

April 15, 1941.

F. W. REYNOLDS

2,238,601

TELEPHOTOGRAPHY.

Filed Oct. 26, 1939

2 Sheets-Sheet 1

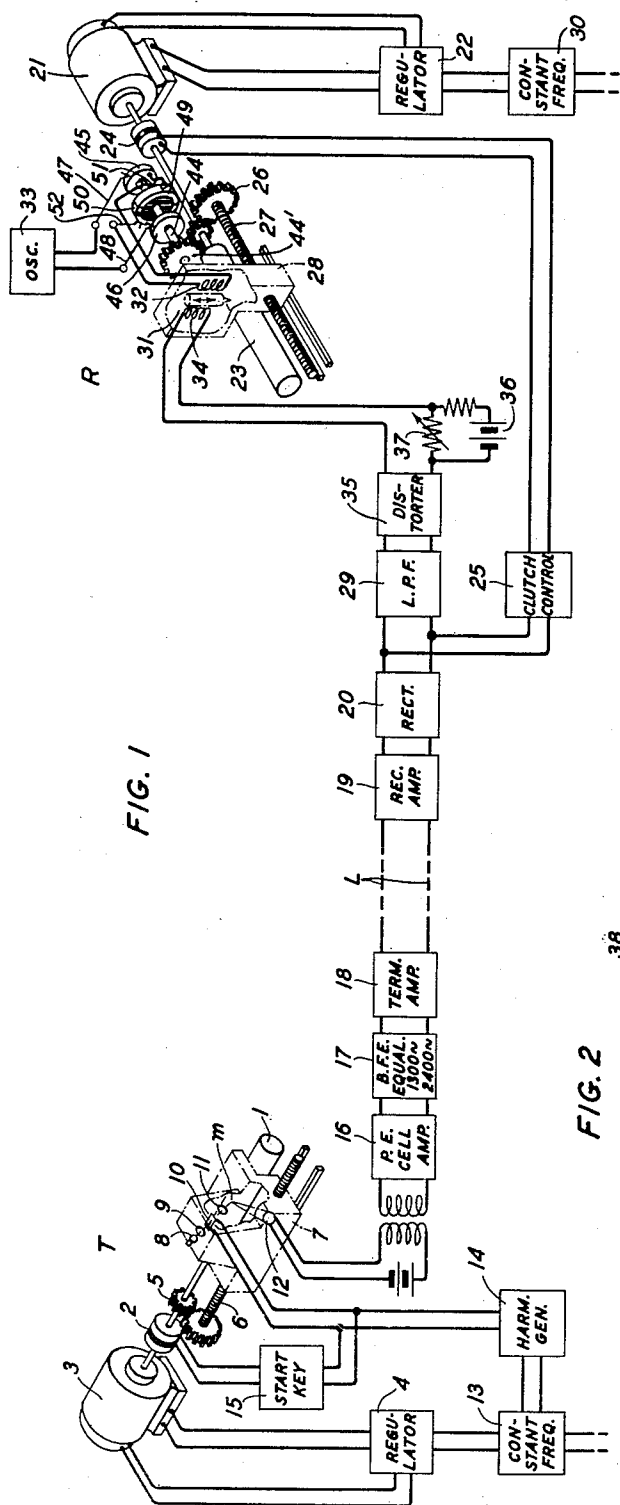


FIG. 1

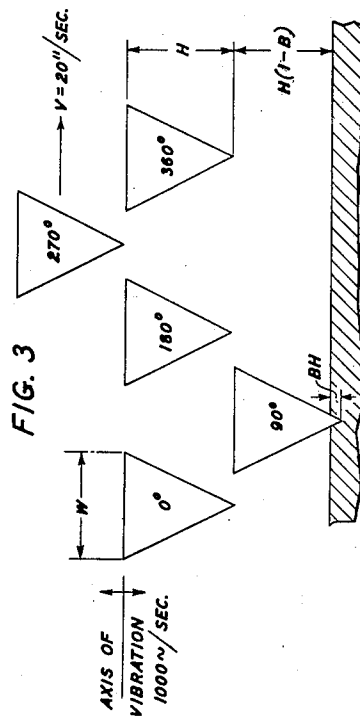


FIG. 3

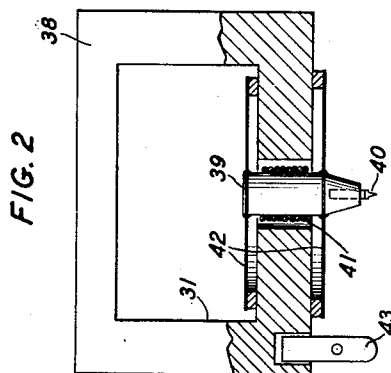


FIG. 2

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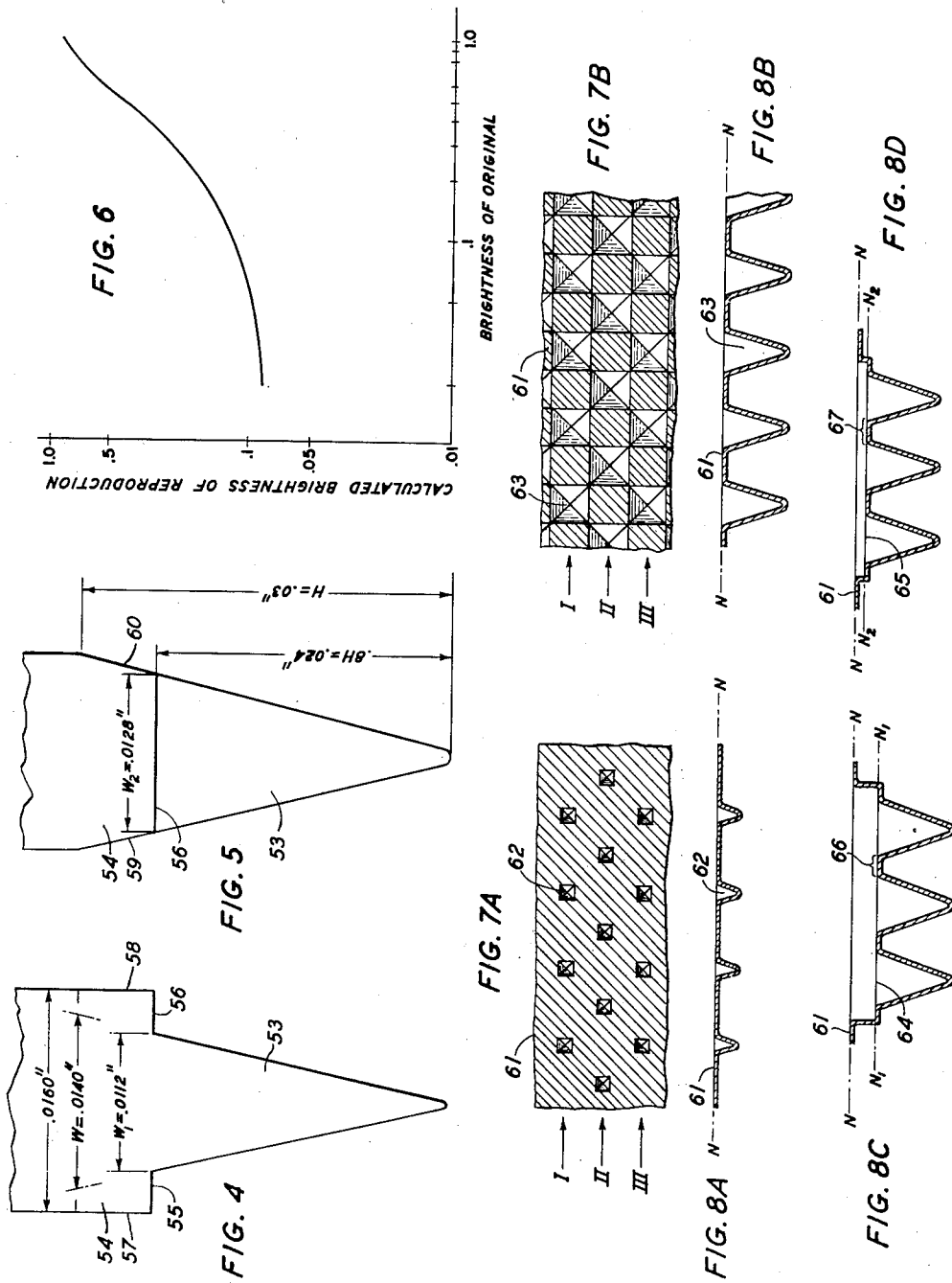
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2 Sheets-Sheet 2



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2,238,601

TELEPHOTOGRAPHY

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16 Claims. (Cl. 178—6.6)

This invention relates to the art of producing images under control of electric currents representative of light-tone values of a picture or view and more particularly to methods of and means for controlling the production of printing plates or stereotypes.

Prior to this invention certain arrangements had been devised for using the incoming currents at the receiving station of a telephotograph system to control a reciprocating embossing tool to emboss a record blank upon the receiving station cylinder in accordance with the amplitude of the received current, the embossed record having a dot structure in the form of parallel rows of conical or pyramidal depressions of varying depths and serving, after being straightened, as a matrix for casting a printing plate. A casting made from such a record has conical or pyramidal extensions of varying height which if partly ground away to cause the extensions to be of the same height presents a printing dot structure composed of parallel rows of round or square dots of different size representative of different tone values. A print made from this printing plate or stereotype would have the well-known half-tone structure.

It has been suggested that instead of grinding off all the peaks of the elevations of the casting the grinding operation be stopped before the peaks of the lowest elevations (which represent high light regions of the picture) are reached. Although these peaks are then at a lower level than the surrounding elevations they are intended to register on the print as very small dots. Such a printing plate having the portion of the dot structure representative of high lights at a somewhat lower level than that of other portions would be similar in this respect to half-tone printing plates which have been subjected to the well-known "bumping" process to give this difference of level in the printing surface. However, a printing plate made in accordance with this suggestion would have the grave defect that there would be no differentiation of different tone values in the high light regions.

An object of the present invention is to provide a method of, and means for, producing a matrix, by means of an embossing tool, under control of currents representative of the tone values of a picture or view, from which can be cast a printing plate or stereotype capable of use without further processing.

Another object is to provide a matrix from which can be cast a printing plate exhibiting

higher fidelity of tone reproduction than can be obtained by methods heretofore suggested.

Another object is to produce a matrix in one operation which gives the cast printing plate the character of a "bumped" plate in which there is differentiation of tone values in the high light regions.

A further object is to provide an improved form of embossing tool.

Other objects and features will appear as the description of the invention proceeds.

The following is a brief description of a form of the invention chosen for illustration and later described in greater detail. The general principles underlying the invention will be apparent from these descriptions. In certain aspects the invention is of more general application than in systems of the type described, as will also be apparent from this description and the appended claims.

A record blank is provided in the form of a thin sheet of soft metal, such as aluminum for example, or other easily deformable material capable of holding its shape sufficiently well to serve as a matrix for casting. A reciprocating pointed stylus or tool under control of the received image current is made to indent, depress, or emboss the record blank to form a dot structure, the depth of the depressions in which are greater than the thickness of the record plate. The rear face of the record so formed has the same contour as the front face and the printing plate is made by using the rear face as the matrix for casting. The path of travel of the tool is made perpendicular to that of the record surface at the recording point. Consequently the shape of the depressions of varying depth is dependent both upon the shape of the tool and the relative movement between the tool and the record.

In the design of the tool account is taken of the relative movement of tool and record so that the dots are symmetrical in shape, preferably square, and of proper dimensions to produce reproductions having proper tone values.

The tool in its preferred form is of pyramidal shape and is provided with shoulders which depress the general level of the record blank in varying degree for large amplitudes of oscillations corresponding to high lights of the picture or view, thus giving the record, and the casting therefrom, the characteristics of a bumped plate.

The invention is described herein as applied to a telephotographic system of the type disclosed in U. S. Patent 2,041,822, May 26, 1936, to Dowd,

which includes a transmitting apparatus connected by a telephone line to a receiver.

The transmitting apparatus comprises a rotating cylinder carrying an original, i. e., a two-dimensional representation, for example, a photograph, picture, drawing, or other similar subject, and an optical system movable longitudinally of the cylinder. The optical system comprises a source of light and a lens system for focusing the light supplied by the source into a beam for illuminating an elemental area of the original, means for modulating or varying the light beam at a carrier frequency, and a light sensitive electric device adapted to be activated by light reflected from the elemental area illuminated by the light beam.

As the cylinder and optical system are moved relatively to each other, the beam of light illuminates successive elemental areas of the original, and light reflected from these areas is applied to the light sensitive electric device, which is thereby activated to control the production of a modulated carrier current, the amplitude of which varies in accordance with the varying tone values of the successively illuminated elemental areas.

One side-band of the picture modulated carrier current and the unmodulated carrier component are transmitted to a receiving station where the incoming components are rectified or demodulated to yield the picture current, which is supplied to a circuit including an element having a non-linear characteristic which distorts the picture current to compensate for the tone distortion introduced by the operation of the electro-optical picture current producing apparatus at the transmitter.

The receiving apparatus is similar to that disclosed in the above-mentioned Dowd patent but differs therefrom in that the optical system is replaced by an electrodynamic unit, similar to that used for sound recording on wax records, provided with a punching or embossing tool, and the relatively thin record blank of deformable material is mounted on the rotating cylinder over a layer of pliable material in place of the photographic film of the patented system. A control coil of the electrodynamic unit is supplied with oscillating current of fixed frequency, whereby the punching or embossing tool is caused to reciprocate at a fixed frequency in a plane in which the axis of the cylinder lies and in a line in that plane at each instant perpendicular to the axis, and to make a depression in the blank at each reciprocation. The compensated current is supplied to a driving coil, included in the electrodynamic unit, to cause the reciprocations of the tool to vary in accordance with the varying amplitudes of this current. The layer of supporting material on the cylinder normally operates to support the blank but is sufficiently pliable to permit embossed material displaced by the tool to protrude into it.

Due to the relative movement of the cylinder and embossing tool, unit areas of the record blank are successively introduced into the path of travel of the reciprocating tool and the compensated current operates to determine the amplitude of reciprocation of the tool.

The embossing tool comprises a section in the form of a pyramid, having its apex directed toward the record blank and its base surmounted by an added section in the form of a frustum of a wedge. The added section is preferably integral with the pyramid, its parallel faces lie in planes which are parallel to a plane passing

through the axis of the tool at right angles to the direction of scanning and its tapering faces are inclined to an axial plane parallel to the direction of scanning. Again this section is symmetrically positioned on the base of the pyramid but its length in the direction of scanning is greater than that of the base so that it extends beyond the edge of the base and its lower face provides a shoulder in a plane parallel to a plane tangent to the surface of the record blank. Its tapering faces are inclined, with respect to a plane passing through the axis of the tool and parallel to the direction of scanning, at the same angle as and constitute extensions of the corresponding faces of the pyramid, but the distances of these faces of the tool from this reference axial plane is somewhat greater than the distance of other faces of the pyramid from the axial plane to which they are inclined. The cross-section of the pyramidal portion is therefore rectangular in any plane perpendicular to the axis of the tool and is parallel to a plane tangent to the surface of the blank and, considering its greater dimension, is transverse to the direction of scanning while its lesser dimension is in the scanning direction. The difference in these dimensions at the level of the record surface for any penetration is made equal to the length of that portion of the mark produced in the blank due to its movement relatively to the tool in the scanning direction. A tool of the type described above will operate to produce square dots. For current strengths representative of high lights the shoulders of the tool also are driven into the blank to a depth dependent upon the tone value thus depressing the general surface level in these regions. This causes the cast printing plate to have the characteristic of a "bumped" plate. As shown below, the dots produced in these high light areas will be substantially square.

The reciprocating frequency is either selected or controlled to cause staggering of the indentations produced in adjacent lines of the record blank.

Assuming that the transmitting and receiving equipments are operated so that the scanning operation at the transmitting station and the embossing operation at the receiving station are effected in synchronism and in phase, that the scanning velocity is 20 inches per second, and that the embossing tool is reciprocated 1,000 cycles per second; the resulting dot structure produced in the record blank is equivalent to that produced with a cross-line screen having 70.7 lines per inch.

By properly selecting the contrast range to be used, giving the embossing tool a desired initial bias toward the blank, insuring that the received picture current operates to control the production of current which compensates tone distortion and using the compensated current to energize the driving coil of the electrodynamic unit, the embossing tool operates to displace unit areas of the blank and thereby produce a record comprising a series of square dots in the surface contiguous to the tool and a series of pyramidal protuberances extending from its other surface, and the embossing operation will be effected in such manner that the dot structure record surface as well as the printing plates or stereotype cast from the record have the printing characteristics of a "bumped" plate, i. e., the areas, corresponding to the picture high lights, are depressed below the normal printing surface and so that varying tone values in this portion of the reproduced picture are differentiated.

Thus the recording apparatus of this invention operates to produce a printing plate and a matrix for printing plates having the desired printing characteristics and effects the result in such manner that routing, etching and other "make ready" operations are eliminated.

A more detailed description follows and is illustrated in the attached drawings, in which:

Fig. 1 is a diagrammatic representation of one form of apparatus for practicing the invention;

Fig. 2 is a cross-sectional view of an electrodynamic operating unit for the impression or embossing tool;

Fig. 3 is a schematic of positions of the tool during one operating cycle;

Fig. 4 is an elevational view of the tool viewed perpendicularly to the direction of scanning;

Fig. 5 is an elevational view of the tool viewed in the scanning direction;

Fig. 6 is a curve showing the relationship between the brightness of the original picture and the calculated brightness of the reproduction;

Figs. 7A and 7B are plan views of portions of a record representative of black and gray, respectively;

Figs. 8A and 8B are cross-sectional views, in elevation, of the portions of the record shown in Figs. 7A and 7B; and

Figs. 8C and 8D are similar views of two different high light portions of a record.

Referring to Fig. 1 there is shown a picture transmitter T connected to a receiver R by a telephone line L.

Briefly, the transmitter T comprises a cylinder 1 driven through a clutch 2 by a constant speed direct current motor 3, which is designed to provide a uniform torque and the speed of which is maintained constant by a regulator 4. This motor is connected by a gearing 5 to a lead screw 6 for driving a carriage 7 provided with a housing enclosing an optical system including a light source 8 supplying light of constant intensity, a condensing lens 9, a light valve 10, a second lens system 11, a small mirror *m* and a light sensitive electric device 12. A beam of light from the source is directed by the condensing lens through the aperture of the light valve and an image of the aperture is focussed by the second lens system to provide an intense spot of light for illuminating an elemental area of the picture carried by the cylinder 1. The light valve is supplied with current of relatively high frequency and is thereby actuated to modulate or vary the light beam at a carrier frequency rate, and light, reflected from successive elemental areas of the representation carried by the cylinder 1, is directed into the light sensitive electric device, which is thereby activated to control the production of a carrier current modulated in amplitude in accordance with the varying tone values of successive elemental areas of the representation.

The speed of the motor 3 determines the rate of scanning the picture, and this speed is maintained constant by the regulator 4, which is controlled by the interaction of current from a generator driven by the motor 3 and current from a constant frequency source 13, and current from the constant frequency source 13 is also used to control a frequency multiplier or harmonic generator 14 which supplies the high frequency current to the light valve ribbons. In this manner, the picture scanning rate and the frequency of modulation of the light beam by the light valve are fixedly related.

The transmitting station is provided with a "start" key 15 which operates to cause the picture sending machine at this station and the reproducing apparatus (to be hereinafter described) at the cooperating receiving station to be simultaneously started. Control of this function may be assigned to the receiving operator, in which event the "start" key 15 would be included in the receiving station.

The picture modulated carrier current supplied by the light sensitive electric device 12, which comprises an unmodulated component of carrier frequency and an upper and a lower side-band, is amplified by the amplifier 16, the lower side-band and the unmodulated component of carrier frequency of the modulated carrier current are selected and the components included therein and equalized by the combined band-pass filter and equalizer 17, and the selected modulation products, after being amplified by the terminal amplifier 18, are transmitted over the line L.

For a more detailed disclosure of the transmitter T and its mode of operation, reference may be made to the above-mentioned Dowd patent.

The incoming side-band components and the carrier frequency component, after being amplified by the receiving amplifier 19—which may also include means for selecting them—are rectified or demodulated by the full wave rectifier 20 to yield the picture current.

The reproducing machine, included in the receiving station, is identical in design and operation to that disclosed in the Dowd patent to this extent, that it comprises a motor 21, which delivers a constant torque and the speed of which is maintained constant by a regulator 22—similar to that used at the transmitting station; the motor is connected to a cylinder 23 by a clutch 24 which is controlled by starting current supplied from the transmitting station over a path including the control circuit 25, and a gear 26 connects the motor 21 to a lead screw 27 for driving a carriage 28. The receiving apparatus also includes a network 29 which selects and equalizes the picture current, and the regulator 22 is controlled by currents, respectively supplied by a generator driven by the motor 21 and a constant frequency source 30.

The reproducer of the present system differs from that of the Dowd patent in that an electrodynamic unit 31, similar to that used for recording sound on wax records but provided with an embossing tool, is mounted on the carriage 28. This unit includes a driving coil 32 supplied with an alternating current of selected frequency from a source 33 to cause the tool to reciprocate at a uniform rate in a plane at right angles to the surface of the record blank carried by the cylinder 23 and also a coil 34 supplied with signal current, produced by a distorting device 35 which in turn is controlled by the picture current supplied by the rectifier or demodulator 20, to control the amplitude of reciprocation of the embossing tool. Signal current is supplied to the coil 34 over a circuit including means, comprising a source 36 and an adjustable resistance 37, for impressing a biasing potential upon the coil 34, whereby the embossing tool may be given an initial bias towards the record blank, and the rotating cylinder comprises a surface layer which, while it is sufficiently rigid to support a record blank of relatively thin metallic or plastic material, is pliable enough to permit embossed material, displaced by the tool, to protrude into it.

The surface of the cylinder may comprise a fabric having a pile which extends outwardly to provide a supporting surface for the record blank, or it may consist of a semiplastic material.

The coils 32 and 34 may take the form of a single coil, as shown in Fig. 2. In this figure, the electrodynamic or operating unit comprises a substantially rectangular yoke 38 in the form of a permanent magnet; but which may be the yoke of an electromagnet carrying a coil supplied with direct current. One arm of the yoke is provided with an aperture through which projects a support 39 carrying the impression or embossing tool 40. The support 39 is mounted on a pair of flexible diaphragms 42, secured to the lowermost portion of the yoke 38. Coil 41 surrounds the support 40 and is supplied with the alternating current of selected frequency and also with signal current. The yoke is provided with an adjustable member 43 adapted to engage the surface of the blank and thereby determine the initial position or bias of the tool with respect to the blank. In the absence of signal current, the alternating current produces a varying field which cooperates with the steady field of the magnet to cause the tool to reciprocate at a constant rate, and, when signal current is supplied to the coil 41 by the distorting device 35, a field is set up which varies in accordance with variations of the last-mentioned current; and this field cooperates with the steady field of the magnet to control the amplitude of reciprocation of the tool. The embossing tool is therefore actuated to transform the blank into a record comprising a dot structure in which the dots recur at the frequency of the alternating current and the size of the respective dots is determined by the instantaneous values of the signal current supplied by the distorting device 35.

The dynamic units described above are identical in operation, and the result effected by them is the same whether a single or a plurality of coils are used and also whether the bias is mechanically or electrically controlled. Therefore the design shown in Fig. 2 may be substituted for that illustrated in Fig. 1, and one bias control means may be substituted for the other.

Use of the distorting device 35 is dictated by the fact that the system described above involves but one photographic operation instead of the two reciprocal processes, negative and positive, which, as is well known, are essential to the production of a picture having the tone values of the original. In the system herein described, the production of a picture which is a linear reproduction of the original, or the conversion of the record blank into a matrix from which printing plates or stereotypes that may be used to print a picture which is a linear reproduction of the original, requires that the picture current be subjected to a counter-distortion which is as nearly as possible an exact reciprocal of that introduced by the operation the picture current producer included in the transmitting apparatus. The distorting device 35 operates to effect the desired modification of the picture current and hence serves to supply coil 34 or 41 with picture current which has been distorted to an extent which is the reciprocal of the distortion introduced by the picture current producing apparatus and therefore a signal current adapted to effect a result corresponding to that which would be introduced by a positive photographic operation. A suitable apparatus for effecting this result is disclosed in U. S. Patent 2,084,119 of

Albersheim, issued June 15, 1937, to which reference may be made for a complete disclosure of the apparatus and its mode of operation. By controlling the device 35 so that it operates to introduce a distortion which is the exact reciprocal of that resulting from the operation of the picture current producing apparatus at the sending station, the coil 34 or 41 will be supplied with energizing current having the desired characteristics.

The dots produced in successive lines of the record blank may be staggered with respect to each other by transmitting the oscillating current supplied by the oscillator 33 to the driving coil 32, over a path including a simple rotary reversing switch mounted on a shaft 44 connected by a gear 44' to the shaft of the cylinder 23, the gear ratio being such that the switch makes one revolution for each two revolutions of the cylinder.

The reversing switch comprises two slip rings 45 and 46, respectively provided with contact brushes 47 and 48 included in the output circuit of the oscillator, and a rotary member comprising two contacts 49 and 50, respectively connected to the slip rings 45 and 46 and engaged by brushes 51 and 52, connected to the driving coil 32. As the cylinder is rotated, the alternating current supplied to coil 32 will be reversed at the end of each revolution, and the dots produced in alternate lines will be shifted half the distance between the dots of the other lines, or a distance equal to one-half cycle of the dot structure frequency.

According to another method, the dots may be staggered by supplying the coil 32 with an oscillating current having a frequency which is independent of that used for driving the motor, but is of such value that the number of marks or dots per revolution of the cylinder is a whole number plus one-half.

The record blank may comprise a relatively thin sheet of aluminum or other material which is so pliable that the portions displaced by the tool will not tend to "spring back" as the tool is withdrawn.

An embossing tool, adapted to produce square dots and which may be controlled to effect the desired result, may be designed as set forth below. This design is based on the assumption that the ink is applied uniformly to the printing plate and that there is no spreading of the image in printing. Under these conditions, reflection R of the printed half-tone image is given by

$$R = (1-r)P/S + r \quad (1)$$

where

R=reflection of the printed picture referred to unprinted white paper as unity;

r=reflection of the ink;

P=all of the removed or non-printing portion of unit screen area, and

S=unit screen area.

The reflection of ordinary black printing ink varies from 2 per cent to 6 per cent. Using an average value of 4 per cent or .04, Equation 1 becomes

$$R = .96P/S + .04 \quad (2)$$

Selecting a reflection range in the printed picture of .10 to .90 and linear reproduction between these limits, values of P/S may be calculated from Equation 2.

In order to simplify the design computations, it is first assumed that the tool has a triangular cross-section in axial planes respectively parallel

and perpendicular to the direction of scanning as shown in Fig. 3, that the tool is initially biased in the direction of the blank, i. e. when no picture current is being received, by an amount equal to .1H, where H is the useful height of the tool, i. e., the distance that it penetrates into the blank when the coil 34 is supplied with maximum signal current, and that this figure illustrates schematically the positions of the tool at various time intervals during one cycle of the dot frequency current supplied to the coil 32. The drawing has been simplified by assigning the horizontal or scanning motion to the tool and allowing the record to remain stationary (as could be done in practice if desired). The conclusions which may be drawn from the calculations are, of course, the same as when the tool holder is stationary and the record is moved.

Let a represent the amplitude of vibration of the tool due to the alternating or dot frequency current, then

$$a = H \sin \omega t \quad (3)$$

In order to produce a dot in the record blank, the axis of vibration of the tool is biased in the direction of the record a distance equal to BH, which is a function of the driving current supplied to coil 34. The instantaneous value of

$$B = B_0 + (1 - B_0) \frac{i_s}{I} \quad (4)$$

where B_0 = the initial bias adjustment for $(i_s) = 0$ and I = the maximum value of i_s .

Let x = the instantaneous value of one-half the width of the tool at the point of contact of the edge of the tool with the surface of the record blank;

y = the instantaneous value of the depth of penetration of the tool into the record;

$$\frac{dx}{dt} =$$

the horizontal velocity of the edge of the tool at the point of contact with the surface of the record, neglecting

V_0 , the picture scanning velocity, which is constant;

V = the total horizontal velocity of the tool at the point of contact with respect to the record blank and hence

$$V = V_0 + \frac{dx}{dt}$$

The depth of penetration of the tool at the time t is given by the equation

$$y = H [\sin \omega t - (1 - B)] \quad (5)$$

And since x equals the horizontal distance from a plane which is transverse to the scanning direction and passes through the apex of the tool to a point of contact of the leading edge of the tool with the surface of the blank at time t , then

$$x = \frac{W}{2} [\sin \omega t - (1 - B)] \quad (6)$$

where W = the width of the tool at its base.

While Equation 5 applies to a tool of the design disclosed in connection with Fig. 3, it is noted that a tool of this type will not operate to produce a record having the printing characteristics of a "bumped" plate, because it embodies no means for causing areas of the record blank to be depressed below the normal level of its surface and, moreover, such a tool cannot be operated to produce high light portions in which varying

tone values are differentiated. In order to depress the high light areas (produce "bumping") the tool is provided with "bumping" shoulders intermediate the height (H) of the tool. In other words, the tool is designed with shoulders at some point H' , less than the maximum height H of the tool.

Equation 5 is applicable to the portion of the tool between its apex and the "bumping" shoulder, i. e., this equation applies for all values of

$$B < \frac{H'}{H} \text{ or } x < \frac{W'}{2}$$

where W' is the width, in the direction of scanning, of that portion of the tool which is triangular in cross-section.

Differentiating Equation 5,

$$\frac{dx}{dt} = \frac{\omega W}{2} \cos \omega t \quad (6)$$

From Equations 3 and 6 it will be apparent that the maximum value of

$$\frac{dx}{dt}$$

occurs when $\omega t = 0$ and that, when this condition obtains, the amplitude of vibration of the tool (a) = 0. Moreover, the velocity

$$\frac{dx}{dt}$$

decreases with increase of ωt from 0 and is zero when $\omega t = 90$ degrees, i. e., at the time when the penetration of the tool into the record is a maximum.

For all except small values of (i_s) , there will be a value (ωt_1) of ωt for which the velocity of the edge of the tool in contact with the record will be zero, as it moves forward into the blank, and a value (ωt_2) when this velocity will be zero as the tool is withdrawn from the blank. For the first of these conditions, i. e., as the tool moves forward into the blank,

$$\frac{\omega W}{2} \cos \omega t_1 = -V_0 \quad (7)$$

or

$$\omega t_1 = \cos^{-1} \left(\frac{-2V_0}{W} \right) \quad (8)$$

and hence

$$\omega t_2 = 180 - \omega t_1 \quad (9)$$

These equations hold for the larger values of i_s as determined by

$$(1 - B) < \sin \omega t_1$$

and this will be referred to as case A.

The length of the mark under these conditions will be

$$d_A = V_0(t_1 - t_2) + 2x_1 \text{ where } x_1 < \frac{W'}{2} \quad (10)$$

For small values of (i_s) the horizontal velocity of the edge of the tool at the point of contact with the blank may be less than the velocity of scanning (V_0).

Under these conditions, i. e., case B, where $(1 - B) > \sin \omega t_1$, also restricted to

$$x < \frac{W'}{2}$$

the length of the mark is determined by the length of time the apex of the tool has been in the blank, i. e.,

$$d_B = V_0(t_3 - t_4) \quad (11)$$

By equating $y=0$, we may determine t_3 and t_4 , i. e.,

$$\sin \omega t_4 = (1-B)$$

and

$$\omega t_3 = 180 - \omega t_4$$

According to case C, i. e., when $(1-B) < \sin \omega t_1$ and

$$x > \frac{W'}{2}$$

the bumping shoulder of the tool penetrates the record blank and the length of the mark is given by

$$d_c = V_0 (t_5 - t_6) + W' \quad (12)$$

By equating $y=H'$, the time t_6 may be determined, since

$$H' = H[(\sin \omega t_6) - (1-B)]$$

whence

$$\omega t_6 = \sin^{-1} \left[\frac{H'}{H} + (1-B) \right]$$

and

$$\omega t_5 = 180 - \omega t_6$$

Assuming that the total useful height of the tool, i. e. the distance from its apex to the point of maximum penetration, is

$$H = .03''$$

that the width of the base of the tool in the direction of scanning and at a distance H from the apex of the tool, is

$$W = .014''$$

that the initial bias of the tool, i. e., when no picture current is present, is

$$B_0 = .10$$

and that the tool is provided with a bumping shoulder at a point remote from the apex of the tool a distance

$$H' = .3H = .024''$$

and using these values in Equations 6 to 10 inclusive, the table given below has been prepared.

Table

Signal	B	1-B	$(t_5 - t_6)V_0$	$2x_1$	$(t_5 - t_4)V_0$	$(t_1 - t_2)V_0$	d	R _F
1.0	1.0	0	.0041				.0153	*.895
.9	.91	.09	.00302				.0142	*.84
.8	.82	.18	.00128				.0125	*.73
.6	.64	.36		.00742		.00304	.0105	*.57
.5	.55	.45		.00615		.00304	.0092	.445
.4	.46	.54		.0049		.00304	.0079	.34
.3	.37	.63		.00364		.00304	.0067	.255
.2	.28	.72		.00238		.00304	.0054	.18
.1	.19	.81		.00112		.00304	.0042	.125
.05	.145	.855		.00049		.00304	.0035	.098
.02	.118	.882		.000112		.00304	.0031	.087
0	.10	.90			.00288		.00288	.08

The points designated (*) in the R_F column, that is, the values of the reflection factor of the effective areas for the four highest values of the signal or driving current supplied to coil 34, have been calculated from the non-punched areas.

In order to provide an embossing tool adapted to produce square dots, its horizontal dimensions transverse to the scanning direction (assuming the axis of the tool to be vertical) corresponding to the signal current values given in the table must be equal to the respective lengths of the mark (d) produced in the blank. In calculating the reflection factors it has been assumed that the dots are square, which is true except in the bumped high light regions. In these regions simple analysis shows that the dots

are rectangular. Although they are not exactly square, they are very nearly so and the bumping action of the tool depressing the record as a whole in the high lights has a tendency to rectify the small departures from the square form.

As shown in Figs. 4 and 5, the tool comprises a section 53 in the form of a pyramid adjacent the blank, surmounted by a second section 54 in the form of a frustum of a wedge. The first section has a height $.3H = .024''$, and it terminates in a rectangular base having a length, in an axial plane parallel to the direction of scanning, $(W_1) = .0112''$ and a width in a direction transverse to the scanning direction $(W_2) = .0128''$. The length of the superposed or second section in an axial plane parallel to the scanning direction $= .0160''$ while its width in an axial plane transverse to the direction of scanning is equal to that of the base of the pyramid, and, since it is symmetrical with respect to the transverse plane passing through the axis of the tool, its ends project in both directions $.0039''$ beyond the edges of the base of the pyramid to provide extensions 55 and 56 which constitute a "bumping" shoulder. The end walls 57 and 58 of this section are substantially parallel to the axial plane transverse to the scanning direction, and its side walls 59 and 60 are inclined, with respect to the axial plane parallel to the scanning direction, at the same angle as the corresponding side walls of the pyramidal portion.

Plotting the brightness values of the original picture versus the calculated values of brightness of the printed reproduction, i. e., the values given in the last column of the table, for printing ink having a reflection factor of .04, on a logarithm scale, provides the curve shown in Fig. 6. From this curve the amount and value of the compensation necessary to linear reproduction can be obtained, and this compensation may be obtained by regulating the operation of the distorting device 35.

If the receiving apparatus described above is

operated in synchronism and phase with the sending machine to scan 100 lines per inch and the rate of scanning is 20 inches per second, the oscillator 33 supplies oscillating current of 1,000 cycles per second to the coil 32 over a path including a switching means comprising the slip rings 45 and 46 and rotating contacts 49 and 50, the incoming picture current is predistorted to compensate for the distortion introduced by the picture current producing apparatus, i. e., as the reciprocal of that indicated by the curve of Fig. 6, and this compensated current is supplied to coil 34 to control the amplitude of reciprocation of an embossing tool designed as described above; a dot structure comprising symmetrical dots arranged in a succession of lines, and with those in alternate lines staggered with respect to each

other, will be produced in the record blank, which structure will be a linear reproduction of the original scanned at the transmitter, and will include high light portions comprising areas depressed different small amounts below the surface of the blank, in which areas the different size of dot structure will be different (as in the other areas) whereby varying shades or tones in these areas are differentiated the same as in other areas.

The character of the dots, produced in the record, is shown in Figs. 7A, 7B, 8A and 8B. Figs. 7A and 7B are plan views of portions of a recording of black and gray, respectively, and Figs. 8A and 8B are diagrammatic cross-sectional views taken on line I of Figs. 7A and 7B.

Figs. 8C and 8D are diagrammatic cross-sectional views of a record similar to Figs. 8A and 8B but of two different high light portions in which the shoulders of the tool have penetrated the record blank to lower the level of the tops of the dot openings below that of adjacent non-high light areas.

The showing in Figs. 7A, 7B, 8A and 8B is of different fragmentary portions of a record 61. Each portion comprises dot structures (62 to 65) representative of a distinctive tone value. These are shown as included in three scanning lines I, II and III.

The part shown in Figs. 7A and 8A consists of a background the casting from which will print as black, and dot portions 61 which will reproduce as white. This represents black. The part shown in Figs. 7B and 8B consists of half-tint dots.

The portions shown in Figs. 8C and 8D (shown only in cross-section) represent different high lights. These are "bumped" areas.

Figs. 7A, 7B, 8A, 8B, 8C and 8D are not drawn to scale. The thickness of the record blank is much exaggerated.

NN is the normal surface level of the record blank. This level is depressed to level N_1N_1 in Fig. 8C and to level N_2N_2 in Fig. 8D. The former of these figures illustrates a small "bumped" area when the driving current has the value 1, table above, and the latter figure, such an area when the driving current is .8. The horizontal portion 65, Fig. 8C, is not as wide as the portion 67, Fig. 8D, because the tool has been longer in contact with the record blank in Fig. 8C, thus making the openings wider.

The embossing tool is controlled by a dot frequency current of 1,000 cycles, the dots produced in adjacent lines are staggered a distance corresponding to $\frac{1}{2}$ cycle of the dot frequency current, and the rate of scanning is 100 lines per inch. Consequently, as indicated in Fig. 7, the distance (measured in the scanning direction) between the centers of successive dots produced in adjacent lines is .01", and their spacing in a direction at right angles to the scanning direction is also .01", therefore the distance between the centers of the dots in the direction indicated by the arrow $x = \sqrt{.02''}$, i. e., the latter distance is equivalent to that produced by a cross-line screen having 70.7 lines per inch, and the size of a unit area equals

$$\frac{1}{(70.7)^2}$$

or .0002 of a square inch. As shown in Fig. 7, the shadow dots 61 are each .004 of an inch square, and the half-tint dots 63 are each .01" square. In Fig. 8, which is not drawn to scale,

it is assumed that the normal level of the surface of the blank is N—N. As therein shown the high light portions comprise areas which are depressed below the normal level of the surface of the blank, and, for purposes of illustration, it is assumed that the initial high light mark 62 (line II) is produced by energizing the coil 34 with a driving current (i_s), the amplitude of which is somewhat less than the maximum supplied by the device 35 but sufficient to cause the shoulder to "bump" the record blank, whereas the succeeding high light mark 62 is produced by supplying maximum driving current to the coil 34.

While the device for compensating the distortion introduced by the picture current producing apparatus is herein disclosed as included in the receiving station, the present invention also contemplates its use at the transmitting station. In this case, a beam of light of constant intensity is used at the transmitting station to scan the original, and light controlled by the latter is directed to a light sensitive electric device which is thereby activated to control the production of a picture current, the latter is supplied to a device of the Albersheim type to compensate tone distortion introduced by the picture current producing apparatus and the resulting compensated current is transmitted over a line to the receiving station, or the compensated current is supplied to a modulator in which it is combined with a carrier current to produce a carrier current modulated in amplitude in accordance with the amplitudes of the compensated current and this modulated current, or one side-band and the unmodulated component of carrier frequency included in the modulation products thereby produced, are selected and transmitted. The transmission in either case may be effected over a line or by radio to the receiving station. In other words, the transmitter includes means for producing a picture current, distorting means of the type disclosed by Albersheim producing a current compensated for the tone distortion introduced by the picture current producing means, and means for transmitting the compensated current over a line, or means, utilizing this current, for producing a signal modulated current suitable for transmission over a line or a radio link to a receiving station.

The transmitter disclosed in Horton U. S. Patent 1,654,374, December 27, 1927, but modified by the insertion of the distorting device 35 between the picture current amplifier PCA, including vacuum tube 11, and the picture modulator PM, comprising vacuum tube 22, may be used at the sending station, and the receiver may be of the type disclosed in this application, except that the compensator 35 is omitted, and the compensated current produced by the rectifier or demodulator 20 is selected by a low-pass filter and is supplied to the signal coil 34 of the electrodynamic unit. If desired, the Horton transmitter may be provided with means whereby light reflected from the original is directed to the light sensitive electric device. This may be accomplished by providing a scanning means of the type herein shown, in which the ribbons of the light valve are not supplied with current of carrier frequency.

In case the line is adapted to the transmission of the compensated current, the output of the compensating device 35 may be connected to the line, and, in each of the modified systems, ampli-

fiers may be used to raise the energy level of the compensated current wherever found desirable, at either the transmitting or receiving station.

Again, the design of the embossing tool, described above, may be modified to effect a distortion which is the reciprocal of that indicated by the curve of Fig. 6 and thereby compensate the tone distortion introduced by the picture current producer, and when the signal coil 34 is supplied with the incoming picture current or the demodulated picture current, the embossing tool will operate to produce a dot structure record of the type herein disclosed, i. e., a structure which is a linear tone reproduction of the original and which has the printing characteristics of a "bumped" plate, or which constitutes a matrix for casting plate having the printing characteristics of a "bumped" plate.

While the invention has been described above as applied to a specific form of system of telephotography it is to be understood that it is applicable also to other forms of systems and in certain of its aspects is not limited to telephotography. For example, the recording may be effected immediately after generation of the image currents without the transmission of these currents to a distance point for recording. A tool shaped in accordance with the invention may be used to produce a printing plate matrix which is relatively thick, the front face serving as the base for casting. In this case the shoulders on the tool are omitted as the "bumping" action must be dispensed with. The record may be in the form of a flat plate and moved as a whole in a single plane rather than being placed around a rotatable cylinder. Again, the record may be stationary and the tool carriage given the necessary movement to effect recording. Other modifications will be apparent to any one familiar with the art of producing embossed plates to be used in half-tone reproduction.

What is claimed is:

1. An image record suitable for use in the art of telephotography, comprising a thin plate having parallel rows of indentations therein corresponding to elemental portions of a picture or view, the depths of said indentations being greater than the thickness of said plate and varying with the tone values of said elemental portions.
2. The record plate of claim 1 having regions containing a group of adjacent perforations which are alike, each said region being representative of a group of elemental portions of the picture or view having the same tone value, which regions are depressed below the level of another region of said plate representative of another tone value by amounts dependent upon the tone values of said first-mentioned regions.
3. An image record plate suitable for use in the art of picture or view reproduction, having surface regions thereon depressed by different amounts in dependence upon the tone values of areas of the original picture or view, each said region having a dot array structure in which the dots are representative of elemental portions respectively of the corresponding area of said picture or view, the surfaces of said plate having like contours.
4. In the art of telephotography, the combination with a record blank of means for continuously moving said blank, a tool, means for oscillating said tool with varying amplitudes, in accordance with variations in a received signal, in a path transverse to the direction of movement

of said blank to cause said tool to repeatedly penetrate the surface of said blank, the width of said tool transversely of the direction of movement of said blank being greater than the dimension of the tool in the direction of movement of the blank in a plane perpendicular to the movement of the tool and each of said dimensions being progressively greater in a direction away from said blank, the speed of movement of said blank and the shape of said tool being such as to cause each surface opening to extend a distance in the direction of travel of said blank substantially equal to the width of said opening.

5. The combination of claim 4 in which said blank is a thin sheet of deformable material in which said tool makes deformations of varying depths, the depth of each of said deformations being greater than the thickness of said sheet.

6. The combination of a tool suitable for use as the stylus in a telephotograph receiving apparatus of the type in which a stylus is oscillated into and out of the path of a moving record blank, the cross-sectional area of said tool being relatively small near one end thereof and progressively increasing therefrom toward the other end, said tool having shoulders separate from each other respectively positioned on opposite sides thereof remote from said small end and no longer than the width of said tool at their level in the direction transverse to record travel, with means for so orienting and driving said tool that said shoulders indent said record for certain values only of driving force.

7. A tool suitable for use as the stylus in a telephotograph receiving apparatus of the type in which a stylus is caused to repeatedly penetrate the surface of a record blank to effect recording, which tool is of general pyramidal shape with four generally diverging sides, one pair of opposite sides having a different slope with respect to the longitudinal axis of the tool than the other pair, the cross-sectional area of said tool in a plane perpendicular to said axis being rectangular in shape.

8. A tool as defined in claim 7 having plane sides only.

9. A tool as defined in claim 7 having each of one pair of opposite sides terminating in a shoulder and the other sides having no shoulders and extending beyond the level of said shoulders with continuing divergence.

10. In the art of reproducing pictures, the method of producing a printing plate which comprises making parallel rows of indentations in the plate of different size in conformity with the light-tone values of the picture to be reproduced and of greater depth than the thickness of the plate whereby the contour of the indented plate is substantially the same on the rear face as on the front face, and utilizing the rear face as a base for casting the printing plate.

11. In the art of telephotography, the method of producing a printing plate which comprises oscillating a stylus into and out of the path of a moving thin record plate under control of incoming telephotograph currents to cause said stylus to produce deformations in said plate in the form of protrusions of varying height on the rear thereof, and utilizing the rear surface of said plate as a base for casting a printing plate.

12. A telephotograph receiving apparatus comprising a record support, a record blank upon said support, a stylus holder, a recording stylus oscillatable in said stylus holder in a direction substantially perpendicular to the record surface

at the recording point at each instant, a source of alternating current for driving said stylus, means for causing comparatively rapid relative cyclic motion between said support and said stylus holder, means for causing comparatively slow relative movement between said support and said stylus holder in a direction perpendicular to said first motion, means for oscillating said stylus alternately into and out of contact with the surface of said record blank a multiplicity of times during each of said cyclic movements, whereby a recording in dot form is produced along parallel lines of said record, said last means including means for causing the oscillatory movement of said stylus to be different at the end of each line from that at the beginning of each line of dots and the same as that at the beginning of the next line, whereby a staggered dot structure is produced.

13. A telephotograph receiving apparatus comprising a record support, a record blank upon said support, a stylus holder, a recording stylus oscillatable in said stylus holder in a direction substantially perpendicular to the record surface at the recording point at each instant, a source of alternating current for driving said stylus, means for causing comparatively rapid relative cyclic motion between said support and said stylus holder, means for causing comparatively slow relative movement between said support and said stylus holder in a direction perpendicular to said first motion, means for oscillating said stylus alternately into and out of contact with the surface of said record blank a multiplicity of times during each of said cyclic movements, whereby a recording in dot form is produced along parallel lines of said record, and means for effectively reversing the direction of current from said source when each line has been completed, whereby the dots in the even lines are staggered with respect to those of the odd lines.

14. The method of producing an image having a staggered dot structure from currents representative of tone values of successively scanned elemental parallel lines of a picture or view, comprising the steps of producing a cyclically varying current, utilizing said current to control the production of a dot during one portion only

of each cycle of said current and a succession of said dots in parallel lines, the frequency of said current being such, with relation to the length of a line, that at the time of completing a line the phase of said current is different from that at the time of beginning said line, and beginning an adjacent line when the current phase is substantially the same as that at the completion of the preceding line.

15. An apparatus for producing a matrix from and corresponding to an original picture or view which is scanned by electro-optical means to produce a current which varies in accordance with the tone values of successive elemental areas thereof, comprising a movable record blank of deformable material, an impression member reciprocated uniformly in a plane normal to the surface of said blank, means controlled by said current for varying the amplitudes of the reciprocations of said tool to cause successive unit areas of said blank to protrude in a series of lines, and means for controlling the relative motion of said blank and said tool to cause certain protruding portions produced in adjacent lines of said blank to overlap each other in both directions.

16. A tool suitable for use as a stylus in a telephotograph receiving apparatus of the type in which a stylus is caused to repeatedly penetrate the surface of a moving record blank to effect recording by deforming the material of the blank without cutting away portions thereof, said tool having a continuous taper throughout the portion thereof designed to penetrate below said surface, each cross-sectional area of said portion in planes parallel to said surface having a slightly lesser maximum dimension in the direction of travel of the tool than in the transverse direction, the respective differences in said dimensions in said planes being just sufficient to cause the surface produced by penetration of said tool to have the same maximum dimension in the direction of travel of the tool as transversely thereof regardless of depth of penetration when a predetermined constant relative speed between said surface and said tool is maintained.

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