

May 11, 1937.

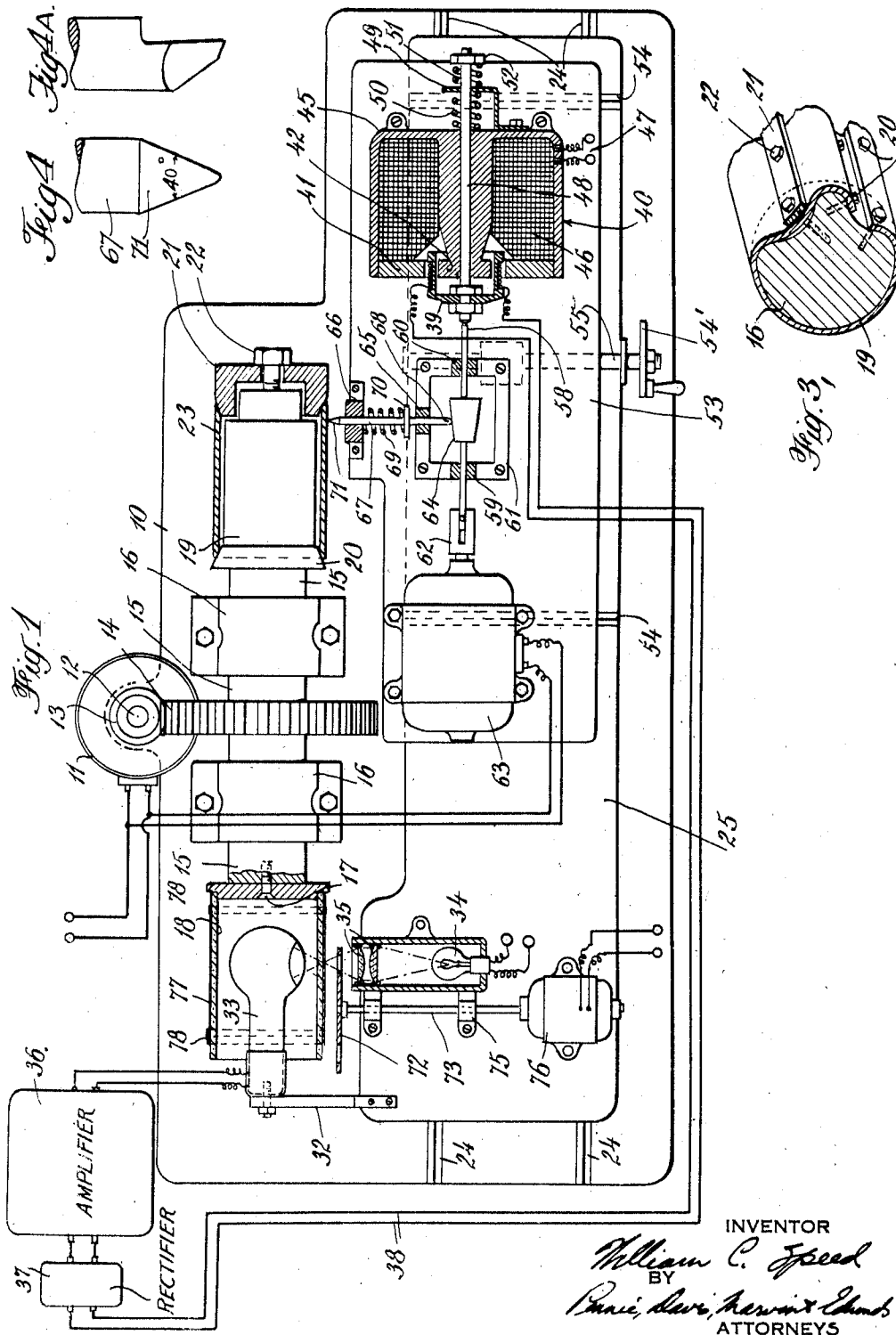
W. C. SPEED

2,079,970

PROCESS AND APPARATUS FOR PHOTOELECTRIC ENGRAVING

Filed Jan. 16, 1933

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

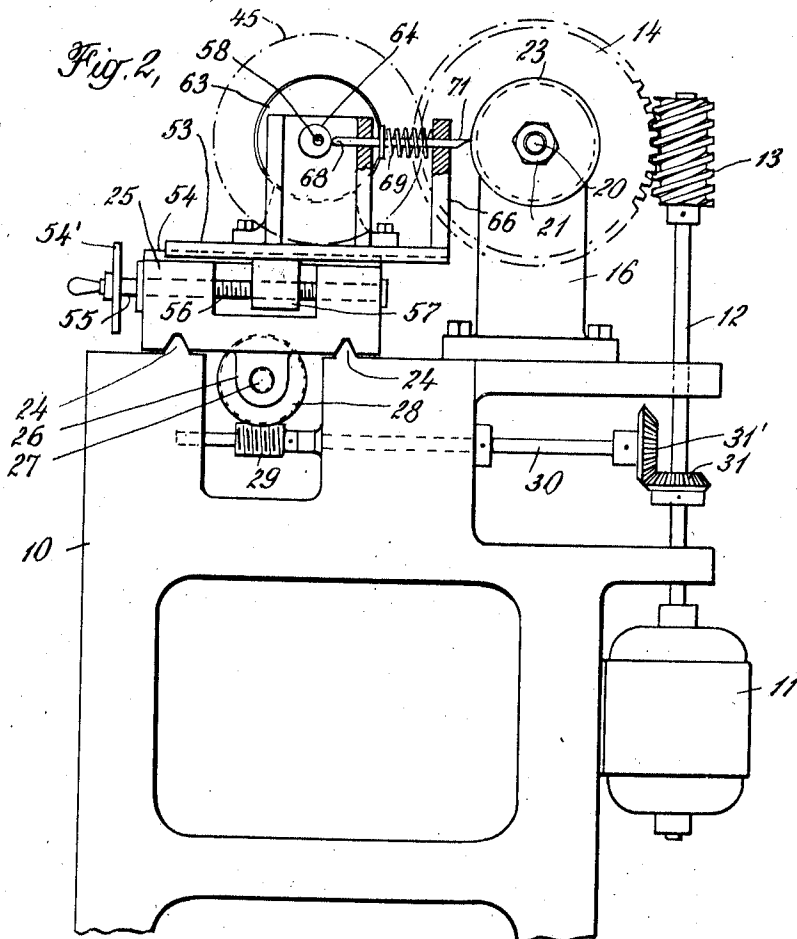


Fig. 5,

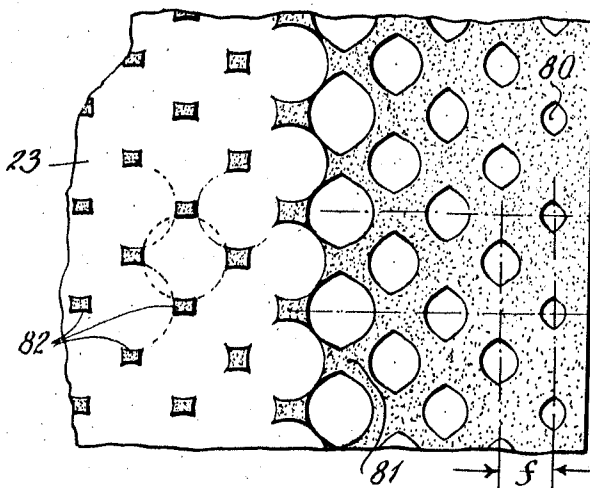
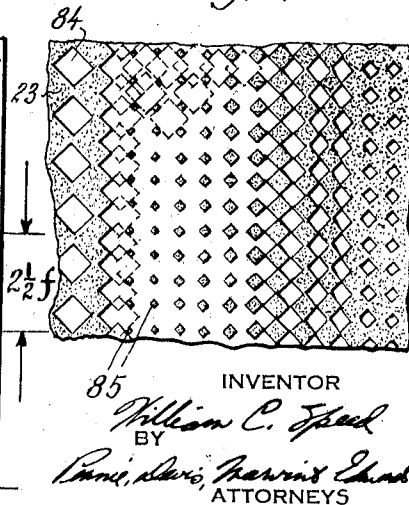


Fig. 6.



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PROCESS AND APPARATUS FOR PHOTO-ELECTRIC ENGRAVING

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16 Claims. (Cl. 178—5)

This invention relates to a process of photoelectric engraving and to apparatus for engraving in accordance with the new process, and has particular reference to the automatic mechanical engraving of "half-tone" plates in accordance with the graduation in tone of adjacent minute areas of the picture to be reproduced as determined optically.

In making "half-tone" plates according to the usual photo-engraving process, the picture to be reproduced is photographed upon the sensitized surface of a metal plate through a screen which subdivides the image into a plurality of closely spaced dots of tones varying from light to heavy, depending upon the graduation in tone of the corresponding minute areas of the picture. The surface of the plate is then etched with acid, which attacks the dotted areas to form pits, the lightly dotted areas being attacked to a lesser degree than the heavily dotted areas, so that minute areas of the plate stand out in varying degrees of relief, determined by the sizes of the pits so formed. The action of the acid cannot be controlled and it does not attack the metal of the plate uniformly, so that pits of an uneven contour are formed, many of the larger pits being undercut or mushroomed. As a result, the distribution of ink by the plate is non-uniform and a blurred half-tone results if the plate is used directly for making half-tone cuts or prints and, if the plate is used for making stereotype mats, the soft pulp pressed into the uneven or undercut pits of the plate comes away rough and ragged and forms an imperfect matrix.

In accordance with the present invention, a process and apparatus for making half-tone plates mechanically is provided in which the pits representing the closely spaced white dots of the half-tone are individual excavations made by a digging tool in the surface of the plate to a depth and area depending upon the tone graduation of the corresponding areas of the picture being reproduced as determined photoelectrically by an optical scanning device. The centers of the pits so formed on the surface of the plate are arranged in a regular geometrical pattern or screen, but the pits are of varying sizes, so that when the adjacent pits are so large that they coalesce, individual uncut areas of the surface of the plate, or "islands", are formed which stand out in relief. These islands and the other uncut areas of the plate form the ink-transferring surfaces thereof if the plate is used directly for making half-tone cuts or prints, and if the plate is used for making a stereotype mat, the corresponding

uncut areas on the mat form the ink-transferring surfaces thereof. This geometrical pattern is obtained by controlling the sequence of the formation of the excavations in the proper way to secure the aforementioned screen effect of the pits. This screen effect may be procured by arranging the pits in horizontal and vertical lines to produce a "square," or by arranging the adjacent pits diagonally or in staggered relation with respect to each other to produce a triangular or hexagonal screen pattern. The latter or diagonal screen effect produces a more pleasing appearance and is preferred, being procured by slightly changing the relationship of the tool with respect to the plate.

A preferred embodiment of the apparatus for mechanically engraving half-tone plates in accordance with this invention includes a photoelectric cell scanning device responsive to fluctuations in the intensity of a beam of light caused by variations in the transparency, translucency, or opacity of the adjacent minute areas of the picture, negative or positive film, or other translucent pictorial subject, or the like, through which the beam of light passes with a scanning movement. The electrical impulses consequently developed in the photoelectric cell are amplified and converted electromagnetically into equivalent mechanical impulses, which are utilized to vary the throw of a continuously reciprocating gouge or digging tool to cause it to gouge or dig out particles of the surface of a metal plate to form spaced independent pits or excavations, the area and depth of which are commensurate with the electrical impulses developed in the photoelectric cell in accordance with the graduations in tone of the picture being reproduced.

The picture, film, or other pictorial representation is preferably mounted on a rotating cylindrical drum with which the plate being engraved, arranged in cylindrical form of the same diameter as the picture drum, rotates synchronously so as to secure precise radial conformity between the minute areas of the picture being scanned by the beam and the corresponding pits simultaneously formed on the plates by the tool. The precise axial conformity between the minute areas of the picture being scanned by the beam and the corresponding pits simultaneously formed on the plate is preferably secured by a simultaneous movement of translation of the scanning beam relatively to the picture and of the tool relatively to the plate in an axial direction. For example, the source of light with the photoelectric cell and the tool with its actuating mechanism may be

mounted on a carriage advanced relatively axially of the two drums by a lead screw mechanism, or any other suitable equivalent arrangement, whereby the necessary relative translational movement between the drums and the beam and tool is obtainable.

The mechanism for producing the excavating movements of the tool and the mechanism for producing the relative translational and rotary movements of the plate are electrically or mechanically interconnected in such a way that the tool and the plate bear a definite relation to each other at all times during the engraving operation. In this way, the fixed relationship between the time required for the tool to perform its excavating movements and the time required by the plate to move from a completed pit to the point where the next pit is to be made by the tool, which is necessary to secure the screen or pattern effect of the finished plate, is obtained and maintained.

The desirable diagonal, triangular, or hexagonal screen effect of the pits may be secured by changing the fixed relationship between the excavating movement of the tool and the rotation of the plate drum, so that the pits of successive circumferential lines of pits will be displaced a distance equal to one-half the circumferential distance between adjacent pits, whereby the pits of adjacent rows are staggered with respect to each other. This variation in the fixed relationship between the movements of the tool and the rotation of the plate drum is conveniently obtained in the machine of the present invention by employing a two-pole synchronous motor for driving the tool-actuating mechanism, and a six-pole synchronous motor for driving the plate drum through a double pitch worm, so that during each revolution of the drum the tool executes the equivalent of one-half more or less digging movement than during the preceding revolution of the plate drum. Various other ways of procuring this same and other effects may be utilized and lie within the scope of the invention.

It will be seen that in accordance with the present invention, half-tone plates of clearer definition may be produced with greater speed, uniformity and accuracy than is possible with the usual photo-engraving process, and that the new machine may be operated by an unskilled attendant in contrast to the relatively high degree of skill required by the photo-engraver in performing the comparatively many steps of the photo-engraving process.

For a more complete understanding of the invention, reference may be had to the accompanying drawings, in which

Figure 1 is a plan view of the mechanical engraving machine embodying this invention;

Figure 2 is a side elevation thereof;

Figure 3 is a perspective view of a special mandrel for holding a flat sheet or plate to be engraved;

Figure 4 illustrates the tip of the engraving tool in front elevation;

Figure 4A is a side elevation thereof; and

Figures 5 and 6 illustrate enlarged portions of plates engraved in accordance with this invention.

Referring to Figures 1 and 2 of these drawings, numeral 10 designates a frame or support on which the elements of the machine are mounted. Suitably secured on the support 10 is a motor 11 which is preferably a synchronous motor which may be of the 60-cycle type operable in the usual

110-volt, 60-cycle lighting current. The extended shaft 12 of motor 11 carries a double-threaded worm 13 which meshes with and drives a worm wheel 14 secured on a shaft 15 suitably journaled in a horizontal position in bearings 16 mounted on the base 10.

Mounted on one end of shaft 15 by means of a screw 17 is a transparent hollow drum 18 of glass or other suitable material. Mounted on the other end of shaft 15 is a mandrel 19 having a fixed tapered cone 20 and a removable cone 21 adjustable axially by a bolt 22 threaded into mandrel 19. A tubular cylinder 23 is adapted to be clamped between cones 20 and 21. This cylinder 23 is of the same diameter as drum 18 and is the plate upon which the reproduction of the picture to be reproduced is engraved, being subsequently flattened into a flat plate after being engraved. The plate is formed of the material of which half-tone plates are made, such as brass, zinc, their alloys, or the like. Brass containing lead and known as free cutting brass is preferable.

If individual plates or sheets of metal are to be engraved, a different type of mandrel is employed, namely, the kind illustrated in Figure 3. In this arrangement the mandrel 19' mounted on shaft 15 is tapped for the reception screws 20', whereby the side edges of the flat plate 23' wrapped around mandrel 19' are secured in place. The mandrel 19' is recessed longitudinally and a tightening bar 21' is clamped by means of bolts 22' against that portion of the plate 23' lying over the recess to draw the plate 23' tightly over the mandrel. The mandrel 19' is so shaped that the heads of screws 20' and bolts 22' lie beneath the surface of the plate 23, so as not to interfere with the digging tool as the mandrel rotates in the manner described.

Slidable on rails 24 on base 10 is a horizontal carriage 25 which is fitted with lugs 26 through which is threaded a lead screw 27 carrying a worm wheel 28 meshing with worm 29 secured to horizontal shaft 30, which is driven from motor shaft 12 by bevel gears 31, 31'. As the motor 11 rotates, worm wheel 28 is driven and advances carriage 25 slowly along lead screw 27 on rails 24 in accordance with standard practice in connection with lathes and other machine tools.

Suitably supported on carriage 25 by a bracket 32 is a photoelectric cell 33 of conventional form. This photoelectric cell 33 is located within glass drum 18 and moves axially thereof as the carriage 25 is advanced relatively to the base 10 in the manner described. Also mounted on the carriage 25 is a condensed source of light 34, such as an automobile head lamp having a small filament coil, the greatly reduced image of which is focused upon the surface of glass cylinder 18 by the lenses 35, and such portion of the light as passes through the picture falls upon the sensitive element of photoelectric cell 33.

The output of the photoelectric cell 33 is amplified by a multi-stage amplifier 36 of conventional design, the output of which is rectified by a suitable rectifier 37 and conducted by wires 38 to the coil of the armature 39 of an electro-dynamic motor 40, such as a loud speaker motor. The field windings 46 of the motor 40 are energized from a suitable source of direct current connected to wires 47.

The armature 39 of the electro-dynamic motor 40 is connected to one end of a rod 48 which slides through the center pole piece 42 and is held slidably in centered position at its other end by a

bracket 49 mounted on the housing 45 of the electro-dynamic motor 40, between which and the housing 45 is a light coil spring 50, while a second light coil spring 51 is interposed between bracket 49 and a nut 52 on the end of rod 48. These springs 50 and 51 serve to hold the armature 39 in centered position with respect to the poles 41 and 42.

The electro-dynamic motor 40 is mounted in a slide 53 movable along transverse rails 54 on the top of carriage 25, so as to be movable relatively to the carriage 25 in a direction at right angles to the normal movement of the carriage 25. The slide 53 is adjustable relatively to the carriage 25 by means of a handwheel 54' mounted in a shaft 55 journaled in the carriage 25 and having a threaded portion 56 passing through a lug 57 on the underside of slide 53.

Normally engaging the end of rod 48 at armature 39 is the end of a light shaft 58, which is journaled at spaced points 59 and 60 and axially slidable in a bracket 61 secured to slide 53. The other end of shaft 58 is splined by a pin-and-slot combination 62 on the shaft of synchronous motor 63 which is connected to the same source of power as motor 11 so that the two motors rotate in angular synchronism, although not necessarily at the same revolutions per minute, for reasons to be described. Mounted eccentrically on rod 58 at a point thereon between its journals 59 and 60 is a cone 64.

Slidably guided at one end in a lug 65 of bracket 61 and slidably guided at its other end in a lug 66 on slide 53 is an engraving tool 67, the rounded inner end 68 of which is constantly urged into engagement with eccentric cone 64 by means of a coil spring 69 interposed between lug 66 and a collar 70 on the tool 67. The engraving or cutting tip 71 of the tool 67 is shaped substantially as illustrated in Figures 4 and 4A, so that as it is driven into the surface of plate cylinder 23 by rotation of eccentric cone 64 it gouges or excavates particles of metal from the surface of plate cylinder 23. The pitch angle of the tip 71 of the tool 67 is preferably approximately 40° as is indicated in Figure 4, but its degree of sharpness and its shape may be varied depending upon the nature of the material forming the surface of the plate 23, the depth and shape desired for the pits, and the like.

In order to utilize an amplifier 36 of conventional design, the beam of light issuing from lamp 34 is rapidly interrupted by a disc 72 having a series of openings through which the beam of light from lamp 34 is directed. This disc 72 is mounted on a shaft 73 journaled in brackets 75 on the carriage 25 and driven by a motor 76, also mounted on carriage 25 and being of any suitable type since it has no direct connection with the operation of the engraving mechanism. This arrangement eliminates the necessity of using a direct current amplifier, and although preferred, equivalent means may be employed with equal facility. For example, a rapidly flickering neon lamp may be employed. It is to be noted that the interruption of the light has no significance in respect to the scanning action, but is provided solely to allow the use of the simpler, more stable, standard types of amplifiers.

In operating the engraving machine of this invention the negative or positive film 77, or print, cut, or other picture rendered translucent by oiling, which is to be reproduced, is wrapped smoothly around the outer surface of transparent drum 18 and held in place thereon by rubber

bands 78 or other suitable fastening means. The carriage 25 is adjusted so that the light beam of the scanning device is in starting position relatively to the pictorial subject 77 being reproduced; i. e., the light beam connects with the leading edge of the picture 77 so as to move slowly over its surface as the carriage 25 moves along its rails 24. The slide 53 is then adjusted transversely of the carriage 25 by means of handwheel 54', so that the engraving tool 67 is positioned relatively to the surface of plate cylinder 23 to gouge out or excavate particles of the metal to form pits in the surface of the plate of the desired depth and size, when the motor 63 is energized and eccentric cone 64 is accordingly rotated.

The machine is started and motor 63 oscillates engraving tool 67 while motor 11 rotates plate cylinder 23 and picture drum 18 at the same rate of surface speed, since they are both secured on the same drive shaft 15 and are of the same diameter. At the same time carriage 25 is driven relatively to picture drum 18 and plate cylinder 23 by lead screw 27 which is also driven by motor 11 in the manner described. The beam of light issuing from lamp 34 accordingly scans minute areas of the surface of the pictorial subject 77 being reproduced and the variations in the intensity of the beam caused by changes in the tone value or translucency, transparency or opacity of the picture 77 are detected by photoelectric cell 33, which accordingly develops impulses which are amplified by amplifier 36 and transmitted to electro-dynamic motor 40, which converts the electrical impulses into mechanical oscillations of the armature 39 in an axial direction. These axial movements of the armature 39 are transmitted by armature rod 48 to rod 58 which also moves axially to change the axial position of eccentric cone 64 with respect to engraving tool 67, so that while the normal stroke of the latter is maintained of the same length, the tool is pushed in and out in accordance with the variation in shading of the picture and thus its tip 71 gouges out or excavates pits of larger or smaller size in the surface of plate cylinder 23 as the latter rotates.

Thus, each minute area of the picture 77 scanned by the scanning device is represented by an independent pit formed in the surface of the plate 23 and having a size and consequent reproducing effect which is equivalent to the tone value of the corresponding area of the picture 77, so that when the picture 77 has been completely scanned the subject thereof is represented precisely on the surface of plate cylinder 23 by independent pits of varying size formed by the tool 67. The throw of the eccentric cone 64 is such that the cutting tip 71 of the engraving tool 67 is completely withdrawn from the surface of the plate cylinder after each cutting operation.

For convenience, the driving motor 63 for tool 67 may be a two-pole, 3600 R. P. M. synchronous motor, so that rapid reciprocation of tool 67 is provided. By properly coordinating the drive of the cylinder 23 and of carriage 25 with the speed of reciprocation of tool 67 a screen of practically any number of pit per square inch may be formed in the surface of plate cylinder 23, the centers of the adjacent pits so formed being uniformly spaced from each other to form the regular geometrical pattern or screen in accordance with the engraving method of this invention. The screen or pattern so formed may be square, or triangular or hexagonal, and since the tri-

angular or hexagonal pattern is more pleasing in appearance and therefore preferred, the manner of procuring it will be described.

The two-pole, 60-cycle synchronous motor 63 is used in conjunction with a six-pole synchronous motor 11 and a 175-tooth worm wheel 14 is selected, so that as the latter is driven by double-threaded worm 13, plate cylinder 23 executes one revolution for $262\frac{1}{2}$ revolutions of motor 63, and consequently cone 64 will make a circumferential row of $262\frac{1}{2}$ pits in the surface of plate cylinder 23. Accordingly, during the second revolution of the plate cylinder 23, the following circumferential row of pits will be displaced a distance equal to one-half the circumferential distance between adjacent pits out of line with the preceding circumferential row of pits, thus forming a plate in which the adjacent pits are arranged in triangular or hexagonal pattern, as is illustrated in the enlarged development of plate cylinder 23 after the engraving operation is completed. Upon examination of Figure 5 it will be noted that the centers of the pits 80 are uniformly spaced throughout the surface of the plate 23, so that a regular geometrical pattern or screen is formed, although the individual pits are of varying sizes, depending upon the variation in the throw of the tool 67 as determined by the variations in tone value of the corresponding areas of the pictorial subject 77, which were detected by the scanning device including the photo-electric cell 33 in the manner described. The pits 80 are accordingly individual excavations in a network 81 of uncut plate surface, and even where the adjacent pits are so large that they coalesce, the "islands" 82 remaining between them are distinct and clear, as is illustrated in Figure 5. By variously correlating the gearing, the angular movements of the motors 11 and 63 in other ways, the same or similar pattern effects may be obtained in a manner readily understood.

Furthermore, variations in the spacing of the pits 80 in circumferential rows with respect to the spacing of the pits in the axial rows may also be obtained by varying the fixed relation between the tool and the plate. For instance, it is important that the transition from the dark shades of the picture, where the pits are small in a black ground, to dots in a white ground, shall be effected with the least possible amount of network 81 (Fig. 5), formed by the uncut surfaces of the plate, because this network is thin, wears rapidly, and does not pull readily from the stereotype matrix. Thus, if the spacing between circumferential rows is equal to f distance, as indicated in Figure 5, and it is desirable to secure a spacing of $2\frac{1}{2}$ times f distance between adjacent axial rows of the pits on the plate 23, the feed of the carriage 25 may be varied in order to obtain this two and one-half to one spacing ratio. Considering the example given above, in which the tool is actuated $262\frac{1}{2}$ times per revolution of plate cylinder 23, the number of pits in a circumferential inch is $26\frac{1}{4}$ for a plate cylinder 23 having a ten-inch circumference. In order to obtain the aforementioned ratio of two and one-half to one, the feed of the carriage 25 must be such that there are $26\frac{1}{4}$ times $2\frac{1}{2}$, or approximately $65\frac{1}{2}$ pits per axial inch. This feed of the carriage may be conveniently obtained by employing a lead screw 27 with 40 threads per inch, gear 28 with 100 teeth, a single-threaded worm 29, the bevel gear 31' on shaft 30 with 43 teeth, and the gear 31 on shaft 12 with 30 teeth. This ratio provides the pit arrangement illustrated by Fig. 5, in which the lines

of the network 81 between adjacent pits 80 in a circumferential direction, indicated by the arrow, is elongated with respect to the lines of the network 81 in an axial direction, and, as is indicated at the center of Fig. 5, the transition network is substantial and not easily worn down nor likely to stick to the stereotype matrix.

These advantages arising from a minimum of interconnecting network, are obtained in another way in accordance with this invention, also by varying the feed of the carriage 25. With the movements of the digging tool equal to an incomplete number of actuations per revolution of plate cylinder 23, such as $262\frac{1}{2}$ in the example given above, or the like, the carriage 25 is advanced every second revolution of the plate cylinder instead of every revolution as in the aforementioned example. This causes the first and second rows of pits to coincide, but the pits do not connect because of the circumferential displacement of the second row of pits; instead, the corresponding pits of both rows overlap a degree depending upon their circumferential displacement, so that the plate resembles Figure 6, in which the left-hand row of circumferential pits 84 has been formed by the tool during the first revolution, while the next adjacent row to the right has been formed by the overlapped or alternate formation of pits during the preceding pair of revolutions, which took place while the carriage 25 remained stationary. This illustrates the result when the pits are deep, while the right side of the plate in Figure 6 illustrates the result of light or shallow pits. The carriage may be driven intermittently by ratchet or Geneva mechanism, or the like, in a manner readily understood, this mechanism being conveniently installed in place of gears 31, 31', for example.

The tool is so formed that as the pits become deeper, they also become wider. The tool is shaped substantially as the tool illustrated in Figure 4 except that the tip angle is approximately 90° instead of approximately 80° and the extreme point of the tip is ground as sharp as possible. This form of tool accordingly makes clean-cut diamond-shaped pits which change from non-printing dots to exceptionally clean individual islands 85 with practically no transitional network at all.

It will be seen that the mechanical reproduction of pictures or the like to produce half-tone plates by the new process of this invention involves gouging or excavating wholly independent spaced pits in the surface of a plate, each of these pits having dimensions corresponding to the color value or the degree of transparency, translucency or opacity of the corresponding minute area of the picture being reproduced; whereby the plate thus formed makes half-tone cuts or prints or stereotype mats and matrices of great definition, accuracy and emphasis without necessarily requiring retouching of the original negative, positive, or other pictorial subject in order to secure definition and emphasis.

Also, by simply varying the speed of movements of rotation or translation of the plate cylinder 23 relatively to the picture drum 18, such as by properly correlating their respective driving connections, distortions, such as foreshortening of the reproduction, and the like, may be obtained. Distortion may also be secured by making the plate cylinder 23 of different diameter than the picture drum 18, and conversion of a negative subject into a positive plate and vice versa may be procured by reversing eccentric cone 64 with re-

spect to the engraving tool, reversing the polarity of the dynamic motor leads, and the like.

Instead of mounting the picture holder 18 and the plate holder 19 on the same carriage 10, they may be mounted remote from each other on separate carriages driven at the same speed by separate motors, such as synchronous motors similar to motor 11, and at the same rate of revolution, while the transmission wires 38 leading from the scanning device to the reproducing device may be any length, so that the machine may be set up with its scanning and reproducing stations located any desirable distance apart.

Although the process of this invention has been described as being carried out by a particular machine, it is to be understood that any other arrangement whereby the process may be carried out may be utilized with equal facility, and, while the particular machine illustrated and described herein has been found to be effective in actual practice, it is to be understood this invention is not limited thereby but is susceptible to changes within the scope of the claims directed to it.

I claim:

1. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in tone of adjacent minute areas of the picture, a gouging tool, means for reciprocating the tool independently of the first means, and connections between the means for varying the depth of gouge of the reciprocating tool to cause it to gouge regularly spaced, independent pits in the surface of the plate of sizes varying in accordance with the graduation in tone of the corresponding minute areas of the picture as determined by the first means.
2. In apparatus for reproducing a picture on a plate, the combination of means responsive to the graduation in tone of adjacent minute areas of the picture, a gouging tool, means independent of the first means for reciprocating the tool relatively to the surface of the plate to gouge regularly spaced independent pits therein at points corresponding to the said minute areas of the picture, and connections between the means for varying the depth of gouge of the tool to alter the sizes of the pits in accordance with the graduation in tone of the corresponding areas of the picture as determined by the first means.
3. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in tone of adjacent minute areas of the picture, a gouging tool, means for reciprocating the tool independently of the first means, connections between the means for varying the depth of gouge of the tool to cause it to gouge regularly spaced independent pits in the surface of the plate of sizes varying in accordance with the graduation in tone of the corresponding minute areas of the picture as determined by the first means, and means for displacing the plate and tool relatively to each other to secure displacement of the pits with respect to the previously formed pits.
4. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in tone of adjacent minute areas of the picture, a gouging tool, means for reciprocating the tool independently of the first means, connections between the means for varying the degree of reciprocation of the tool to cause it to gouge regularly spaced independent pits in the surface of the plate of sizes varying in accordance with the graduation in tone of the corresponding minute areas of the picture as deter-

mined by the first means, and means for displacing the tool and the plate relatively to each other to displace the pits relatively to the position of the corresponding areas of the picture.

5. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in the tone of adjacent minute areas of the picture, mechanism for relatively moving the means and the picture, a gouging tool, means independently of the first means for reciprocating the tool to cause it to gouge the surface of the plate at regularly spaced intervals, connections between the mechanism and the tool and plate to cause them to move relatively to each other at the same rate as the first means and the picture for spacing the pits formed in the plate by the tool according to the spacing of the said minute areas of the picture, and connections between the means for varying the degree of reciprocation of the tool to form pits of sizes commensurate with the graduation in tone of the corresponding minute areas of the picture.

6. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in the tone of adjacent minute areas of the picture, mechanism for relatively moving the means and the picture, a gouging tool, means for reciprocating the tool to cause it to gouge the surface of the plate, connections between the mechanism and the tool and plate to cause them to move relatively to each other at the same rate as the first means and the picture for spacing the pits formed in the plate by the tool according to the spacing of the said minute areas of the picture, connections between the means for varying the degree of reciprocation of the tool to form pits of sizes commensurate with the graduation in tone of the corresponding minute areas of the picture, and means for varying the relationship between the tool and the plate to displace the pits relatively to the position of the corresponding areas of the picture.

7. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in tone of minute areas of the picture, a gouging tool, means for reciprocating the tool to gouge the surface of the plate, connections between the means for varying the degree of reciprocation of the tool to vary the sizes of the pits in accordance with the graduation in tone of corresponding areas of the picture, means for relatively moving the first means and picture at a different rate than that at which the tool and the picture are moved relatively to each other to secure a variation in the reproduction of the picture on the plate.

8. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in tone of minute areas of the picture, a gouging tool, means for reciprocating the tool to gouge the surface of the plate, connections between the means for varying the degree of reciprocation of the tool to vary the sizes of the pits in accordance with the graduation in tone of corresponding areas of the picture, means for moving the plate and tool relatively to each other in one direction to form a row of pits, means for moving the plate and tool relatively to each other in a direction at an angle to the first direction to form adjacent rows of the pits and means for varying the rate of movement of one of said means.

9. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in tone of minute areas of the picture, 75

a gouging tool, means for reciprocating the tool to gouge the surface of the plate, connections between the means for varying the degree of reciprocation of the tool to vary the sizes of the pits in accordance with the graduation in tone of corresponding areas of the picture, means for moving the plate and tool relatively to each other in one direction to form a row of pits, and means for moving the plate and tool relatively to each other in a direction at an angle to the first direction to form adjacent rows of the pits, said last means being timed with respect to said first means to cause a predetermined number of successive rows of pits to overlap.

10. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in tone of minute areas of the picture, a gouging tool, means for reciprocating the tool to gouge the surface of the plate, connections between the means for varying the degree of reciprocation of the tool to vary the sizes of the pits in accordance with the graduation in tone of corresponding areas of the picture, means for moving the plate and tool relatively to each other in one direction to form a row of pits, and means for moving the plate and tool relatively to each other in a direction at an angle to the first direction to form adjacent rows of the pits, said first means being timed with respect to said last means to cause the pits of adjacent rows to be displaced with respect to each other lengthwise of the rows.

11. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in tone of minute areas of the picture, a gouging tool, means for reciprocating the tool to gouge the surface of the plate, connections between the means for varying the degree of reciprocation of the tool to vary the sizes of the pits in accordance with the graduation in tone of corresponding areas of the picture, means for moving the plate and tool relatively to each other in one direction to form a row of pits, and means for moving the plate and tool relatively to each other in a direction at an angle to the first direction to form adjacent rows of the pits, said means being timed with respect to each other to cause groups of adjacent pits to assume a regular geometrical pattern.

12. In apparatus for reproducing a picture on a plate, the combination of means responsive to graduation in tone of minute areas of the picture, a gouging tool, means for reciprocating the tool to gouge the surface of the plate, connections between the means for varying the degree of reciprocation of the tool to vary the sizes of the pits in accordance with the graduation in tone of corresponding areas of the picture, means for moving the plate and tool relatively to each other in one direction to form a row of pits, and means for moving the plate and tool relatively to each other in a direction at an angle to the first direction to form adjacent rows of the pits, said means being timed with respect to

each other to cause the spacing between adjacent pits in the rows to bear a predetermined relation to the spacing between adjacent rows.

13. In apparatus for reproducing a picture on a plate, the combination of electrical scanning means responsive to graduation in the tone of adjacent areas of the subject picture, a gouging tool, means independent of the scanning means for reciprocating the tool to cause it to gouge substantially uniformly sized pits in the plate, means for relatively moving the plate and tool at a uniform rate proportional to the rate at which the minute areas of the subject picture are scanned by the scanning means to secure a regular pattern of pits on the plate, and electrical connections between the scanning means and tool reciprocating means for varying the throw of the tool to vary the normal size of the pits in accordance with the graduation in tone of the corresponding minute areas of the subject picture.

14. In apparatus for reproducing a picture on a plate, the combination of electrical scanning means responsive to graduation in the tone of adjacent areas of the subject picture, a gouging tool, means independent of the scanning means for reciprocating the tool to cause it to gouge substantially uniformly sized pits in the plate, means for relatively moving the plate and tool at a uniform rate proportional to the rate at which the minute areas of the subject picture are scanned by the scanning means to secure a regular pattern of pits on the plate, electromagnetic control means connected to the tool reciprocating means for varying the throw of the tool, and electrical connections between the scanning means and the control means whereby the sizes of the pits are varied in accordance with the graduation in tone of the corresponding minute areas of the subject picture.

15. The process of reproducing a picture on a plate, which comprises determining the tone value of adjacent minute areas of the picture by scanning, forming a row of spaced individual pits in the surface of the plate of sizes commensurate with the tone values of the corresponding areas of the picture, and forming a second row of similar spaced individual pits in adjacent parallel relation to the first row with the pits of the second row lying in staggered positions with respect to the pits of the first row.

16. In an apparatus for reproducing a picture on a plate, the combination of electrical scanning means responsive to graduations in the tone of adjacent minute areas of the picture, a gouging tool, an adjustable cam for reciprocating the tool independently of the first means to gouge the surface of the plate, and connections between the scanning means and said cam for adjusting the position of the cam relative to the tool whereby the sizes of the pits are varied in accordance with the graduation in tone of corresponding areas of the picture.

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