

Jan. 12, 1937.

W. C. HOWEY ET AL

2,067,489

PHOTOELECTRIC ENGRAVING

Filed Nov. 4, 1931

2 Sheets-Sheet 1

Fig. 1.

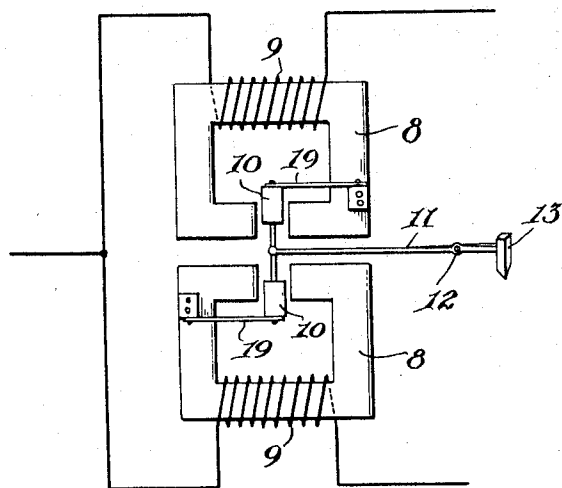


Fig. 2.

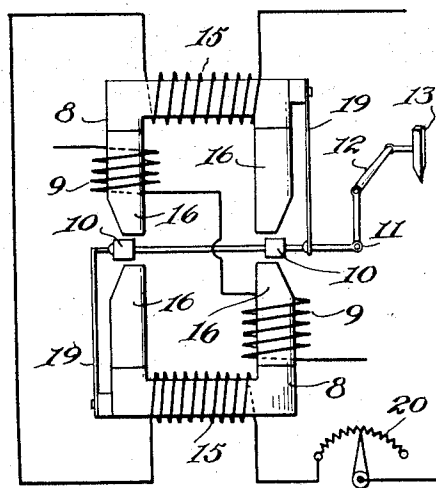


Fig. 3.

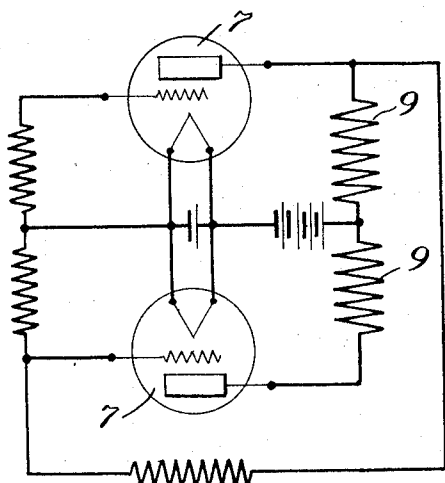
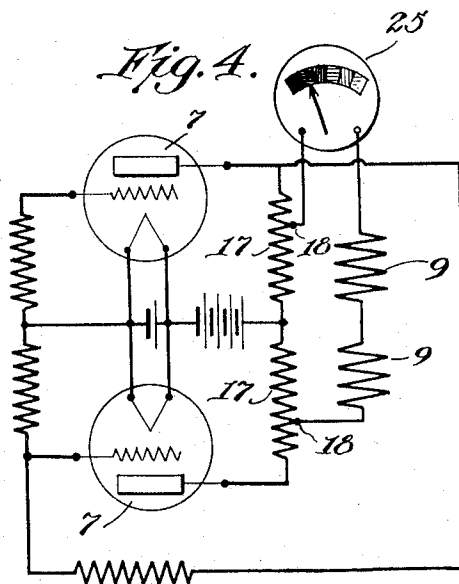


Fig. 4.



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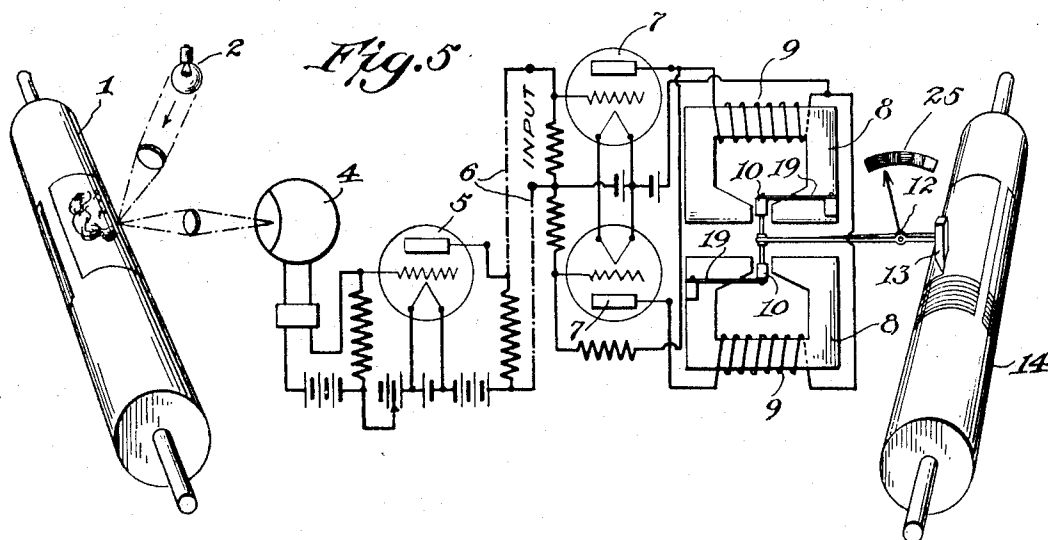
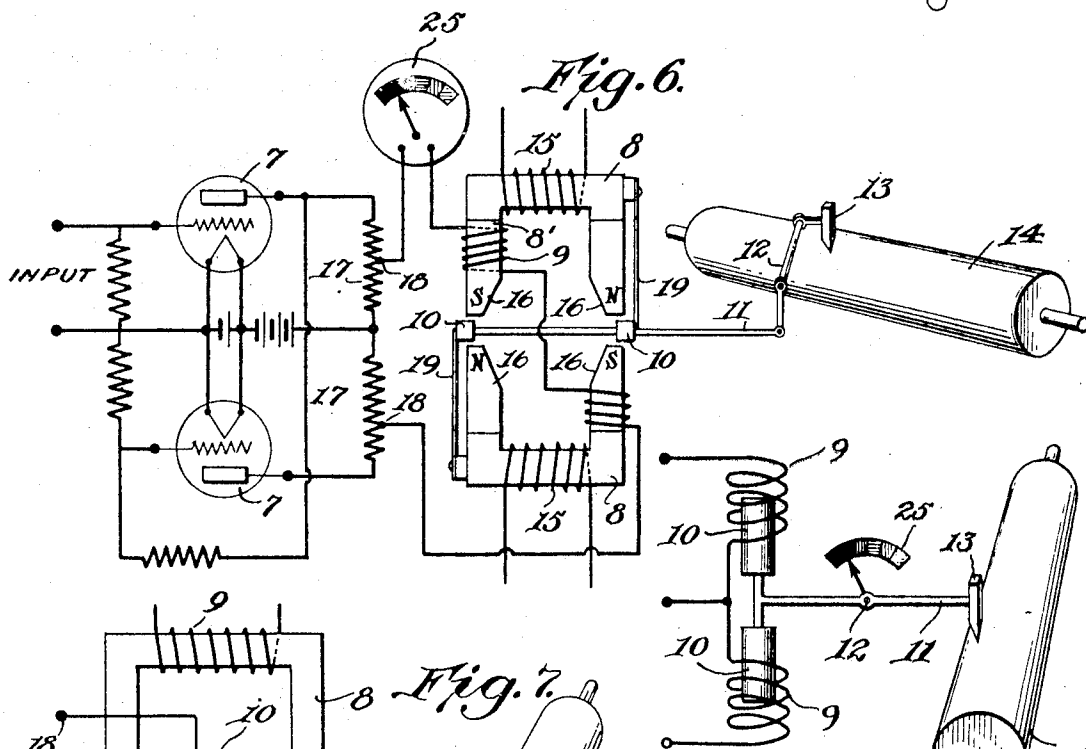
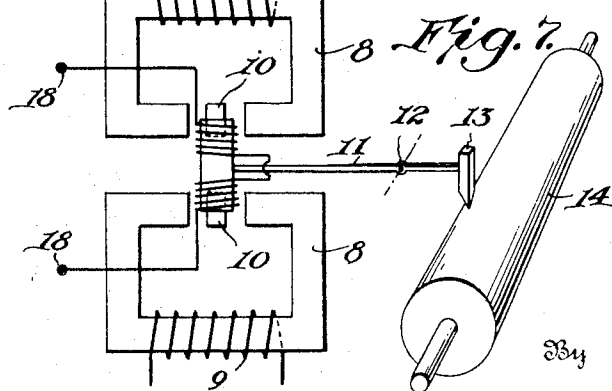
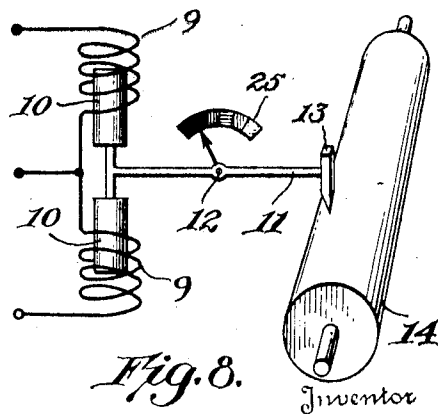
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,067,489

PHOTOELECTRIC ENGRAVING

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Application November 4, 1931, Serial No. 572,999½

4 Claims. (Cl. 178—5)

My present invention is an improvement in processes of photoelectric engraving and picture telephony, with particular improvements in the method of translating received impulses, comprising picture and tone frequencies into automatically engraved plates ready for press printing. It embraces features described in the annexed specifications and claims.

This invention is an improvement in the photoelectric engraving art exemplified in the following U. S. patents issued to Walter Howey viz:— 1,914,258 of June 13, 1933 for Machine for producing printing plates; No. 1,815,105 on Cylindrical scanning, July 21, 1931; No. 1,849,544 on The process of and apparatus for producing printing plates, March 15, 1932; and No. 1,923,208 on Pantographic scanning, August 22, 1933.

In U. S. Patent, No. 1,914,258, June 13, 1933, two methods of tone control were indicated. One was an induction type solenoid, using a spring for counter control. The other plan utilized a magnetically controlled variable stop in conjunction with an intermittent magnetic relay-operated pivoted lever. The present invention provides for a cutting head comprising a graver and means for maintaining complete control over its movements, subject to the picture and tone frequencies, both for black and white or line engraving, and for tone engraving including delicate gradations in tone which may occur as low as ten cycles or just above zero frequency. It also provides for engraving at high speed into metal without making the controlling unit subject to shock and vibration from metal shavings. It also provides for maximum power applied to the controlling unit throughout the whole range of tones from black through the middle tones to white. This is accomplished by the use of reverse current on the controlling unit.

It also provides for the control with continuous torque, by the output of the amplifying three or more element vacuum tube circuit, of a push-pull inductive relay in such manner that a small amount input power is amplified by the relay itself, and this, together with mechanical leverage, cuts into metal with the delicate response of a milliammeter and the accuracy of one six thousandth of an inch, so as to engrave a tonal reproduction of the photoelectrically transmitted subject. It has been found that as much power is required to withdraw the graver for cutting shadows, as to hold it at a middle point for cutting middle tones or to sink it for the highlights.

In the process of automatic photoelectric en-

graving, which is described heretofore, it is necessary that the device which engraves the picture be accurately responsive to minute impulses of short duration as well as powerful impulses of long or short duration or any other combination of strength of impulse and duration of time involved. That is, an engraving device suitable for engraving halftone pictures by the variable area line or dot method described in the above said patents, must respond equally well to all the variations of tone in the subject. It should be capable of responding to the variations at high speeds, since one of the objects of the photoelectric engraving process is to reduce materially the time of engraving. It should be able to engrave a line or groove of constant width until such time that the light reaching the controlling photoelectric cell dictates a change in the width of said line.

Heretofore, it has been found difficult to combine all of the above described desirable characteristics in one engraving device. The motors which had suitable frequency response characteristics were found to lack in power needed for engraving in metals. Those which had sufficient power were found to be sluggish in operation due to the inertia of their moving parts. None of them could engrave a half tone with all of the detail of photoengraving, since, when the armature of the motor was in a position for engraving a halftone line, the power applied to the tool was neutralized. Another reason for previous types of vibratory motors failing to engrave halftone detail with the accuracy of photoengraving was that the force with which the armature drove the tool into the material being engraved was proportional to the square of the distance which the tool cut into the material.

It is clear that, since a photograph or picture having gradual tone gradations will reflect corresponding values of light gradations, a device designed to engrave an exact reproduction of the original must respond to and hold the position of the cutting tool for each of the particular tones as long as that tone is being scanned. It is this particular feature of our invention that sets this device apart as novel over the old forms of engraving devices. Another novel feature of our invention is the use of magnetic leverage to obtain greater power than is dissipated in the controlling coils of the device. Another feature which enhances greatly the usefulness of our invention is the arrangement of the mechanical leverage so that all of the shock of cutting the metal is directed against the

supporting bearings of the cutting arm not shown. This reduces mechanical vibration to a minimum and prevents damage to the delicate controlling mechanism. Before using this expedient, it was impossible to engrave an undistorted picture due to the vibration of the cutting arm.

In the device described herein, the armature responds with equal force regardless of the depth to which it cuts. When once the power of the device has been adjusted to drive the cutting tool to a sufficient depth into the material, the variations in the depth depend only on the intensity of the current in the controlling coils of the magnets. Although it is possible to make a motor of the type described which will engrave suitably without the use of leverage, it has been found that the proper use of leverage not only increases the power available for engraving, but increases the response since the moving parts may be made correspondingly lighter thus having less inertia.

It is obvious that any motive device which depends on the action of a spring for moving its armature in one direction, is subject to control in one direction only. Withdrawal, as well as insertion, of the cutter from the metal to be cut should be under photoelectric cell control.

In order that a device designed to be controlled with equal precision in both directions of the movement of its armature may be thus controlled, the output of the controlling amplifier must be arranged for pushpull operation. One reason for this is that the power obtained from one tube may be used to move the armature in one direction and the power from the other tube to control the movement of the armature in an opposite direction while the combination of the power from both tubes is used to control the variations in the middle tones. Other reasons for employing pushpull amplification will be made apparent in the following specifications and description.

One object of our invention is, therefore, to provide a source of motive power for electrically controlled engraving in which the amplitude of the variations of the movement of the armature will be a linear function of the controlling aperiodic electric current.

Another object of our invention is to provide an engraving head, in which the use of leverage will make it possible to realize a relatively large amount of power with a relatively small amount of controlling power.

Still another object of our invention is to provide a vibratory engraving head which does not depend on spring action for any part of its movement.

Other objects of our invention will be apparent from the following specifications and description:

Fig. 1 is a diagrammatic modification of Fig. 2 accompanying the specifications of our application, Serial No. 424,809 filed Jan. 31, 1930 which on March 15, 1932 matured into Patent No. 1,849,544.

Fig. 2 is a diagram of an improvement over the device of Fig. 1.

Fig. 3 is a diagram of the pushpull vacuum tube circuit used to control the device of Fig. 1.

Fig. 4 is the diagram of the pushpull direct current circuit used to control the device of Fig. 2.

Fig. 5 is a diagram of photoelectric engraving, showing a mechanical tone indicator.

Fig. 6 is a diagram of an improved form of engraving head connected to the output circuit of a power amplifier, and an electrical tone meter.

Fig. 7 is a diagram of an electrodynamic coil type of engraving head.

Fig. 8 is a diagram of a pushpull solenoid type of engraving head.

In practicing our invention, we may use whatever alternatives of structure which the exigencies of the case may demand, without departing from the broad spirit of the invention.

Fig. 1 shows two electromagnets 8 in juxtaposition to each other and energized by the coils 9. In the air-gap between the electromagnets is suspended an armature 10, so that when part of the armature is in the field of one of the electromagnets, a great part of the armature will be out of the field of the other magnet. That is, if each half of the armature is equal in width to the width of the field of one of the electromagnets, when one-half of the armature is entirely in the field of one it will be entirely out of the field of the other. The armature may be suspended in the center of the air-gap by the flat springs 19 or by any suitable method, which will prevent the armature from striking the pole-faces.

The armature may be connected to a lever 11, which is pivoted at 12 and on the end of which is a cutting tool 13. The coils 9 are connected in series and the center tap used for the positive plate supply terminal. The other two terminals of the coils are each connected to the plate of the vacuum tube arranged for pushpull operation.

Fig. 2 shows two electromagnets 8, mounted in juxtaposition each to the other, so that the magnetic field of one will be in series with the magnetic field of the other as shown. These magnets may be energized by the coils 15 or by permanent means. If it is desirable that the magnetic force be variable, a rheostat 20 may be inserted in the circuit with the coils 15. The magnets 8 are provided with pole-pieces 16 on which are wound, for convenience, on diametrically opposite poles, coils 9, which constitute the controlling elements of the device. The coils are wound so that the direction of the current in one coil tends to increase the magnetic force across one set of poles while the current through the other coil tends to decrease the magnetic force across its corresponding set of poles, at the same instant.

In the gap between the two magnets is suspended an armature 10 in such a way, that when half of the armature is in the field of one set of poles, the other half of the armature will be entirely out of the field of the other set of poles. It is assumed here as for the device in Fig. 1 that the width of half of the armature is equal to the width of one set of pole faces. The armature may be suspended in the center of the air-gap by the flat springs 19 or by any other suitable means which will prevent the armature from striking the pole-faces, but which will allow free longitudinal movement of the armature.

The armature may be engaged with a lever 11 which is pivoted at 12 and on the end of which is a graving tool 13. The windings of the coils 9 are connected in series and the two other terminals connected to the output of the power amplifier.

Fig. 3 shows a vacuum tube circuit arrangement for push-pull operation, in which the coils 9 of Fig. 1 constitute the plate circuit of the

tubes 7. The power tubes may be controlled by any suitable amplifier which will satisfy the particular conditions to be met.

Fig. 4 shows a similar circuit as that in Fig. 3, but with the tapped resistors 17 replacing the coils in the plate circuits of the power tubes 7. The resistors 17 are tapped at the points 18 which are determined by the amount of current which it is desired shall flow in the coils 9 and the plate resistance of the tubes 7.

Fig. 5 shows a rotatable cylinder 1 adapted to hold a pictorial subject to be engraved. Light from a source 2 is focused on the picture, and the light reflected therefrom focused on the photoelectric cell 4 by the optical system 3. The photoelectric impulses are amplified by the head amplifier 5 and may then be transmitted to a distant point by radio, or wire, or further amplified, any of which expedients being illustrated by the dotted lines 6. The direct current output of the push-pull tubes 7, which is controlled in intensity by the amplified photoelectric currents, is fed through the coils 9 of the magnets 8. Suspended in the fields of these magnets is an armature 10 which is coupled to a lever 11 which in turn is pivoted at 12 and on the opposite end of which is held an engraving tool 13. Controlled by the variations in the strength of the magnetic fields of the coils 9, the tool is made to engrave in a plate of suitable material held on a second cylinder 14, which may be geared to the first cylinder or, if remote from the transmitting cylinder, may be driven by a synchronized motor (not shown).

Coupled to the lever 11 at the point of pivot 12 so as to swing in an arc over a dial 25, is an indicating pointer. The dial may be graduated in tones ranging from black to white or from one end of the spectrum to the other as desired. The pointer is adjusted so that when the lever is in such position that the tool is sunk to the maximum depth into the metal, it will point to white and when the tool is in position to engrave the deepest shadows, the indicator points to black. The indicator will then point to all of the intermediate tones or colors which the graving tool cuts.

In series with the coils 9 and mounted conveniently so as to be easily observed is an electrical tone indicator 25. This tone indicator consists of a zero center milliammeter provided with a special scale which is graduated in tone gradations ranging from black to white. Since the current in the coils 9 reverses when changing from black to white or vice versa, as the photoelectric cell dictates, it is obvious that when the milliammeter reads maximum current in one direction, the tool will be engraving a shadow and maximum current in the other direction will indicate that the tool is engraving a highlight. When the meter indicates zero current flowing in the coils, the tool is engraving the middle tone of the scale. If then the hand of the meter is made to follow a graduate scale of tints or tones, it will provide an accurate indication at all times of the position of the tool in the metal or other substance being engraved and enables the operator to more easily adjust the electrical circuit to conform to the tones of the picture he is engraving.

Fig. 6 shows a variation in the design of the electromagnetic engraving head, and in the plate circuit of the push-pull power amplifier tubes 7. In the arrangement of Fig. 6, coils 15 are connected to a source of direct current and are for

the purpose of providing an intense magnetic field. The electromagnets 8 are provided with polepieces 16 on which are wound small coils 9. These coils are connected in series as shown and connected across the resistor 17 at 18 which points on the resistors are variable in position and are determined by the amount of current which it is desired that the coils 9 shall carry. The operation of the engraving head is as was explained in connection with Fig. 2, and causes the engraving tool 13 to engrave in a suitable plate held on the cylinder 14.

In series with the coils 9 and mounted conveniently so as to be easily observed is an electrical tone indicator or meter 25. This tone meter consists of a zero center milliammeter provided with a special scale which is graduated in tone gradations ranging from black to white. Since the current in the coils 9 reverses when changing from black to white or vice versa, as the photoelectric cell dictates, it is obvious that when the milliammeter reads maximum current in one direction, the tool will be engraving a shadow and maximum current in the other direction will indicate that the tool is engraving a highlight. When the meter indicates zero current flowing in the coils, the tool is engraving the middle tone of the scale. If then the hand of the meter is made to follow a graduated scale of tints or pictorial tones, it will provide an accurate indication at all times of the position of the tool in the metal or other substance being engraved and enables the operator of the machine to more easily adjust the electrical circuit to conform to the tones of the picture he is to engrave.

Fig. 7 shows an engraving head in which the inductive armature of the type illustrated in Figs. 1 and 2 is replaced by the moving coil armature 10. In this device the armature is connected in the circuit of the pushpull output tubes in the same way as in the device of Fig. 2 as shown in Fig. 6. The coils are mounted on a suitable frame which is coupled to a lever 11 and actuate the tool 13, causing it to engrave in a plate held on the cylinder 14.

As does the engraving head of Fig. 2, the moving coil type shown in Fig. 7 depends on the reversal of current in the coils 10 to control the variations in depth to which the tool 13 cuts. That is, when the current flows in one direction through the coils, the tool moves in one direction and when the current reverses through the coils, the tool moves in the opposite direction.

Fig. 8 shows an engraving head comprising two solenoids 9 connected in pushpull as shown in the circuit of Fig. 3 or for reverse current as shown in Fig. 4. An armature 10 which is common to both solenoids actuates a lever 11 to which is fastened the graving tool 13.

As shown in the diagram the flow of current through one solenoid will draw the armature in one direction while current through the other solenoid will draw it in the other direction. Equal current in each solenoid will center the armature and cause the tool to engrave the middle tone. Any other variation of the ratio of currents in the two solenoids will then cause the armature to assume corresponding positions and engraved the other tones from black to white.

The operation of the device shown in Fig. 1 is as follows: The two electromagnets 8 are magnetically separate and independent of each other in their action. The armature 10 is made in two parts magnetically insulated from each

other, but rigidly connected together and attached to a lever 11, which may be used to actuate a cutting tool 13. The armature is suspended in the fields of the magnets, so that the air-gaps between the armature and the pole-faces are equal on each side and so that when the armature is balanced in the middle of its swing, part of each half of the armature will be in the field of its corresponding magnet. It is important here that the armature be in or out of the field in opposite directions, so that any tendency of one half of the armature to move into its field will force the other half out of its field an equal amount.

Referring to the diagram of Fig. 3, it will be seen that, since the vacuum tubes 7 are arranged in push-pull, if the plate current of one tube rises to a maximum value, the plate current of the other tube will fall to zero and vice versa; if the plate current of one tube is half of its maximum value, the plate current of the other tube will assume an equal value.

It is then clear that if the coil of one electromagnet forms the plate load of one tube and the coil of the other electromagnet forms the plate load of the other tube of the push-pull circuit, the magnetic flux of the electromagnets will rise and fall in accordance with the rise and fall in the plate currents of the corresponding tubes.

An increase in the density of the magnetic flux in the field of one magnet will cause the armature to shift its position so as to put more iron in the field and thus decrease the reluctance of the magnetic circuit. This, as specified above, will move the other half out of its field in an opposite direction. However, when the plate current of the first tube is caused to decrease, the current and consequently the magnetic flux of the other magnet increases, causing the armature to shift in the other direction. If the plate currents of both tubes are the same, the armature will assume a position midway between the two extremes of its swing. Since the position of the armature is a linear function of the plate currents of both tubes, it will be seen that any position taken by the armature will be held until the plate currents of the tubes change due to the controlling impulses on the grids of the tubes.

In this type of engraving head, the power which may be realized depends on the number of turns of wire in the energizing coils and the intensity of the plate current flowing through the coils. It also depends on the width of the air-gap, being greater for small gaps. However, the power may be greatly increased by employing leverage. Either simple or compound levers may be used. By employing a simple lever of the type shown in Fig. 1, of about four-to-one ratio, enough power may be obtained to engrave to suitable depths in metals such as zinc and copper. By increasing the leverage, the tool may be made to cut into steel or any of the materials commonly used for engraving purposes.

While the engraving head described above and illustrated in Fig. 1 is powerful and is useful for certain types of engraving, its frequency response is inherently low, due to the necessarily high inductance of the magnet coils, and the inertia of its armature which must be large in order to obtain the power needed. It was with a view to increasing the frequency response, rather than the power, that the improvement shown in Fig. 2 was invented.

In this type of engraving head, the magnets 8 may be permanently magnetized or may be electromagnets. In any case the magnetism of these cores remains constant. The two magnets are not independent of each other, but are arranged so that their fields are in series and therefore form a complete magnetic circuit. The magnetic circuit is broken by spaces between the polepieces in which the armature is suspended. The armature 10 is suspended by the springs 19 in the same way as in the device of Fig. 1, and the action which causes the armature to shift its position with respect to the field is the same as was described for the first type of motor.

On each pole of the two magnets, is a soft iron pole-piece. On one of the pole-pieces of each magnet, for convenience two of which are diagonally opposite, is wound a coil of a suitable number of turns of wire, such that the inductance of the coil will be relatively low and the amount of current which they will carry will match the current in the plate circuit of a power tube when operated under normal conditions. One set of coils used had a direct current resistance of approximately three hundred ohms, and had about five hundred turns of wire. The two coils are connected permanently in series, in such a way that current through one coil tends to increase the magnetic flux across one pair of pole-pieces, while at the same time the current through the other coil tends to decrease the flux across the other pair of pole-pieces. The armature then shifts in the direction in which the flux is a maximum, or, when the flux across each pair of poles is the same value, assumes a midway point. It will then be seen that the position of the armature in the fields of the magnets, depends on the direction of the current in the coils. That is, for each shift in direction of movement of the armature, the direction of current in the two coils must change simultaneously, which will be the case when the two are connected in series.

Referring now to the diagrammatic circuit of Fig. 4, it will be noted that the circuit is substantially the same as the circuit of Fig. 3. In this circuit, however, the two tapped resistors 17 take the place of the coils 9 of Fig. 3. In operation, the terminals of the series coils of Fig. 2 are connected to the taps as shown in the drawings. The position of the taps will depend on the plate resistance of the tubes used in push-pull and the intensity of the current which it is desired that the coils shall carry. It is important that for efficient operation, the total impedance of the plate circuits of the tubes with the coils connected, shall not be less than the impedance of the vacuum tube used.

Although the current in each branch of the push-pull circuit as illustrated by the resistors 17, does not change direction, because the coils 9 are connected across an equal amount of each resistor, the current through it will be in one direction when one tube draws current, and in the other direction when the other tube draws current. This is because the plate current of each tube passes through the same coil, and in order to reach each tube from the same source must reverse in direction.

If it is desirable that the strength of the magnetic field be variable to suit the particular problems of engraving in hard and soft materials, or to increase the frequency response, a rheo-

stat 20 may be inserted in the circuit carrying the current for the coils of the magnets 8.

In the use of the words, subject, photograph, or picture they include all the areas that in any suitable arrangement for synchronously scanning and engraving, may be effectively scanned and synchronously engraved. The subject may comprise one or more pictures within the area that is being scanned simultaneously and synchronously reversed to read from right to left from subjects reading from left to right.

What we claim is:

1. A photo-electric engraving system, comprising photo-electric means for successively scanning elemental areas of a subject, vacuum tube direct current amplification for the output of the scanner, a pivoted member, an armature having disconnected poles attached to the member at one side of the pivot, an engraving tool attached to the member on the other side of the pivot, a separate magnetic field for each armature pole, a push-pull amplifier receiving its input from the amplified scanning current and delivering its output to differentially maintain the magnetic fields in accordance with the changes of the scanning current to thereby produce an engraving through the variable penetration of the engraving tool into a suitable material serviceable for direct printing, and means for moving the material synchronously with the subject.

2. A photo-electric engraving machine which comprises light sensitive means for scanning a subject and producing therefrom a scanning current, direct current means for amplifying the scanning current, a pivoted engraving arm, an engraving tool at one end, a bipolar armature at the other end, a push-pull amplifier responsive to the output of the amplifying means, a magnetic field adjacent each pole of the armature energized differentially by the output of the push-pull amplifier, means for directing the amplified currents to definitely hold the armature and the engraving tool at variable positions with respect to the surface of an engraving material corresponding to the lights and shades of the

subject which is being scanned, and means for moving the subject and the material synchronously so as to thereby produce an engraving for direct printing.

3. An engraving device comprising a material to be engraved, a fulcrummed holder, an engraving tool supported on the holder spaced apart from the fulcrum, a two part armature on the holder removed from the fulcrum and the tool, one part of the armature serving to move the tool in one direction and the other part serving to move the tool in the opposite direction, a separate magnetic field for each part of the armature, a photo cell for scanning a subject possessing changes of tone values and producing therefrom a scanning current, means for amplifying the scanning current, means for automatically utilizing corresponding changes of current to modify the magnetic fields and control the tool to produce an engraving for direct printing under the direction of the subject, and means for moving the material and the subject synchronously.

4. A system of photo-electric engraving, comprising light sensitive means for scanning a picture composed of varying lights and shades and producing currents corresponding thereto, push-pull amplifying means responsive to currents produced by the scanning, an engraving tool, a fulcrummed arm for supporting at its one end the tool, an armature on the arm, in spaced apart relation to the tool and the fulcrum adapted when attracted to move the tool into an engraving material, a separate armature adjacent to and separated from the former to move the tool in an opposite direction, a separate magnetic field and windings therefor for each armature, connections from the push-pull amplifier to differentially attract the armatures to thereby positively hold the tool at different positions to interpret the picture into an engraving for immediate printing, and means for moving the picture and engraving material synchronously.

WALTER CRAWFORD HOWEY.
BENJAMIN WESTON WOODWARD.