United States Patent [19]

De Vos et al.

[11] **3,769,455**

[45] **Oct. 30, 1973**

[54] **METHOD AND APPARATUS FOR MAKING HALF-TONE SCREEN PRINTING CYLINDERS**

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[73] Assignee: **N. V. Werkspoor-Amsterdam,** Amsterdam, Netherlands

[22] Filed: **Mar. 1, 1972**

[21] Appl. No.: **230,649**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 807,905, March 17, 1969, abandoned.

[52] **U.S. Cl.** ..... **178/6.6 B**

[51] **Int. Cl.** **H04m 5/76,** H04m 1/06

[58] **Field of Search** ..... 178/6.6 B, 6.7 R; 101/DIG. 2

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Primary Examiner—Terrell W. Fears
Assistant Examiner—Alfred H. Eddleman
Attorney—John P. Snyder et al.

[57] **ABSTRACT**

The depth of penetration of the electromagnetically driven engraving element of an engraving machine into the material to be engraved is regulated by controlling the electromagnetic driving system of the engraving element with the aid of alternating current and of direct current. The value of the direct current and also the amplitude of the alternating current are varied in dependence on the measured grey value of the required engraving and the engraving element is spring biased in the direction to penetrate into the cylinder being engraved. The alternating and direct current signals are combined to produce a combined signal in which the amplitude excursions opposing the biasing spring are clamped to a selected level at which the winding of the engraving assembly is saturated. The frequency of the ac signal is greater than the resonant frequency of the engraving assembly and the sum of the displacements of the engraving element in opposition to the biasing spring, which displacements are due respectively to the dc signal and to the ac signal, is a constant. The movement of the engraving element is in phase opposition to the current through the engraving assembly winding and the winding current effects saturation thereof at the point of maximum penetration by the engraving element.

13 Claims, 7 Drawing Figures

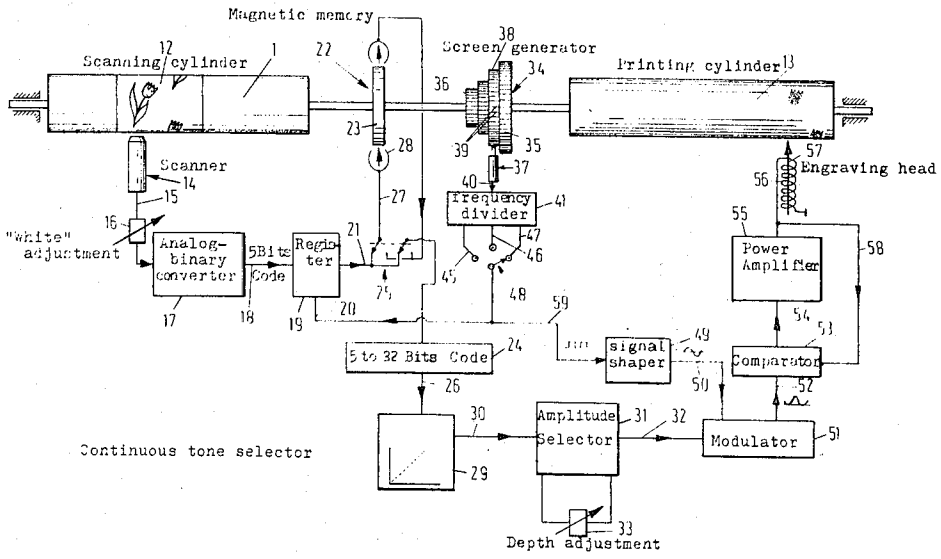


FIG. 1

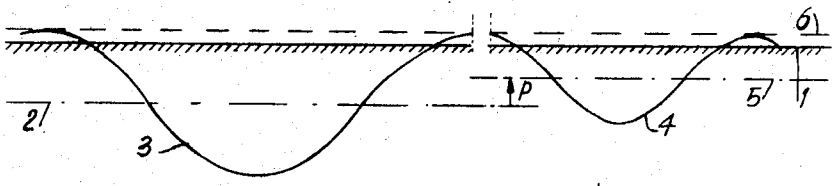


FIG. 2

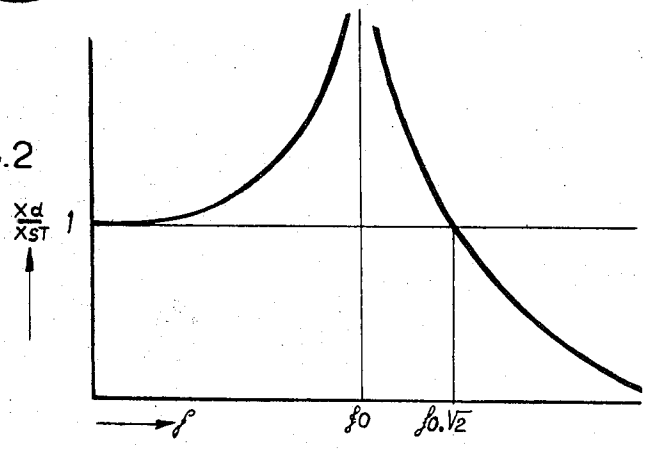
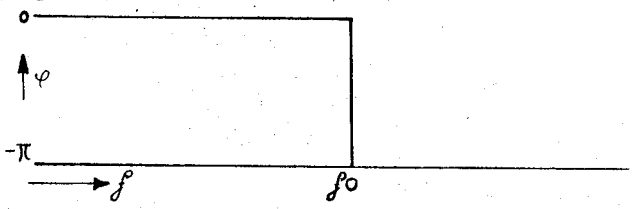


FIG. 3



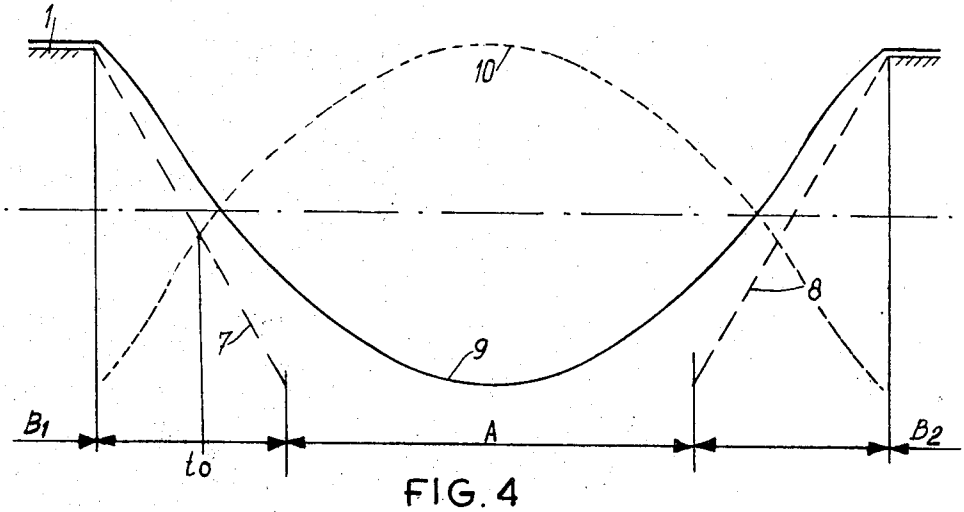


FIG. 4

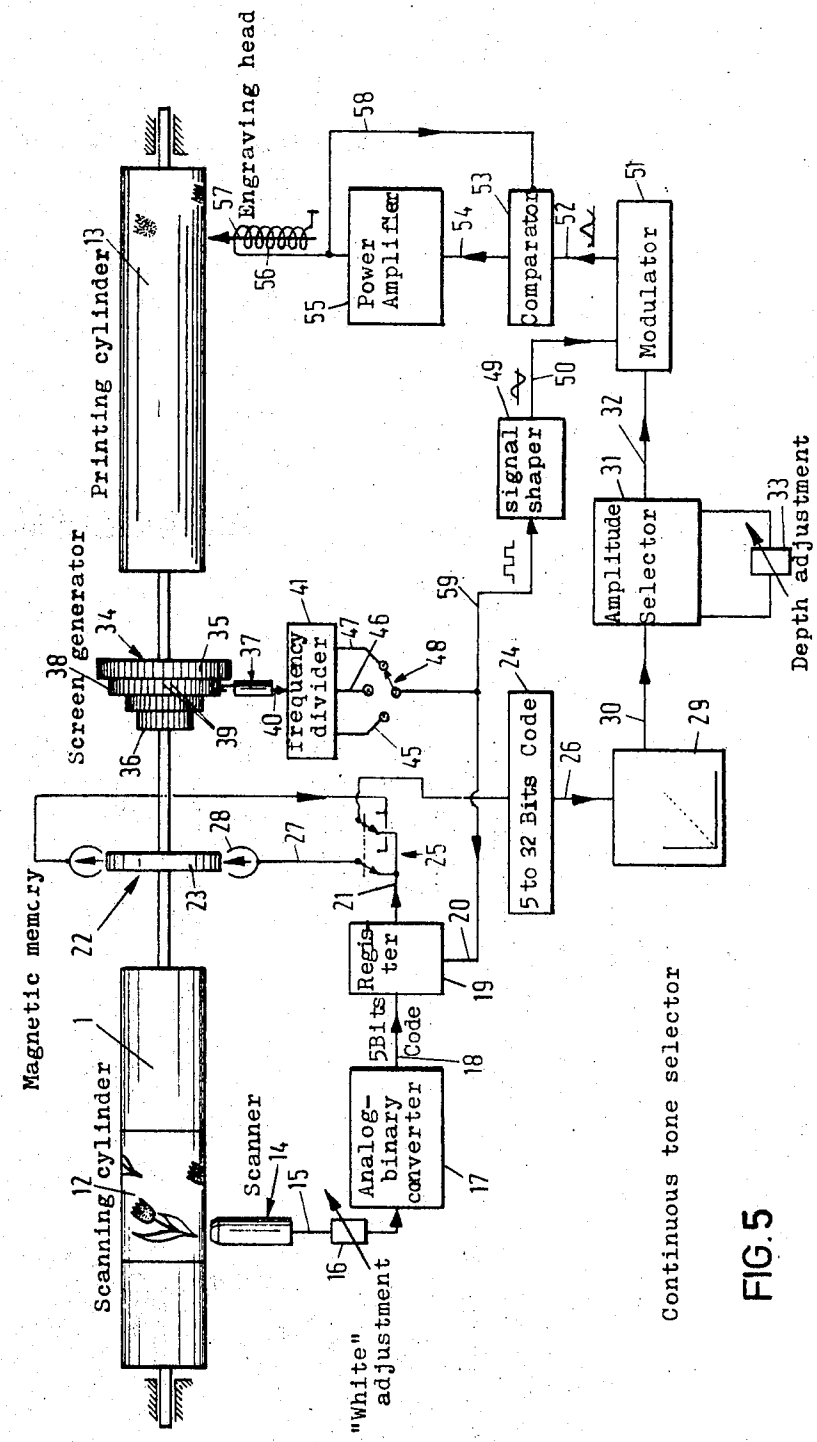

Engraving head
Printing cylinder
Power Amplifier
Comparator
Modulator
signal shaper
Amplitude Selector
Depth adjustment
Screen generator
frequency divider
5 to 32 Bits Code
Magnetic memory
Scanning cylinder
Scanner
Analog-binary converter
5 Bits Code
Register
"White" adjustment
Continuous tone selector

FIG. 5

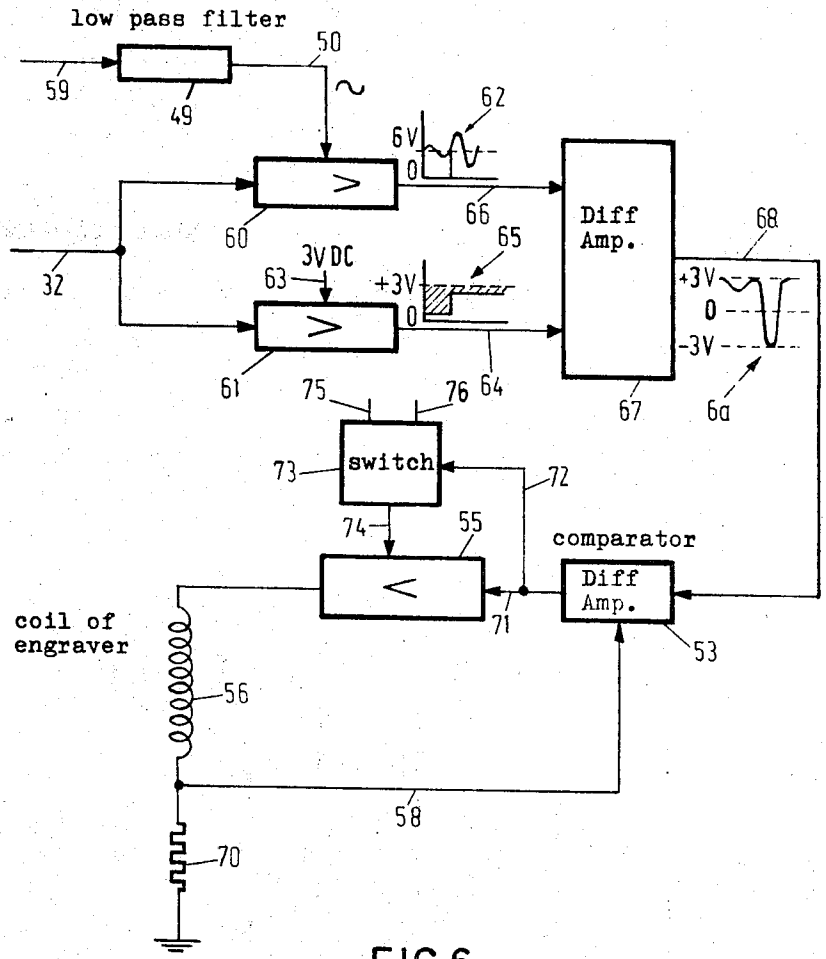

low pass filter
50
59
49
62
6V
0
60
66
Diff
Amp.
68
32
3V DC
63
+3V
65
0
61
64
+3V
0
-3V
67
6a
75
76
switch
73
72
74
55
comparator
Diff
Amp.
71
53
coil of
engraver
56
58
70

FIG.6

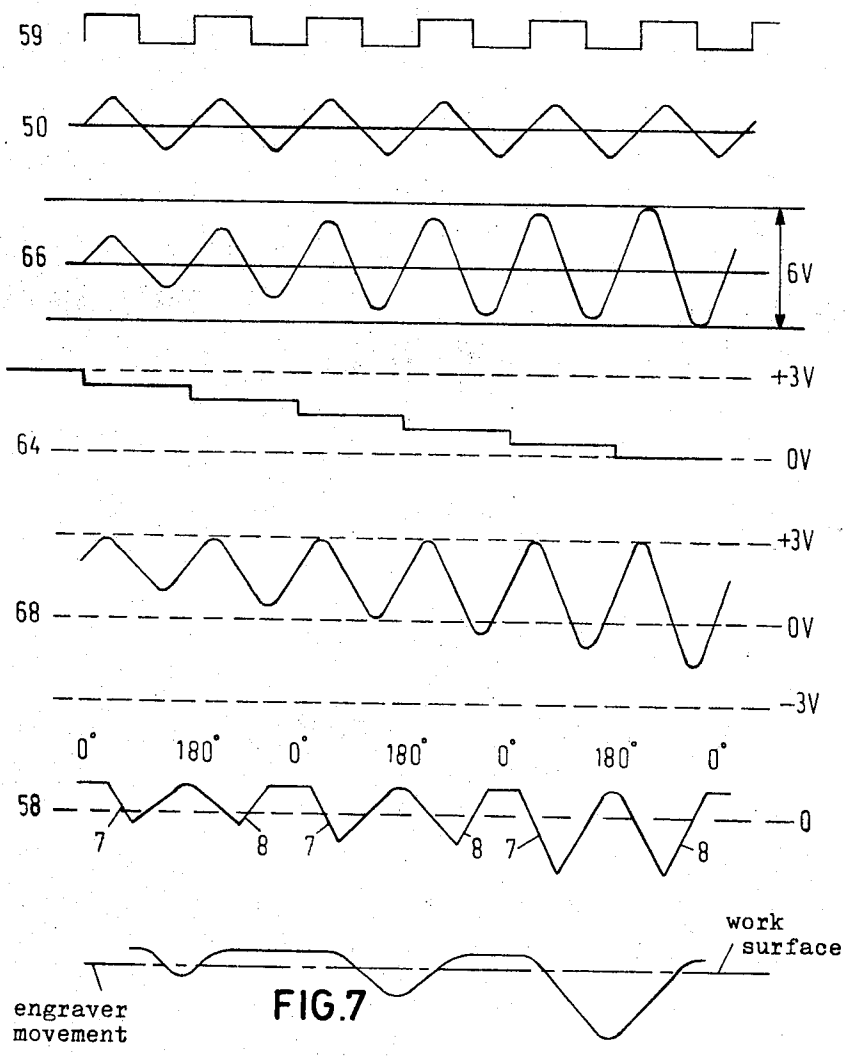

59
50
66
6V
+3V
64
0V
+3V
68
0V
-3V
0°
180°
0°
180°
0°
180°
0°
58
0
7
8
7
8
7
8
work surface
engraver movement

FIG.7

METHOD AND APPARATUS FOR MAKING HALF-TONE SCREEN PRINTING CYLINDERS

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of application 807,905, filed Mar. 17, 1969, and now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to method and apparatus for controlling the electromagnetic engraving element of an engraving machine in such fashion that the depth of penetration of the engraving element into the material undergoing engraving is regulated by controlling the electromagnetic system by means of alternating current and also by means of a direct current, both of which signals are controlled in dependence on the measured grey value of the required engraving.

Methods of controlling an engraving tool are known in which the electromagnetic system is controlled by an alternating current, the amplitude and frequency of which are constant, and by a direct current which varies in accord with the measured grey value of the required engraving and which is utilized to shift the zero line of the alternating movement of the engraving tool effected by the alternating current of fixed frequency and amplitude. In such systems, the sensitivity of the system is not optimal. By the term "sensitivity" as used herein, it is meant the contrast between different grey values and, with the apparatus as described above, the sensitivity is not linear. In other words, the contrast between grey values of the image produced in the engraved cylinder is not the same as on the master from which the engraving is made because the contrast will be more at one end of the grey value scale than it will be at the other and will be constantly varying in between the extremes, for example.

BRIEF SUMMARY OF THE INVENTION

The object of the present invention is to so control the engraving element on an engraving machine as to obtain maximum sensitivity throughout the grey tone value range. The inadequacies of prior art arrangements with regard to sensitivity are due to the fact that the penetration of the engraving element depends upon the resistance of the material undergoing engraving to such penetration. According to the present invention, the force controlling the engraving tool is much greater than the resistance offered by the material so that the depth of penetration of the engraving tool into the printing cylinder is only slightly influenced by the resistance of the material.

According to the present invention, the engraving element is normally spring biased toward a position in which the engraving element penetrates into the printing cylinder and an inductive winding is provided which may be energized with a predetermined d.c. value to oppose the spring means and to retract the engraving element to a predetermined position outside of the workpiece. From this position, the engraving element is controlled by controlling the current through the inductive winding, the controlling current being derived from an alternating current signal and a direct current signal. The alternating current signal is varied between the predetermined direct current value and a sinusoidal signal having its maximum at the predetermined dc level while, correspondingly, the dc signal varies between a minimum and a maximum. These signals are

combined to provide an alternating signal having amplitude excursions of the sense which causes the inductive winding to oppose the spring biasing means is clamped to a reference level so that the excursions of the opposite sense are variable with respect to such level in accord with the depth of penetration to be obtained. The sum of the displacements of the engraving element away from the position to which the spring biasing means would otherwise urge the engraving element, which displacements are due respectively to the alternating current signal and to the dc current signal is a constant and, the inductive winding is always in saturated condition.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

FIG. 1 is a diagrammatic view illustrating the engraving of a printing surface;

FIG. 2 is a graph illustrating the relationship between the displacement of the engraving element as a result of the dc and the displacement as a result of the alternating current, as a function of the frequency of the alternating current;

FIG. 3 is a graph illustrating the phase difference between the alternating current and the movement of the engraving tool as a function of the frequency of the alternating current;

FIG. 4 is a view showing the relationship between the current in the inductive winding and the displacement of the engraving element;

FIG. 5 is a block diagram illustrating the engraving system in somewhat simplified form;

FIG. 6 is an expanded block diagram of a portion of the circuitry shown in FIG. 5; and

FIG. 7 is a wave form diagram illustrating wave forms at various points in FIG. 6 and showing also engraving tool movement as related to current through the inductive winding.

DETAILED DESCRIPTION OF THE INVENTION

With reference first to FIG. 5 wherein the overall system diagrammatically is shown, the scanning or master cylinder 1 will be seen to be provided with a pattern or image section 12 which is desired to be reproduced on the printing cylinder 13. A scanner 14 of conventional construction optically scans the pattern 12 as the cylinder 1 is rotated with respect thereto and produces an analog output electrical signal at the conductor 15 as a result of the optical point by point scanning. The circuit 16 is provided to compensate for variation in the intensity of the scanning light which occurs naturally as same ages and its output is applied to the analog-to-digital converting device 17 which is of entirely conventional form and, in the specific example shown, converts the analog signal applied thereto into a 5-bit word in which the bits appear in parallel at the output 18 which is shown as a single line in FIG. 5 for the sake of convenience. Thus, the 5-bit word allows for 32 different tone levels (i.e., grey levels) to be presentd. This 5-bit parallel word is applied to a shift register device 19 having a shift input conductor 20 which simultaneously shifts out a stored 5-bit information word and stores the next word for subsequent shifting. The 5-bit parallel word which is shifted out of the register 19 appears at the conductor 21 and is stored on the magnetic memory 22 and, in particular, on the periphery of the wheel 23 thereof and is also applied to the circuit 24

through the switch 25. The circuit 24 may have as many as 32 outputs, one for each of the grey tone levels which may be represented by the 5-bit words and has one conductor for each output, one of which is shown at 26 in FIG. 5 for the sake of simplicity. The circuit 24 is merely a logic circuit which produces one output only in response to a 5-bit word input, corresponding to the grey level represented by the input word.

The input to the magnetic memory 22 is over the conductor 27 and, through the recording head 28, to the material forming the surface of the wheel 23. It simply stores the master pattern when the switch 25 is in the position shown, but may be used later to repeat the master pattern, the switch 25 then being in its other position.

The tone selector 29 may be of construction according to pending application Ser. No. 135,732, filed Apr. 20, 1971, which is a Streamlined Continuation of application Ser. No. 776,320, filed Nov. 18, 1968 and now abandoned. The selector 29 has a plurality of output conductors, one for each of the grey tone levels, only one of which is indicated in FIG. 5 by the reference character 30 and these conductors are connected to an amplitude selector circuit 31, which selector circuit 31 has a single output at the conductor 32 the analog level of which is controlled by which of the inputs at 30 is active. Thus, the circuits 24 and 31 form, in effect, a digital-to-analog conversion, the amplitude of the analog signal being a function of the level indicated by the 5-bit input words to the circuit 24. The overall level of the analog outputs at the conductor 32 may be adjusted by means of the circuit 33.

The screen generator 34 will be seen to consist of a plurality of wheels, the largest of which is indicated by the reference character 35 and the smallest of which is indicated by the reference character 36. As shown in FIG. 5, the transducer 37 is associated with an intermediately sized wheel 38 which, like all of the wheels of the screen generator are provided with teeth or discrete elements 39 which cooperate with the transducer 37 to produce a particular number of output pulses per revolution of the scanning and printing cylinders 1 and 13. The output pulses appearing at the conductor 40 are applied to a frequency dividing circuit 41 having a plurality of outputs at the conductors 45, 46 and 47, one of which is selected by means of the rotary switch 48. The frequency divider is of any conventional configuration and construction and produces a square wave output at each of the conductors 45, 46 and 47, each having a different frequency which is a fraction of the frequency at the input conductor 40, all as is conventional and well known.

The frequency divider signal in square wave form is applied to a signal shaping circuit 49 which converts the square wave pulses to a sinusoidal output at the conductor 50, which signal is applied, together with the analog signal at the conductor 32, to the modulator circuit 51. The output of the modulator circuit at the conductor 52 is applied to a comparator circuit 53 through the output at the conductor 54 is connected to the power amplifier 55 which drives the inductive winding 56 to control movements of the engraving element 57. It will be understood that the engraving element 57 normally is spring biased to penetrate into the printing cyliner 13 and that the current through the inuctive winding 56 is such as to effect the requisite engraving action as hereinafter described. In FIG. 5, a current feedback conductor is illustrated at 58, the purpose of which will be apparent from the description of FIG. 6.

As shown in FIG. 6, the analog output at the conductor 32 which is indicative of the grey level of the points being scanned by the scanner 14 is applied to the two amplifiers 60 and 61. The amplifier 60 is provided with the sinusoidal signal of fixed amplitude and frequency appearing at the conductor 50 as obtained from the screen frequency divided signal appearing at the conductor 59 after wave shaping in the circuit 49 so that the output of the amplifier 60 at its output conductor 66 is of the form indicated generally by the reference character 62 in FIG. 6. The output at the conductor 66 is zero volt when the signal at the conductor 32 corresponds to a "white" level scanned, and when the signal at 32 corresponds to "black" the signal at the conductor 66 is at its maximum value of 6 volts swinging peak-to-peak, at grey level tones in between white and black, intermediate levels of amplitude are present at the conductor 66.

The amplifier 61 causes the output signal at the conductor 64 to be between 0 and 3 volts depending on the analog level at the conductor 32. Thus, when the signal at the conductor 32 corresponds to "white" the output at the conductor 64 is at +3 volts and when the signal at the conductor 32 corresponds to "black" the output at the conductor 64 is at 0 volts. The ac signal at the conductor 66 and the dc signal at the conductor 64 are applied to the difference amplifier 67 having an output at the conductor 68 generally of the form indicated by the reference character 69 in FIG. 6. When engraving is taking place, the output signal at the conductor 68 has positive excursions which are clamped to +3 volts dc level and may swing, at maximum corresponding to "black" to −3 volts. This illustrates the invention wherein the sum of the displacements of the engraving member in opposition to the spring means due respectively to the dc and ac signal is a constant.

The signal at the conductor 68 and the signal at the conductor 58 which is indicative of the current through the winding 56 taken across the resistor 70, are applied to the difference amplifier 53 to produce an error signal output at the conductor 71 which is connected to the power amplifier 55. The error signal at the conductor 71 is indicative of the difference between the current through the winding 56 and the control signal 68. When the error signals at the conductor 71 exceeds a predetermined level, the conductor 72 connecting this error signal with the switch 73 causes the switch to respond to connect a high voltage level source at the conductor 75 to the amplifier 55 through the conductor 74. When the error signal is below this predetermined level, the switch 73 responds to connect the low voltage level force at the conductor 76 to the power amplifier 55 through the conductor 74.

The operation of the system of FIG. 6 will be apparent from the wave forms shown in FIG. 7. In FIG. 7 the various wave forms at different points in the circuitry of FIG. 6 are indicated at the left hand side by the reference characters identifying the conductors at which the signals are present. The bottom line of FIG. 7 repre-

sents movements of the engraving element and in this bottom line and the immediately preceeding line, the time base scale is twice that of the remaining wave forms.

The screen frequency divided signal at the conductor 59 is shown at the uppermost line of FIG. 7 and the sinusoidal signal of fixed frequency and amplitude obtained from this screen frequency divided signal is shown in the second lines of FIG. 7. As illustrated in the third line of FIG. 7, the output of the amplifier 60 is such as to be of increasing amplitude as the scanned image progresses from light to dark, reading from left to right in FIG. 7. The fourth line of FIG. 7 illustrates the output of the amplifier 61 which decreases progressively from +3 volts towards 0 volts as the intensity of the scanned image increases from light to dark.

The fifth line in FIG. 7 shows the clamped output signal from the differential amplifier 67 and shows clearly that the sum of the displacements of the engraving element in opposition to the spring biasing means due respectively to the dc and ac signals is a constant. It will be appreciated that when "white" is scanned, the ac signal at the conductor 66 will be a dc or essentially a dc signal at the +3 volt base line level whereas, simultaneously, the dc signal at the conductor 64 will also be at +3 volts. When "black" is being scanned, the resultant ac signal at the conductor 66 will be at maximum value of 6 volts peak-to-peak and simultaneously the dc voltage level at the conductor 64 will be at 0 volts. At all intermediate grey levels corresponding variations in the amplitude variation of the signal at the conductor 66 and the dc level of the signal at the conductor 64 will be correspondingly modified so that the sum of the displacements as mentioned above is a constant.

The penultimate line of FIG. 7 is a wave form of the current through the winding 56 and the effect of switching between the normal or low voltage applied to the amplifier 55 and the high voltage to this amplifier as effected by the switch 73 will be seen. Thus, the ramp 7 is caused by switching from the low to the high voltage source and the ramp 8 is caused by switching back from the high to the low voltage source. The slopes of these ramps will of course depend upon the value of the inductance of the winding 56, the parameters of the mass-spring system formed by the engraving tool and the spring which normally retracts it from the work, and the voltage difference between the high and low voltage source levels at the conductors 75 and 76.

In FIG. 1, reference character 1 indicates the surface of the printing cylinder which is to be engraved while the reference character 6 designates the provision of the engraving element when it is fully retracted and corresponds to a position in which the engraving element will be positioned when the combined signal from the differential amplifier 67 of FIG. 6 will be at the +3 volt level. In FIG. 1, a relatively deep penetration of the engraving tool is depicted by the reference character 3 and the corresponding zero line for such engraving movement is depicted by the reference character 2. A further but more shallow engraving movement of the engraving element is indicated by the reference character 4 and its corresponding zero line is indicated by the reference character 5. As will be evident, the zero line has been shifted in the direction of the arrow P in the two positions shown in FIG. 1.

When "white" is to be engraved, the amplitude of the alternating current is at a minimum as hereinbefore described and when "black" is to be engraved, the alternating current is at a maximum value. The magnitude of the sum of the ac and dc signals, is kept constant such that the electromagnetic systems is always saturated.

FIG. 2 illustrates the relationship between the displacement of the engraving element as a result of the direct current and the displacement of the engraving element as a result of the alternating current as a function of the frequency of the alternating current with the present electromagnetic system. X_d indicates the displacement of the engraving element as a result of the alternating current amplitude while X_{ST} denotes the displacement of the engraving element produced by the direct current. In order that the depth of penetration may not be influenced by the resistance of the material undergoing engraving, or else only slightly influenced thereby, it is advantageous to satisfy the above requirement, namely that the displacement as a result of the direct current should be substantially equal to the displacement as a result of the alternating current amplitude, with the maximum possible frequency of the alternating current. This condition is satisfied if the working frequency is $\sqrt{2\,(1-2\beta^2)} \cdot fo$, where β is the damping factor and fo is the resonant frequency of the system. This frequency can be promoted by $\sqrt{2}\,fo$. In one exemplified embodiment, this frequency may be approximately 3000 Hz. If, however, the working frequency is selected to be above the resonant frequency, the alternating current and the resultant movement of the engraving element are not in phase with one another and a phase shift of approximately π occurs. FIG. 3 shows the relationship between the phase difference and the frequency of the alternating current for an ideal case. ϕ denotes the phase angle between the alternating current and the movement of the engraving element and f denotes the frequency of the alternating current. The result is that on the changeover from the static state in which only direct current flows through the electromagnetic system, to the dynamic state in which an alternating current will flow through the system in addition to direct current for the engraving operation, the direction of the current must change. This is indicated in FIG. 4 for engraving a "black" engraving, in which therefore practically no direct current flows through the system while the alternating current is at a maximum.

FIG. 4 shows the engraving tool movement as a function of the time t during engraving, indicated by the line 9, while the controlling alternating current is indicated by reference 10. During the period of time denoted by reference A, when the engraving tool is performing the cutting movement, practically only alternating current flows through the system, while in the static periods B_1 and B_2 direct current is applied. The changeover from B_1 to A and from A to B_2, i.e., the change of the direction of the current should occur as rapidly as possible in order to obviate any adverse phenomena during the changeover. To this end, the system receives a current pulse which is shown be reference 7 in FIG. 4 and effects a rapid changeover from the static state to the dynamic state. This current pulse is stopped at the appropriate time to and the movement is controlled further by the alternating current 10. Similar considerations apply to the changeover from A to B_2, when the current for obtaining a stable static state must again change direction. The current pulse indicated by reference 8 en-

sures that the static state is rapidly attained without the engraving tool continuing to cut the material as a result of subsequent vibration of the system.

In practice, however, the pulse difference between the alternating current and the movement of the engraving tool will not be completely equal to π, as suggested in FIG. 4, because the damping in the electromagnetic and mass spring system cannot be disregarded. The actual path of these pulses, and the phase difference, are dependent upon the parameters of the individual system. It is therefore preferable to be able to adjust the time at which the pulses 7 and 8 respectively occur.

What is claimed is:

1. In a system for producing half-tone screen printing cylinders, in combination:
a master cylinder having an image thereon;
a printing cylinder upon which the image on said master cylinder is to be engraved;
means for circumferentially scanning said master cylinder to produce a dc signal which varies directly in amplitude according to the intensity of the image on said master cylinder;
an engraving assembly associated with said printing cylinder and including an engraving member, spring means for urging the engraving member into the printing cylinder and inductive winding means for opposing said spring means normally to retract said engraving member out of the printing cylinder;
means for producing an ac signal at a frequency related to circumferential scanning and varying in amplitude inversely with respect to the intensity of the image on said master cylinder;
means for combining said ac signal and said dc signal and for energizing said winding means such that amplitude excursions of the combined signal opposing said spring means are clamped to a selected value.

2. In a system as defined in claim 1 wherein the frequency of said ac signal is greater than the resonant frequency of said engraving assembly.

3. In a system as defined in claim 2 wherein said means for combining includes a differential amplifier having said combined signal and the current through said winding means as inputs thereto.

4. In a system as defined in claim 3 including an amplifier driving said winding means and having the output of said differential amplifier connected thereto.

5. In a system for producing half-tone screen printing cylinders, in combination:
a master cylinder having an image thereon;
a printing cylinder upon which the image on said master cylinder is to be engraved;
means for circumferentially scanning said master cylinder to produce an ac signal which varies directly in amplitude according to the intensity of the image on said master cylinder;
an engraving assembly associated with said printing cylinder and including an engraving member, spring means for urging said engraving member into said printing cylinder, and inductive winding means for opposing said spring means normally to retract said engraving member out of the printing cylinder;
means for producing an ac signal at a frequency related to circumferential scanning and varying in amplitude inversely with respect to the intensity of the image on said master cylinder;
means for combining said ac signal and said dc signal and for energizing said winding means so that the sum of the displacements of said engraving member in opposition to said spring means due respectively to said dc signal and to said ac signal is a constant.

6. A system as defined in claim 5 wherein said means for combining includes a differential amplifier having said dc and ac signals as inputs thereto.

7. In a system as defined in claim 5 wherein the displacement of the engraving member in opposition to said spring-biasing due to dc current alone is equal to the displacement in the same sense due to ac current amplitude alone.

8. In a system for producing half-tone screen printing cylinders, in combination:
a master cylinder having an image thereon;
a printing cylinder upon which the image on said master cylinder is to be engraved;
means for circumferentially scanning said master cylinder to produce a dc signal which varies stepwise in decreasing amplitude steps in accord with discrete levels of intensity of the image on said master cylinder as such levels progress from light to dark;
an engraving assembly associated with said printing cylinder and including an engraving member; spring means for urging the engraving member into the printing cylinder, and inductive winding means for opposing said spring means to retract said engraving member out of the printing cylinder, said engraving assembly having a fixed natural frequency of oscillation;
means for producing an ac signal at a selected frequency related to said natural frequency of the engraving assembly and of variable amplitude which increases according to the level of intensity of said image on the master cylinder as such intensity progresses from light to dark;
means for combining said dc signal and said ac signal and for energizing said winding means with such combined signal; and
the frequency of said ac signal being sufficiently different from the natural frequency of said engraving assembly so that the sum of the displacements of said engraving member in opposition to said spring means due respectively to said dc signal and to said ac signal is a constant for each of said discrete levels of intensity of said image on the master cylinder.

9. In a system as defined in claim 8 wherein the displacements of said engraving member due respectively to said dc signal and to said ac signal are substantially equal for each of said levels of intensity of said image on the master cylinder.

10. In a system as defined in claim 9 wherein the frequency of said ac signal is substantially $\sqrt{2}\,f$ where f is the natural frequency of said engraving assembly.

11. The method of producing a half-tone screen printing cylinder which comprises the steps of:
a. rotating a screen printing cylinder at a uniform speed while periodically electro-mechanically engraving the cylinder at a frequency f which is about $\sqrt{2}$ times the natural resonant frequency of the assembly used for engraving;

b. generating dc signals at said frequency *f* whose amplitudes vary stepwise in decreasing amplitude in accord with discrete levels of intensity of an image to be produced as such levels progress from light to dark;

c. generating an ac signal at said frequency *f* and of variable amplitude which increases according to said levels of intensity as such levels of intensity progress from light to dark;

d. combining the dc and ac signals of steps (*b*) and (*c*) such that displacements of the engraving assembly due respectively to the dc and ac components of the combined signal are substantially equal for all levels of intensity; and

e. energizing the engraving assembly with the combined signal of step (*d*).

12. The method according to claim **11** including the step of constantly spring-biasing the engraving element toward the cylinder.

13. The method according to claim **12** wherein the ac component of the driving current is substantially in phase opposition to movement of the engraving member.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,769,455 Dated October 30, 1973

Inventor(s) Ferdinand Allard deVos & Jan Hendrik ter Steege

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

---Foreign Application Priority Data

[30] March 26, 1968 Netherlands 68.04234---

Signed and sealed this 25th day of June 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
☆ U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334

UNITED STATES PATENT OFFICE
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(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
☆ U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334