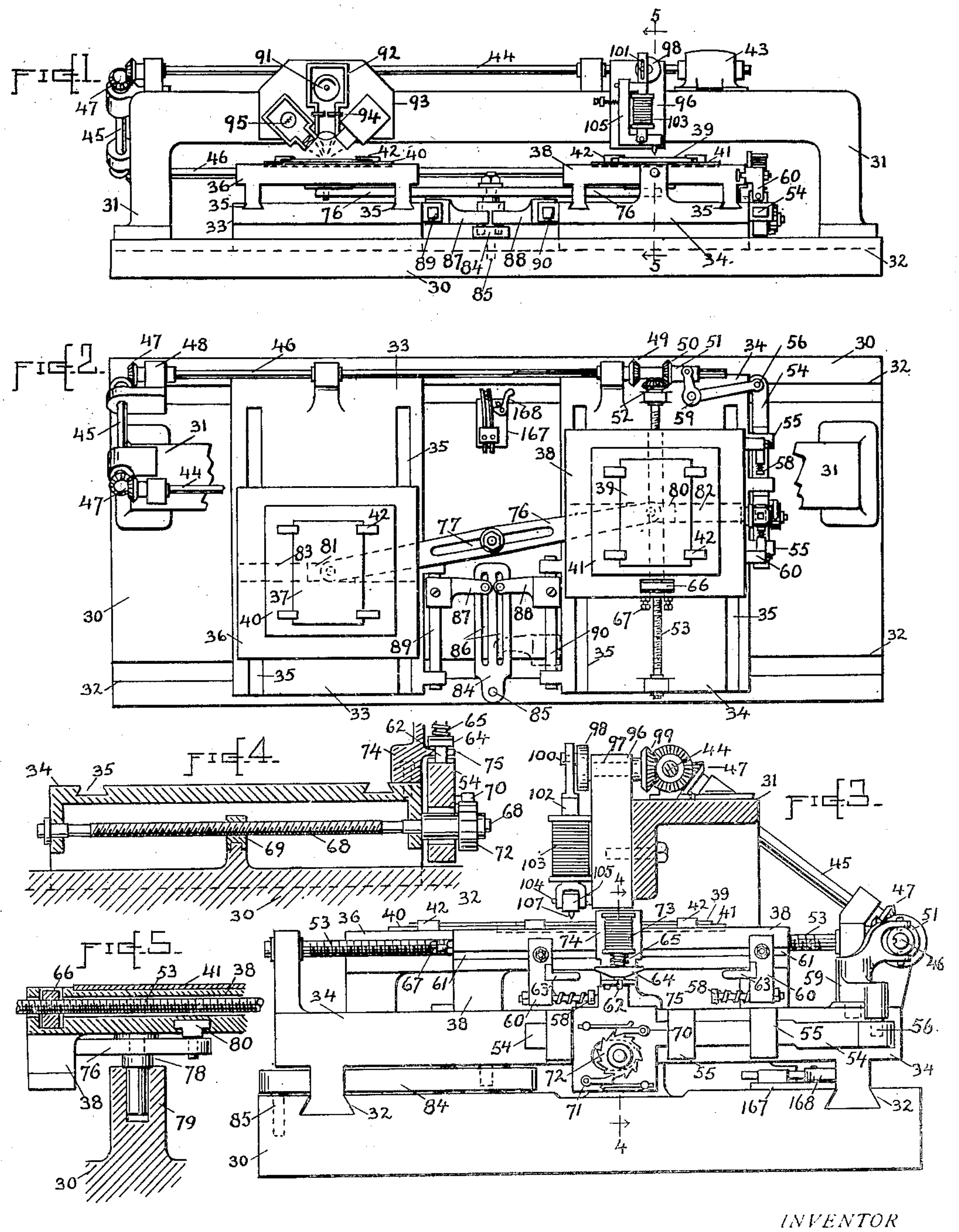
July 13, 1937. O. W. GREENBERG 2,086,798

PHOTOELECTRICAL DEVICE FOR PRODUCING HALF TONE CUTS

Filed June 22, 1932 4 Sheets-Sheet 1



INVENTOR

Otto W. Greenberg

July 13, 1937. O. W. GREENBERG 2,086,798

PHOTOELECTRICAL DEVICE FOR PRODUCING HALF TONE CUTS

Filed June 22, 1932 4 Sheets-Sheet 2

FIG. 12.

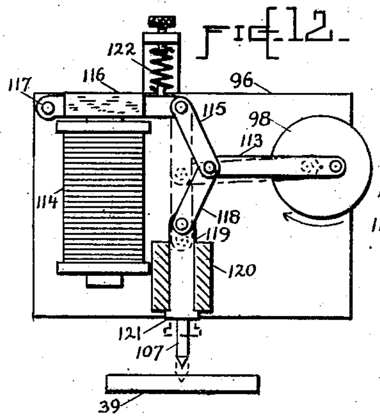


FIG. 14.

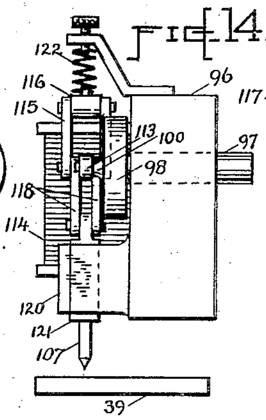


FIG. 13.

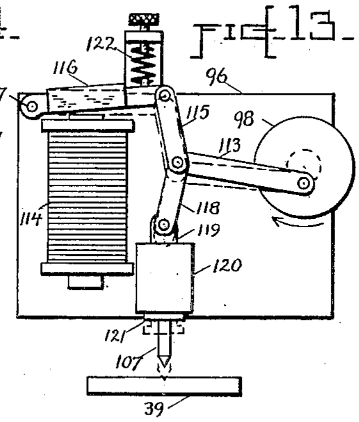


FIG. 15.

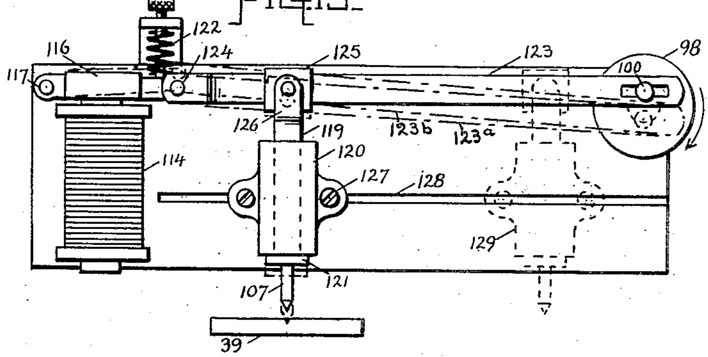


FIG. 16.

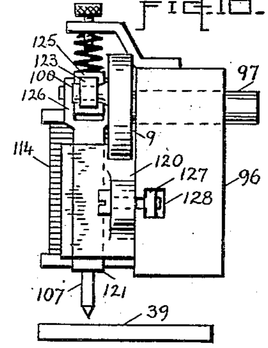


FIG. 6.

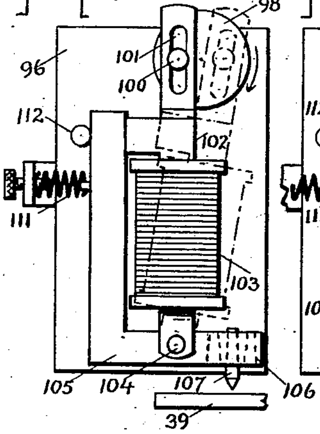


FIG. 7.

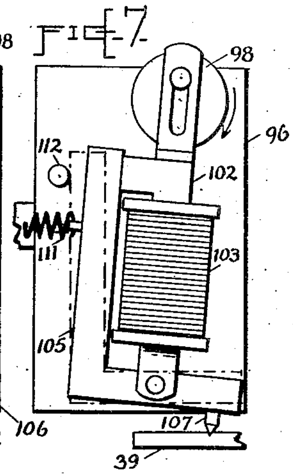


FIG. 8.

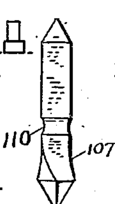


FIG. 10.

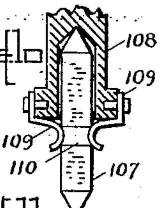


FIG. 9.

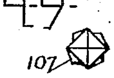
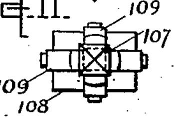


FIG. 11.



INVENTOR

Otto W Greenberg

July 13, 1937. O. W. GREENBERG 2,086,798

PHOTOELECTRICAL DEVICE FOR PRODUCING HALF TONE CUTS

Filed June 22, 1932 4 Sheets-Sheet 3

FIG. 17.

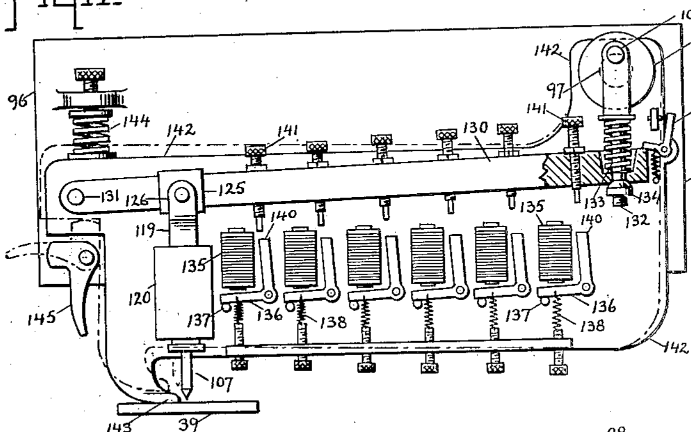


FIG. 21.

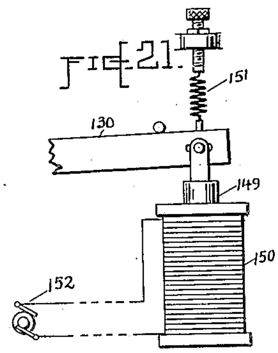


FIG. 18.

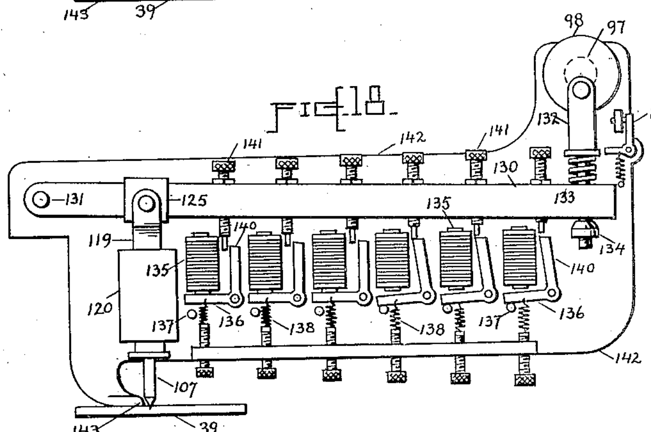


FIG. 26.

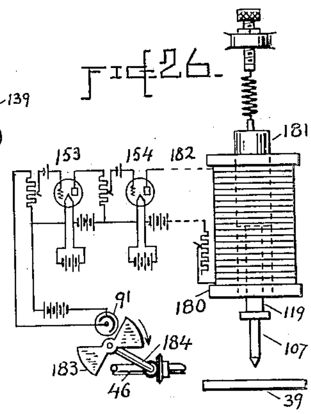


FIG. 19.

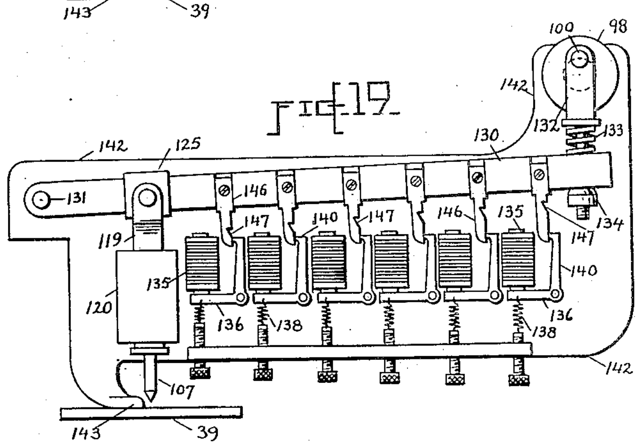
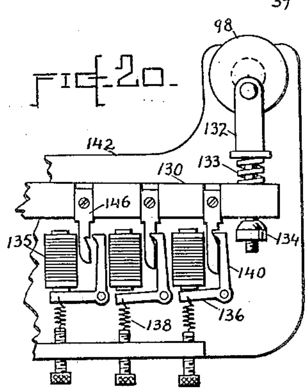


FIG. 20.



INVENTOR

Otto W Greenberg

July 13, 1937. O. W. GREENBERG 2,086,798

PHOTOELECTRICAL DEVICE FOR PRODUCING HALF TONE CUTS

Filed June 22, 1932 4 Sheets-Sheet 4

FIG. 23.

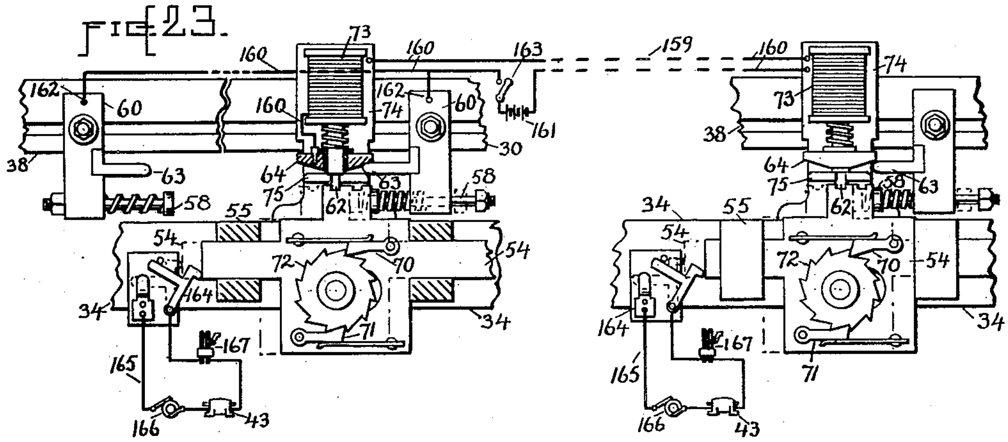


FIG. 22.

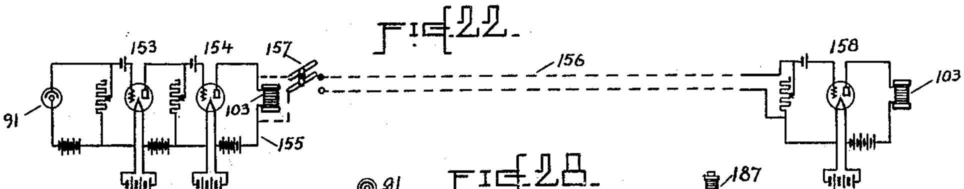


FIG. 28.

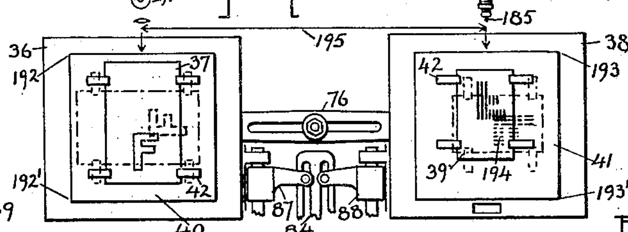


FIG. 27.

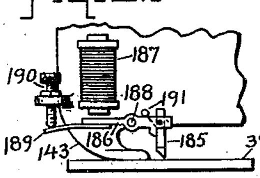
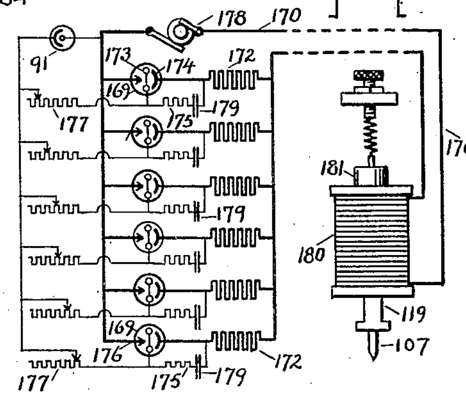


FIG. 25.



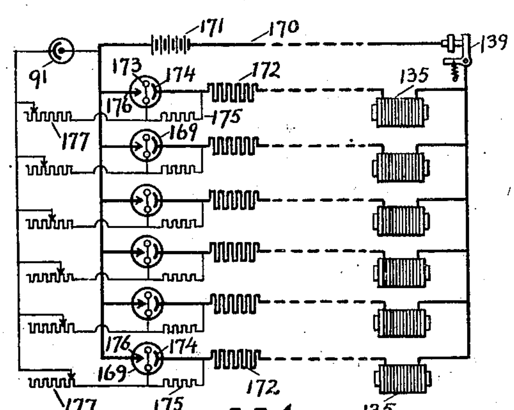


FIG. 24.

INVENTOR

Otto W Greenberg

UNITED STATES PATENT OFFICE

2,086,798

PHOTOELECTRICAL DEVICE FOR PRODUCING HALF-TONE CUTS

Otto William Greenberg, Ocean City, N. J.

Application June 22, 1932, Serial No. 618,796

11 Claims. (Cl. 178—6.6)

This invention has reference to machines wherein a photo-electric cell is employed in the production of half-tone cuts used for printing illustrations. The photo-electric cell scans the illustration to be reproduced and a tool controlled by the current passed by the cell forms the half-tone on the surface of a blank.

Hitherto the appearance of shading in half-tones so produced was brought about by parallel lines of varying widths cut into the surface of a blank.

The object of my invention relates to the means to produce the appearance of shades by dots or minute areas of variable size formed in the surface of the blank. A further object of this invention relates to the means to obtain more certain and positive reactions to the illumination on the photo-electric cell, and other desirable effects.

The eye has a natural tendency to follow lines and can observe and differentiate one from another more readily than it can distinguish one dot from another, so that the appearance of uniformity in a shaded area produced by dots is much greater than in that produced by parallel lines. This is particularly true where the lines are farther apart as they must of necessity be in half-tones printed on coarse paper, such as used for newspapers.

The photo-engravings produced by the photographic and chemical processes are made up of dots to produce the effect of shading, and are therefore universally preferred although as is well known the process of producing them is long-drawn out, complex and relatively costly, requiring the careful and constant manipulation and attention of expert and skilled artizans.

Attempts have been made to produce half-tones consisting of dots employing the photo-electric cell method by cutting conical depressions in the surface of a blank by means of a tapered revolving drill but owing to the inherent characteristics of a drill tapered to an extremely fine point essential for this work, it has been found impractical and has been abandoned. The fine point of the drill has no cutting edge and cannot cut the very minute depressions required, besides it is too delicate to resist breakage. The blank, traversing the drill at right angles, applies a lateral pressure on the point.

The objects of this invention are accomplished primarily by providing the machine with a reciprocating tapered compression tool in the place of a rotating cutting tool, and by impressing sufficient force upon the said tool to compress the material of the blank to form minute indented areas which appear as dots when a printed impression is made therefrom. The production of half-tones consisting of dots, the main object of my invention, may also be accomplished in another way, in two operations. One by reproducing the image on the blank with a series of parallel lines cut into the surface of the blank, and the second by again reproducing the image by a series of parallel lines cut across the first set and in angular relation thereto, thereby forming minute areas polygonal in form.

The compression tool employed to produce the half-tones is tapered and the size of the dot produced at the surface of the blank is proportional to the depth of the indentation. The depth of the indentations is controlled by novel electro-magnetic devices. These devices operate by virtue of the magnetic hold on an armature in contact or substantially in contact with the core of an electro-magnet, as distinguished from operation at a distance through a gap.

This results in stability and exactitude of response and requires a minimum current for maximum effects.

There are several other novel features that take part in accomplishing the objects of this invention, which will be hereinafter described.

Referring to the drawings, Fig. 1 is a front elevation of an exemplification of the machine.

Fig. 2 is a plan view of Fig. 1 with the cross-head of the machine partly broken away.

Fig. 3 is a side elevation on a larger scale with the crosshead partly broken away.

Fig. 4 is a cross section on the line **4—4** of Fig. 3 of parts of the machine.

Fig. 5 is an enlarged section on the line **5—5** of Fig. 1, of parts of the machine.

Figs. 6 and 7 are front elevations and details of one of the electro-magnetic control devices shown mounted on the machine in Figs. 1 and 3.

Fig. 8 is a modified form of a compression tool.

Fig. 9 is a bottom view of Fig. 8.

Fig. 10 is a compression tool and holder for same in section.

Fig. 11 is a bottom view of Fig. 10.

Figs. 12 and 13 are front elevations of an alternative form of the electro-magnetic device to control the depth of the indentations.

Fig. 14 is a side elevation of Figs. 12 and 13.

Fig. 15 is still another and preferred form of the electro-magnetic device to control the depth of the indentations.

Fig. 16 is a side elevation of Fig. 15.

Fig. 17 is a front elevation of a modified form of control mounted on a presser foot and provided with a plurality of electro-magnets each of which controls the descent of the tool to a different depth.

Fig. 18 is the same as Fig. 17 with the parts in a different operative position.

Fig. 19 is a modification of the control device shown in Figs. 17 and 18.

Fig. 20 shows a portion of Fig. 19 with the parts in a different operative position.

Fig. 21 illustrates diagrammatically one of the ways in which a solenoid may replace the mechanical means for operating the up-and-down movement of the tool and the source of current supply.

Fig. 22 illustrates diagrammatically a photo-electric cell with amplifiers applicable to the various devices for controlling the tool.

Fig. 23 shows similar parts of two of the machines located at distant points electrically connected and provided with means for synchronization, whereby an illustration mounted on one machine can reproduce a half-tone on a blank on the other machine as well as on a blank mounted on the same machine.

Figs. 24 and 25 are schematic diagrams showing novel circuits employing a plurality of grid-glow tubes, the output current of which varies in value and is a function of the current passed by a photo-electric cell.

Fig. 26 is a schematic diagram of a photo-electric cell, amplifying circuit and means whereby the output current is utilized to reciprocate a compression tool as well as to control the depth of the indentations thereof, applicable for the reproduction of certain kinds of half-tones.

Figs. 27 and 28 illustrate a novel method for producing half-tone engravings made up of dots by means of lines cut in the surface of the blank across each other in two separate operations.

The mechanical parts of the machine and its operation will be described first.

Referring to Figs. 1 to 5, the machine consists of a base **30**, on which is mounted a cross frame **31**, extending from one side of the base **30** to the other and supported on upright portions at each end. Dovetail grooves **32** cut in its upper surface extend from one side of the base **30** to the other.

Two sub-carriages **33** and **34**, one on each side of the machine, are slidably mounted in the grooves **32** enabling them to be moved from right to left and vice versa. The upper surface of each sub-carriage **33** and **34** is provided with dovetail grooves **35** cut transversely to the dovetail grooves **32** in the base **30**.

A carriage **36** for the illustration **37** that is to be reproduced is slidably mounted on the sub-carriage **33** in the grooves **35**. A similar carriage **38** for a blank **39** to be made into a half-tone is slidably mounted on the sub-carriage **34** in the grooves **35**.

It is thus evident that the carriage **36** with the illustration **37** thereon and the carriage **38** carrying the blank **39** are movable forward and backward as well as in a direction perpendicular thereto from right to left.

The illustration **37** and the blank **39** are secured to plates or intermediate-holders **40** and **41**, respectively, by suitable clamps **42**. The intermediate-holders serve to hold the illustration and the blank in place on their respective carriages. They are exact squares in outline and fit depressions in the surface of each carriage, providing convenient means for removing the work for examination and for returning same to the exact location on the carriage from which they were removed. These intermediate-holders will be again referred to in this specification.

A motor **43** mounted on the cross frame **31** drives the power shaft **44**, supported in bearings on the frame.

A connecting shaft **45** mounted diagonally transmits power from the shaft **44** to a lower shaft **46** through operative connection by means of bevels **47** at its upper and lower ends.

The lower shaft **46** is mounted in a bearing **48** on the base **30** of the machine, on a bearing on the sub-carriage **33** and one on the sub-carriage **34**; the two latter bearings are free to slide axially on the shaft **44** with their respective carriages.

Two bevels **49** and **50** facing each other and secured to an elongated sleeve **51** which is slidably keyed in a slot on the shaft **46**, alternate under control in meshing with a bevel **52** on a threaded rod **53** to reverse its rotation as one or the other is engaged.

The threaded rod **53** operates to move the carriage **38** back and forth in the grooves **35** on the sub-carriage **34** as it is rotated in one direction or the other.

The reversing bevels **49** and **50** are alternately brought into mesh with the bevel **52** by a crank lever **59** which engages a sleeve **51** by means of pins carried in a yoke and held in an annular groove in the sleeve. The crank lever **59** is pivotally mounted on the sub-carriage **34** and is operated by a bar **54** slidably mounted in bearings **55** on the sub-carriage to which it is pivotally connected at the end of its long arm at **56**.

The slide bar **54**, Figs. 3 and 23, is shifted to one or the other of its positions at the end of each stroke of the carriage **38** by bumpers **58** provided with springs which alternately apply pressure on opposite sides of an upwardly extending portion of the slide bar **54**.

The bumpers **58** are carried on the lower end of brackets **60** adjustably secured by T-bolts in a T-slot **61** formed in the side of the carriage **38**.

A pin **62** engages alternately two notches formed in the upwardly extending portion of the slide bar **54** at points which correspond to the two positions of said slide bar and holds it against the pressure applied by one or the other of the bumpers **58** as they are advanced by the travel of the carriage **38**.

An arm **63** extending from each bracket **60** co-operates with each bumper **58** and serves to withdraw the pin **62** out of engagement with the slide bar **54**. The end of the arm **63**, advancing a suitable distance behind the bumper, engages the cam on the under surface of a cross piece **64** attached to the pin **62** and operates to raise it against the action of a spring **65** after sufficient pressure has been applied by the bumpers against the slide bar **54**, so that when the pin **62** disengages the slide bar **54** it is suddenly shifted to its other position. The travel of the carriage **38** is reversed and the operation repeated in the opposite direction when it reaches the end of the return stroke.

The pin **62** is formed on the lower end of a bar which serves as a plunger for a solenoid **73**, which when energized by an electric current, will also withdraw the pin **62** from engagement with the slide bar **54**.

The solenoid **73** is employed only when the machine is used for reproducing a half-tone on a machine located at a distance at a receiving station.

A bracket **74**, Fig. 4, secured to the sub-carriage 34, serves to support the solenoid 73 and provides a guide 75 for the pin 62.

The threaded rod 53 is rotatably mounted at each end in supports on the carriage 34, and is threaded in an enlarged rectangular screw nut 66, held against rotation in a pocket provided for it in the carriage 38, Fig. 5. The screw nut 66 has axial play in the pocket, the amount of which can be regulated by lock bolts 67. This, as will be readily understood, gives the carriage 38 a limited lost motion at the beginning of each stroke, the object of which will be hereinafter explained.

The slide bar 54 is provided with a slot in its enlarged portion through which the end of a feed screw 68, Fig. 4, protrudes. The feed screw is rotatably mounted in the sub-carriage 34 and threaded in a post 69 on the base 30 of the machine.

An upper pawl 70 and a lower pawl 71 on the enlarged portion of the slide bar 54 engage a ratchet wheel 72 secured to the end of the feed screw 68. When the slide bar 54 is thrown to the right, Fig. 3 and Fig. 23, the lower pawl 71 actuates the ratchet 72 and turns the feed screw 68 a step counter-clockwise, and when the slide bar 54 is thrown to the left, the upper pawl 70 actuates the ratchet and turns the feed screw 68 a step in the same counter-clockwise direction.

The reciprocation and the transverse feeding of the carriage 38 is communicated to the carriage 36 on which the illustration is mounted by means of levers in such a way that reverse cuts to print facsimiles will be produced by the machine. These levers are provided with means whereby enlargements or reductions may be reproduced by varying the relative lengths of their arms.

A communicating lever 76 provided with a downwardly extending stud, Fig. 5, which can be secured in any part of a slot 77 in the lever by a nut pressing against a shoulder on the stud 78, is pivotally mounted on a boss 79 projecting upward from the base 30 which provides bearing for it. A block 80 and a similar block 81 pivotally secured to each end of the lever 76 are slidably mounted in transverse T-grooves 82 and 83 in the under surfaces of the carriages 38 and 36 so that movement of the former will be communicated to the latter but in the opposite direction.

Transverse feeding of the carriage 36 in the same direction as that of carriage 38 is accomplished by a lever 84 pivotally mounted at one end on a stud in the base, indicated at 85. This lever 84 is provided with two slots 86 that engage pins on the end of arms 87 and 88, the former adjustably secured and projecting from a bracket 89 on the sub-carriage 33, and the latter adjustably secured and projecting from a bracket 90 on the sub-carriage 34.

In the drawings the arms of levers 76 and 84 are shown adjusted to produce a half-tone of the same size as the illustration.

For reductions, the lever 76 is secured to the stud 78 in the slot 77 at a point to the right of its center, and for enlargements, at a point to the left, the relative lengths of the arms of the lever 76 determining the distance that the carriage 33 will travel in relation to that of the carriage 38.

The distance that the carriage 36 will travel transversely in feeding in relation to that of the carriage 38 is determined by the relative positions of the arms 87 and 88 to each other, in the slots in the lever 84. When the arm 88 is secured in the position indicated by broken lines, the carriage 36 will travel a greater distance than the carriage 38, corresponding to a position of the stud 78 in the slot of the lever 76 to the right for reductions. For enlarging the reproduction, the arm 87 is secured on its bracket 89 at a point to engage the lever 84 closer to its fulcrum or stud 85 than the arm 88 engages it.

Similar markings on each lever, not shown in the drawings, facilitate in adjusting the machine for reductions and enlargements.

A photo-electric cell 91 enclosed in a housing 92, the cover of which is shown removed, is mounted on a head 93, secured to the cross frame 31 at a point above the carriage 36 and in relation to the illustration 37 to be reproduced. The cell 91 is provided with a lens to focus the image reflected from the illustration 37 on to a shutter 94 which limits the light entering the photo-electric cell 91 to the unit area being scanned.

Two light sources 95, each enclosed in a housing, the cover of one of which is shown removed, concentrate light on the surface of the illustration 37 under the lens.

Above the carriage 38, and in relation to the blank 39, a head 96 is mounted and suitably secured to the cross frame 31. A short shaft 97 passes through the head 96, on the front end of which it has a disk wheel 98, and on the rear end a bevel 99 which meshes with a bevel on the power supply shaft 44.

A crank-pin 100 on the disk wheel 98 working in a slot 101 on an extension of an inverted L-shaped core 102 of an electro-magnet 103 gives the electro-magnet an oscillating motion with a pin 104 on which it is mounted as a center.

The pin 104 also serves as a mounting and center of oscillation for an L-shaped armature 105 which, when held by the magnetic lines of force to the core 102 of the electro-magnet 103 oscillates therewith.

The lower arm of the L-shaped armature 105 is provided with one or more holders 106 for a tapered tool 107, the leverage desired, determining the holder employed.

The tapered end of the tool 107 is positioned in close proximity to the surface of the blank 39 and on its descent with the oscillation of the armature 105, Fig. 7, it comes in contact with and indents, by compression, the material of the surface of the blank 39. Thus an evenly increasing pressure is applied on the blank at the point of contact. The area depressed will not take ink, and in printing will register a light dot.

The number of oscillations bears a fixed relation to the linear distance traveled by the blank 39 in a given time, and the depressions which follow one another in line until the end of the stroke of the carriage will be evenly spaced. When the end of the stroke is reached, the carriage is fed a step laterally and the direction of travel is reversed for the production of a succeeding line of depressions until the illustration has been completely scanned, and the half-tone completed.

To prevent the depressions in one line being formed opposite those in the preceding line, the carriage 38, as hereinbefore mentioned, is given a lost motion equal to half the distance between the depressions, so that the depressions formed in the succeeding line will lie opposite the spaces between those of the preceding line, in staggered relationship to them thereby giving the appearance of diagonally located dots.

The contour of the dots formed by the depressions will be circular if the tool employed is tapered like an inverted cone. However, my method of making depressions, enables me to obtain elementary areas that are square in contour, Figs. 8 to 11.

A taper on the end of the compression tool having a cross sectional area of a hexagon or other polygon may be employed if desired to obtain various effects in the half-tone print. One that is a square in cross section but formed diagonally to its shank, Figs. 8 and 9, will form squares diagonally positioned with respect to each other and will give a diagonal effect to the reproduction as a whole. This effect is very much desired in the art.

To obtain high lights in the print, all or nearly all the surface must be depressed. This can only be obtained with depressions of polygonal contour without the depressions overlapping each other. To obtain the high lights with circular depressions, one circle must overlap the other and in attempts made hitherto to produce half-tones with a rotating cutting tool, the cutting tool would creep where it overlapped a depression already formed, resulting in unsatisfactory reproductions as well as in broken tool points.

Referring to Figs. 10 and 11, a tool holder 108 is shown on an enlarged scale in which the tool 107 has lateral play and is held resiliently in vertical position as by springs 109 secured to the holder 108 and pressing against the tool 107 in shallow depressions 110 formed around its shank. This is to prevent interference with the travel of the blank during the time the tool 107 is in contact with it where no provision has been made to halt the blank itself during the period of time it is operated upon by the tool.

The mechanical power derived from the disk wheel 98 is capable of applying a force on the tool 107 sufficient to form a depression in the blank 39 to the maximum depth with each stroke, but the reaction to the work of compression breaks the hold of the electro-magnet on the armature 105. When this occurs the force derived from the disk wheel 98 is no longer transmitted to the tool and the compression of the blank is discontinued for that stroke, as will be readily understood.

The valve of the reaction to the work of compression increases, of course, from zero to maximum from the instant that the point of the tool makes contact with the blank until the maximum depth is attained. When the tool reaches a depth such that the reaction overcomes the magnetic hold on the armature, the armature is released and a spring 111 returns it to its position, indicated in broken lines, Fig. 7, against a stop 112, the tool 107 is withdrawn from the surface of the blank 39 and the compression is interrupted and ceases for that oscillation, the electro-magnet continuing its travel to its extreme position indicated in broken lines, Fig. 6.

On the next revolution of the disk wheel 98, the core 102 of the electro-magnet is once more brought into contact with the armature 105 to re-establish the hole, and the operation is repeated.

The strength of current flowing through the electro-magnet at any given time is a direct function of the amount of light reflected from the unit area of the illustration under the photo-electric cell. This current determines at what depth of compression the armature is released, which in turn determines the area of the dot that will appear white in the print.

The amount of amplification of current required for the electromagnet will depend on the material of the blanks employed, for the greater the resistance to indenting, the stronger must be the hold on the armature for a given depth of depression. Thus zinc, copper, and the other materials in the plates employed for printing and stereotyping half-tones, offer different degrees of resistance to the indenting tool, all relatively high. To form a depression in these, a force must be applied capable of distorting the plate at its surface, forcing the material thereof from one place to another.

By employing plates made of vulcanized fibre or of other material of a porous consistency, I am enabled, not only to utilize less current for the electromagnet, and less intense illumination on the copy, but also less power to operate the machine with less wear and tear on its parts.

The nature of vulcanized fibre is such, that in making room for the point of the tool, it offers less resistance to compression than to the forcing of its substance from one place to another, and as a result, no burrs or ridges are formed on the surface. Thus, when the plate is surfaced, as with an abrasive, and then subjected to the action of the tool to form the design thereon, it is not necessary to again surface the plate before printing or stereotyping therewith.

In Figs. 12, 13, and 14, there is shown an alternative form of the electro-magnet control device of my invention, in which the hold of an armature is utilized to provide a variable control by a different arrangement of parts. As shown in broken lines, Fig. 12, the force derived from the disk wheel 98 is applied alternately to straighten and to flex a toggle joint, through a connecting link 113. The upper link 115 of the toggle is connected to one end of an armature 116 of a fixed electro-magnet 114, the other end of which is pivoted at 117 to the head 96. The lower link 118 of the toggle is connected to a tool holder 119, slidably held in bearings 120 mounted on the head 96 and provided with a stop 121 which limits its motion upward. The entire force is applied on the tool to compress the material of the blank when the armature 116 is held by the electro-magnet, but the reaction to the work tends to break that hold. When this occurs at a point as shown in broken lines, Fig. 13, a spring 112 pulls up the armature and toggle and withdraws the tool from contact with the blank as shown in Fig. 13 until the next cycle. When the toggle joint is flexed, Fig. 12, the armature is again made to contact the electro-magnet and the cycle is repeated. The pull of the spring 122 is adjusted to a tension just short of breaking the hold on the armature, when no light enters the photo-electric cell, so that the slightest resistance offered to the point of the tool 107 on making contact with the blank 39 will cause its withdrawal. As in the device shown in Figs. 6 and 7, the depth of the depression is directly proportional to the strength of the current flowing in the electro-magnet.

In Figs. 15 and 16, there is shown still another electro-magnetic control device which has a number of features that make it the preferred form. A lever 123, rectangular in cross section, is caused to move up and down by the crank-pin 100 on the disk wheel 98. It is pivoted at 124 to the end of the armature 116 and is provided with a slide piece 125. A yoke 126, formed on the upper end of the tool holder

119, is pivotally connected to the slide piece 125. The tool holder 119 is slidably mounted in the bearing 120, which is adjustably secured by T-bolts 127 engaging a slot 128 in the head 96. The spring 122 is adjusted in the same manner and has the same purpose as that in Fig. 12.

The downward force applied on the lever 123 by the disk wheel 98 operates to compress the blank 39 as indicated by the broken lines 123*a* and the reaction to this work tends to break the hold on the armature 116. When this occurs the spring 122 raises the armature 116 and the fulcrum end of the lever indicated by the broken lines 123*b*, thereby withdrawing the tool 107 from the blank 39 to a position limited by the stop 121. When the disk wheel 98 has raised the lever 123 to the position shown in full lines, the armature 116 is again brought into contact with the electro-magnet 114.

The slide piece 125, tool holder 119, and the mounting 120 for same may be secured at any point along the T-slot 128, as indicated by the position shown in dotted lines 129. At this position, not only will the throw of the tool be increased, but much smaller variations in the current flowing in the electro-magnet will control the work to be performed owing to the change in leverage.

In Figs. 17 and 18, an electro-magnetic control device is shown that differs from those hereinbefore described in that it consists of a number of units. Each unit controlling the compression tool 107 operates to produce a depression of a certain fixed depth for that unit. The units are adjusted to produce depressions ranging from a minimum to a maximum depth. In the drawings provision is made to obtain six different depths under control.

Within certain limits this control device is unaffected by variations in the line voltage when same is used as a source of electric supply for the photo-electric cell, amplifiers, or to illuminate the illustration.

A lever 130 pivoted at 131 is given an up and down motion by the disk wheel 98 through its connection by a link 132 with the crank-pin 100. The link 132 is resiliently connected to the end of the lever 130 between a spring 133 and an adjusting nut 134, so that its down position, Fig. 18, is not fixed by virtue of the compressibility of the said spring 133.

The slide piece 125 transmits pressure to the point of the tool 107 through the yoke 126 on the upper end of the tool holder.

A plurality of electro-magnets 135, each with an armature 136, normally held against a stop pin 137 by an adjustable spring 138, are connected either in series or parallel with the amplified current of the photo-electric cell 91. The circuit of the electro-magnets 135 includes the circuit breaker 139 which breaks the circuit on each up stroke of the lever 130 and which, by the action of its spring, re-establishes the circuit on the descent of the lever.

Each spring 138 is adjusted to a different tension increasing from the first spring on the left to the last one on the right. When the circuit is re-established on each downward stroke of the tool 107 one or more of the armatures 136, in succession from left to right, will be attracted to its related electro-magnet 135, the number so attracted increasing with the strength of the current in the circuit.

Each armature 136 has an upwardly extending arm 140, the upper end of which, when the armature 136 is in its normal position against its stop pin 137, lies in the path of a related stop screw 141 projecting downwardly from the lever 130, and when engaged, stops the further descent of the lever. But when the armature is drawn up the upper end of the arm 140 is moved to one side of the path taken by its related stop screw which can then pass beyond it.

The stop screws 141 are adjusted and set in such manner that on the descent of the lever they may contact the upper end of the arms 140 in succession from left to right, making contact with the first succeeding the one, the armature of which is held by its electro-magnet. As shown in Fig. 18, wherein a current of intermediate strength has overcome the resistance of the first three springs, the stop screw 141 of the fourth unit has made contact and limits the descent of the lever 130 at that point.

In the device just described, the number of armatures drawn up by a given current strength, is determined by the tension of the springs 138; however, the same may be accomplished without departing from the spirit of the invention, by locating the stop pins 137 at different levels, or by introducing resistances or shunts of different values in each electro-magnetic unit, or by varying the number of turns of wire in each coil.

Certain shades in the illustration to be reproduced may be accentuated by adjustments of the stop screws 141 or by varying the tensions of the springs 138.

The device is shown mounted on an enlarged portion 142 of a presser foot 143, which, when in operation, is held against the surface of the blank 139 by an adjustable spring 144 on the head 96, but which can be raised and held in a position above the blank 39 by a cam lever 145 as indicated in broken lines. The presser foot is mounted on the head 96 by bearings formed in its enlarged portion 142 in which the shaft 97 rotates. By thus mounting the electric control device on the presser foot, its freedom to move up and down occasioned by variations in the thickness of the blank or warped condition thereof is not interfered with by reactions that may be due to the operation of the control device.

A modification of the device just described is shown in Figs. 19 and 20.

Downwardly extending stops 146 adjustably secured to the lever 130 take the place of the stop screws 141 in Figs. 17 and 18. These stops 146 move up and down with the lever 130 on one side of and in relation to each arm 140 extending upward from the armature 136 against which they present a cam surface 147 that operates to bring the armature 136 into contact with its electro-magnet 135, on each descent of the lever as in the position shown in Fig. 19.

When the current flowing through the coils of the electro-magnets 135 is not strong enough as against the tension of the spring 138 in a particular unit to maintain the hold on the armature 136 of that unit, the upper end of the arm 140 will engage the stop 146 formed above the cam 147, on the descent and stop the lever 130 at that point as indicated by the middle of the three units shown in Fig. 20.

The adjustments are the same as in the control device shown in Figs. 17 and 18.

In this modification very much less control current is required and its reactions are more positive and dependable than that of Figs. 17 and 18, by virtue of the fact that the hold on the armatures is utilized as a control. Further, the circuit breaker is dispensed with in this modification.

The lever 130 is not necessarily operated up and down by mechanical means though same is preferred. It may be operated electrically, as shown in Fig. 21. Here the lever 130, the end only of which is shown, is connected to a plunger 149 of a solenoid 150, acting against the tension of an adjustable spring 151 and actuated by a source of alternating current as at 152.

The electric circuit that may be employed to transmit variations in a photo-electric cell current to the electro-magnet or magnets of the various control devices hereinbefore described is illustrated diagrammatically in Fig. 22, in which the photo-electric cell 91 and two stages of amplification 153 and 154 are directly coupled to each other. The output circuit 155 of the last stage includes the electro-magnet 103 representative of the electro-magnet or electro-magnets employed in the various modifications.

This circuit may be connected to line wires 156 by a switch 157 to transmit impulses to a distant point where, after amplification, as illustrated at 158, the current may be made to operate the control 103 for the compression tools on one or more machines similar to that of the transmitting end of the line. A means for synchronizing the machines will be hereinafter described. Thus a single illustration mounted on one machine may be reproduced not only on the same machine but also on one or more machines located at the same or at distant points.

Referring to Fig. 23, there are shown parts of the carriage 38 and parts of the reversing mechanism of the machine at the transmitting end and that of the receiving end, the former on the left and the latter on the right, connected by line wires 159 in the circuit 160. This circuit is used for synchronization.

In making half-tones at a distant point, the arms 63 and the cross pieces 64 are not utilized to disengage the pins 62 from the cross bars 54. This function is performed by the solenoids 73 on the transmitting and on the receiving machines, and takes place at the end of each stroke but before the arms 63 have advanced far enough to operate and raise the cross pieces 64.

The circuit 160 is provided with a suitable source of current supply 161 which serves to energize the solenoids at both ends to disengage the pin 62, and thereby reverse the stroke of the carriages 38 simultaneously.

One of the end wires of the circuit 160 is connected in parallel to the brackets 60 on the transmitting machine as at 162.

The end of the arm 63 on either bracket serves as the terminal for the circuit 160. The other end wire of this circuit is connected to the electrically insulated cross piece 64, shown in section, which serves as the other terminal of the circuit. When the circuit 160 is not in use it is disconnected by means of the switch at 163.

Mounted on a sub-carriage 34 of each machine, in relation to the free end of the slide bar 54, is a switch 164 in the circuit of a suitable source of current supply 166, and the synchronous motor 43 which drives the shaft 44, Fig. 1. When the slide bar 54 is thrown to its position to the left, shown in broken lines, the switch 164 is closed and remains so closed.

The method of operation for the production of a half-tone at a distant point is as follows: The picture to be reproduced, having been mounted on the machine at the transmitting end, and the blank on the machine at the receiving end, the carriages 38 of both machines are set in the starting position shown in Fig. 23, wherein pressure is being applied by the bumper 58 against the slide bar 54 to throw same to the left, and the end of the arm 63 of the transmitting machine is in electrical contact with the cross piece 64. The switch 163 in the circuit 160, and a switch 164 in the power circuits at both ends are open. On closing the switch 163 the solenoids 73 at both ends are energized, the pins 62 are withdrawn and the slidebars 54 are released, thereby closing the switches 164 and starting the motors 43 in unison to operate the machines.

The line 156 transmitting the photo-electric impulses is then switched in at 157, Fig. 22.

When the image has been reproduced each machine may be automatically stopped by opening the power circuit 165 as by a circuit breaker 167 on the base 30 of the machine, Fig. 2. The circuit breaker 167 is so positioned in relation to the sub-carriage 34 that when the latter has reached a certain position to the left it will throw a lever 168 to separate the contacts on the circuit breaker 167.

Hitherto the grid glow tube has been limited in its application in electrical devices to its use as a relay. It has the advantage of being very sensitive, instantaneous in response, and in supplying an output current relatively high in value, but fixed in intensity. The output current does not vary with variations in the input except to a very limited degree under special conditions, and the grid glow tube could not be employed to amplify variations in the photo-electric cell to produce half-tone cuts or to produce similar reactions or effects.

However, by a novel arrangement of circuits and combination of a plurality of grid glow tubes, I am enabled to obtain any desired number of graduated values in the output, each a function of the illumination on the photo-electric cell. It is adaptable to the operation of various electrical devices but is herein shown and described in connection with the production of half-tone cuts.

The schematic diagram in Fig. 24 shows six grid glow tubes and circuits as applied to the control device of Fig. 17. The grid glow tubes 169 are connected in parallel with the series part of the circuit 170 which includes a source of direct current supply 171 and a circuit breaker 139 of Figs. 17 and 18.

A current limiting resistor 172 to prevent overloading, and the electro-magnets 135 of the control device, are connected in series with each tube 169 which, when it breaks into a glow and passes current, energizes that electro-magnet with which it is in circuit.

The grid 173 of each tube 169 is connected to its cathode 174 by a grid resistor 175 and to its anode 176 by a variable resistance 177 and the photo-electric cell 91 which is in series with all the anodes 176.

The grid resistor 175 passes a little current and brings the potential of the grid near to that of the cathode, preventing the glow discharge and flow of current when the photo-electric cell is dark and passes no current between the anode and grid. When the resistance of the photo-electric cell 91 is decreased by illumination and the value of the resistance 177 in the path to the grid of any given tube is not too great, the potential of the grid is brought nearer to that of the anode and the tube breaks into a glow and passes current.

The resistance 177 of each unit is so adjusted that one is greater than the other so that, as shown in the drawings, the lowermost unit will operate with the minimum illumination on the cell. As the illumination is increased and the resistance of the photo-electric cell thereby reduced, more and more units will be thrown into a glow.

The circuit breaker 139 serves to interrupt the current supply of the tubes and stop the glow discharge thereof. The quantity of current passed by each tube being substantially the same, the tension of the springs 138, Figs. 17 and 18, is adjusted to offer the same resistance against the pull of the electro-magnets 135.

All the electro-magnets 135 may be connected in series in the main part of the circuit 170 so that the current passed by every tube will flow through all the electro-magnets. When so connected the current flow will increase as more and more tubes break into glow, the tensions of the springs 138 determining the number of armatures drawn up.

The schematic diagram shown in Fig. 25 is similar to that of Fig. 24. Here the circuit 170 is shown energized by an alternating current supplied as by an alternator 178. The circuit breaker 139 of Fig. 24 is not needed in this circuit as the discharge glow of the tubes is stopped in each cycle of the alternating current with the fall of potential. In addition to the grid resistors 175, grid condensers 179, are shown introduced in the coupling between the grid 173 and the cathode 174 of each tube.

For convenience here, as in the diagram of Fig. 24, the values of the resistances 177 between the anodes and grids have been shown graduated to control the glow discharges. The same object may be accomplished by graduating the capacities of the grid condensers 179 or the resistances 175 between the cathodes and grids or that of the current-limiting resistors 172, or by a combination of some or all of them. The photo-electric cell may be connected in series with the couplings between the cathode and grid instead of that between the anodes and grids, as shown. In such case, the tubes will break into glow when the photo-electric cell is dark and cease to glow when illuminated.

The grid glow tubes 169 are connected in parallel as to each other and in series with an electrical device which they are intended to operate and control. As a representative type a solenoid 180 is shown in Fig. 25 connected in the circuit 170. A plunger 181 in the solenoid carries the tool holder 119 and the tool 107 on its lower end and is drawn down against the resistance of the adjustable spring 182 by an electro-magnetic force depending upon the number of tubes passing current. The force applied is intermittent and always in the same direction, as the tubes pass current in one direction only. The solenoid 180 or an electro-magnet that may be employed in its place is applicable for the production of half-tones having a relatively large number of dots to the inch, where the depressions are smaller and of less depth, for it will be seen that the same current that controls the depth of the depressions must also provide sufficient energy to compress the material of the blank, whereas in the devices hereinbefore described a separate and more powerful source of energy is utilized to perform the latter function.

The rotor of the alternator 178 is geared to the shaft 146 of the machine so that the number of alternations in the current generated will bear a fixed relation to the distance that the carriage 38 moves in a given period of time.

Referring to Fig. 26, the output from the last stage of a number of amplifiers 153 and 154 coupled to the photo-electric cell 91 may be utilized to operate the solenoid 180. The tool 107 is caused to move up and down by interrupting the illumination on the photo-electric cell 91 thereby interrupting the impulses in the output circuit 182. A revolving shutter 183 provided with two blades interrupts the illumination on the photo-electric cell 91 twice in each revolution of the shaft 184 on which it is mounted. The shaft 184 is geared to the shaft 46 of the machine so that the number of interruptions of the illumination on the photo-electric cell 91 and therefore the number of depressions produced by the tool 107 will bear a fixed relation to the distance that the carriage 38 travels in a given time.

As hereinbefore mentioned, the object of this invention may also be accomplished by cuttings made into the surface of the blank with a cutting tool in a novel manner.

Referring to Figs. 27 and 28, the tool 185 has a V-shaped cutting point, the depth of the cut determining the width of the line produced. The tool is pivotally mounted on one end of an armature 186 of an electro-magnet 187 carried on the presser foot 143. The armature 186 is pivoted at 188 and is provided with a flat spring 189, the tension of which can be adjusted and set by a screw 190. The spring 189 opposes the pull of the electro-magnet on the armature and normally holds it against a stop 191. In this position, the cutting point of the tool 185 is just above the surface of the blank 39.

The electro-magnet 187 is connected in the output of one of the circuits hereinbefore described. The current flowing through it is a function of the illumination on the photo-cell and determines the distance the armature is drawn up and the depth of the cut resulting therefrom, which in turn determines the amount of printing surface removed from the blank.

The photo-electric cell 91 is caused to scan or traverse the illustration 37 and the tool 185 is caused to traverse the surface of the blank 39 to cut a series of parallel lines thereinto.

As the width of each line under the influence of the photo-electric cell 91 varies along its length an image of the illustration is cut in the blank. When this image has been cut the illustration and the blank are again scanned or traversed to cut the blank and reproduce the image a second time. This time with a series of lines that are cut across the first image, preferably in perpendicular relation to the first set, thereby producing a half-tone consisting of dots or elementary areas rectangular in outline.

By mounting the illustration diagonally on its holder, both series of lines will lie diagonally across the image and the dots will give the well-known diagonal effect thereto.

The two cutting operations, one in angular relation to the other, may be accomplished by providing the machine with means whereby the longitudinal and transverse feeding movements of the machine are interchangeable (not shown in the drawings). The tool would then be so mounted that it could be turned with its point as center to present its cutting edge in the proper direction for each cutting.

However, to avoid the complexity in the construction of the machine entailed in providing it with means whereby the longitudinal and feeding motions may be interchanged, I reset the illustration and the blank after the first cutting and position them so that the second image will be reproduced with lines cut perpendicular to the first and will coincide with the first image.

I am enabled to do the resetting in a very simple manner, accurate and automatic, by means of the plates or intermediate-holders **40** and **41**. It is not necessary to mark or otherwise mutilate the copy or the blank, and serves not only for producing half-tones of the same size, as the copy, enlargements and reductions, but also serves to reproduce these copies in reverse direction. The illustration and the blank may be of any size and shape and no special precautions are required in positioning them on the holders.

The mode of operation is as follows: The first image having been cut, the holder **40** with the copy thereon, is reset. It is removed from the depression in which it rests, turned either to the right or the left through an angle of 90 degrees and replaced. Supposing it to have been turned to the left or counter-clockwise, the corner of the holder at **192** would then be located at **192'** and a letter F representative of any portion of the copy would be positioned as shown in broken lines.

The holder **41** with the blank thereon is then reset. It is removed, also turned through an arc of 90 degrees, but in the direction opposite to that in which the holder **40** is turned and then replaced. The corner **193** will then be located at **193'**, and the image **194** of the letter F on the blank will be positioned as shown in broken lines. The machine is then again started and the tool **185** will cut lines across those already there and reproduce a second image identical with the first and coincident therewith.

The holders **40** and **41** are shown square in outline for convenience. They may be shaped and formed differently and may be provided with other means for mounting them on the machine for the two operations than by means of depressions in the surface of the two carriages.

There will be coincidence of the two images under all conditions when the machine is so assembled that in the position as shown in Fig. 28 the lateral distance between the centers about which the holders are turned for resetting is the same as the lateral distance **195** between the point of the tool and the center of the beam of reflected light.

Although two operations are required to produce a half-tone consisting of dots made by a cutting tool as above described, it nevertheless has the advantage of speed over the method of producing half-tones of the same character by means of a reciprocating compression tool; however, the resistance offered to compression makes possible a better control in correct reproduction. Moreover, a compression tool has greater endurance than a cutting tool which has frequently to be reground with extreme precision.

I claim:

1. In a device for photo-electrically reproducing an illustration on a blank from a copy, a tool, driving means operatively connected to said tool to reciprocate the same into the blank, said operative connection including collapsible means for rendering said drive ineffective, magnetic means for holding said means from collapsing, whereby the depth of penetration of said tool is determined by the strength of said magnet and means for varying the strength of said magnet with an electric current under the control of the radiant energy passing from the said copy.

2. A tool, driving means operatively connected to said tool for reciprocating the same into the work, said operative connection including collapsible means for rendering said drive ineffective, magnetic means for holding said means from collapsing, whereby the depth of penetration of said tool is determined by the strength of said magnet and means for varying the strength of said magnet.

3. In a device for reproducing an illustration on a blank by photo-electric means or in other similar devices wherein an electro-magnet controls the operation of a tool, a tool, driving means operatively connected to said tool for reciprocating the same into the work, said operative connection including collapsible means for rendering said drive ineffective, magnetic means for holding said means from collapsing, whereby the depth of penetration of said tool is determined by the strength of said magnet and electrical means for varying the strength of said magnet.

4. In a device for reproducing an illustration on a blank by photo-electric means or in similar devices wherein an electro-magnet controls the operation of a tool, a tool operatively coupled to an armature of a magnet, driving means operatively coupled to the core of said magnet, means for contacting the said armature and core, whereby operative connection between the said driving means and the said tool is established, and electric means for varying the strength of the said magnet, whereby the strength of the operative connection is determined, and the amount of work of the tool controlled thereby.

5. In a device for reproducing an illustration on a blank by photo-electric means or other similar devices wherein an electro-magnet controls the operation of a tool, a reciprocating tool to operate on the blank, an electro-magnet, a lever coupled to the said tool and to the armature of the said electro-magnet, driving means to oscillate the said lever, the said armature coupling or the said tool coupling serving as a fulcrum therefor, depending upon whether the magnetic hold on the armature or the reaction developed by the work of the tool on the blank offers the greater resistance to displacement of the lever at the respective couplings, means whereby the said driving means reestablishes contact between the armature and core after same is broken and means for varying the input current of the electro-magnet.

6. The method of photo-electrically reproducing an illustration on a plate for printing, wherein circumscribed elementary areas are formed at the surface of the plate proportional to the radiant energy passed from related areas of a copy, consisting in subjecting the surface of the plate to the action of a tool to form a series of linear grooves therein under the control of the said radiant energy passing from the copy and then again subjecting the same surface of the said plate to the action of a tool to form a series of similar linear grooves therein in angular relation to the first series of grooves and under the control of the said radiant energy passing from the said copy.

7. A device for photo-electrically reproducing a half-tone illustration on a printing plate from a pictorial copy, including means whereby a photo-sensitive device scans the said copy and an indenting tool traverses the said plate in a series of rectilinear and parallel paths, said indenting

tool having a tapered end substantially square in cross section and diagonally positioned in relation to the said rectilinear paths, driving means to reciprocate the said tool into the plate and means whereby the radiant energy passing from the copy, controls the operation of the said tool.

8. A device for photo-electrically reproducing an illustration on a blank from a copy, including a tapered tool, means for reciprocating same into said blank, means for traversing said blank with said tool and a holder for said tool provided with means to allow the end of said tool limited lateral play, whereby it may advance with said blank, when traversing and engaged therewith.

9. In a device for photo-electrically reproducing an illustration on a blank from a copy, a photo-sensitive device for scanning the copy, a tool for traversing the blank, a driving shaft, means operatively connected to the said driving shaft to reciprocate the said tool into the blank, means operatively connected to the said driving shaft to traverse the said tool over the blank, electro-magnetic means for controlling the reciprocations of the said tool, and means responsive to the photo-sensitive device through the electro-magnetic means, whereby the radiant energy received by the photo-sensitive device determines the depth of penetration of the said tool.

10. In a device for reproducing an illustration on a blank from a pictorial copy, a photo-sensitive device, means for scanning the copy with the photo-sensitive device, a reciprocating tool to form a series of parallel lines of depressions in the blank, means whereby the depressions in adjacent lines are formed in staggered relation to each other, means for traversing the blank with the tool, electro-magnetic means for controlling the operation of the tool and means responsive to the photo-electric device for varying the strength of current through the electro-magnetic means, whereby the radiant energy received by the photo-sensitive device determines the depth of penetration of the tool.

11. The method of producing a plate for printing a halftone illustration, which consists in preparing a smooth surface suitable for receiving ink from an inking roller on a plate having a porous texture and then compacting in succession portions of the plate at the said surface with a tool at regular intervals to depress elementary areas thereof below the reach of the inking roller.

OTTO WILLIAM GREENBERG.