

July 8, 1941.

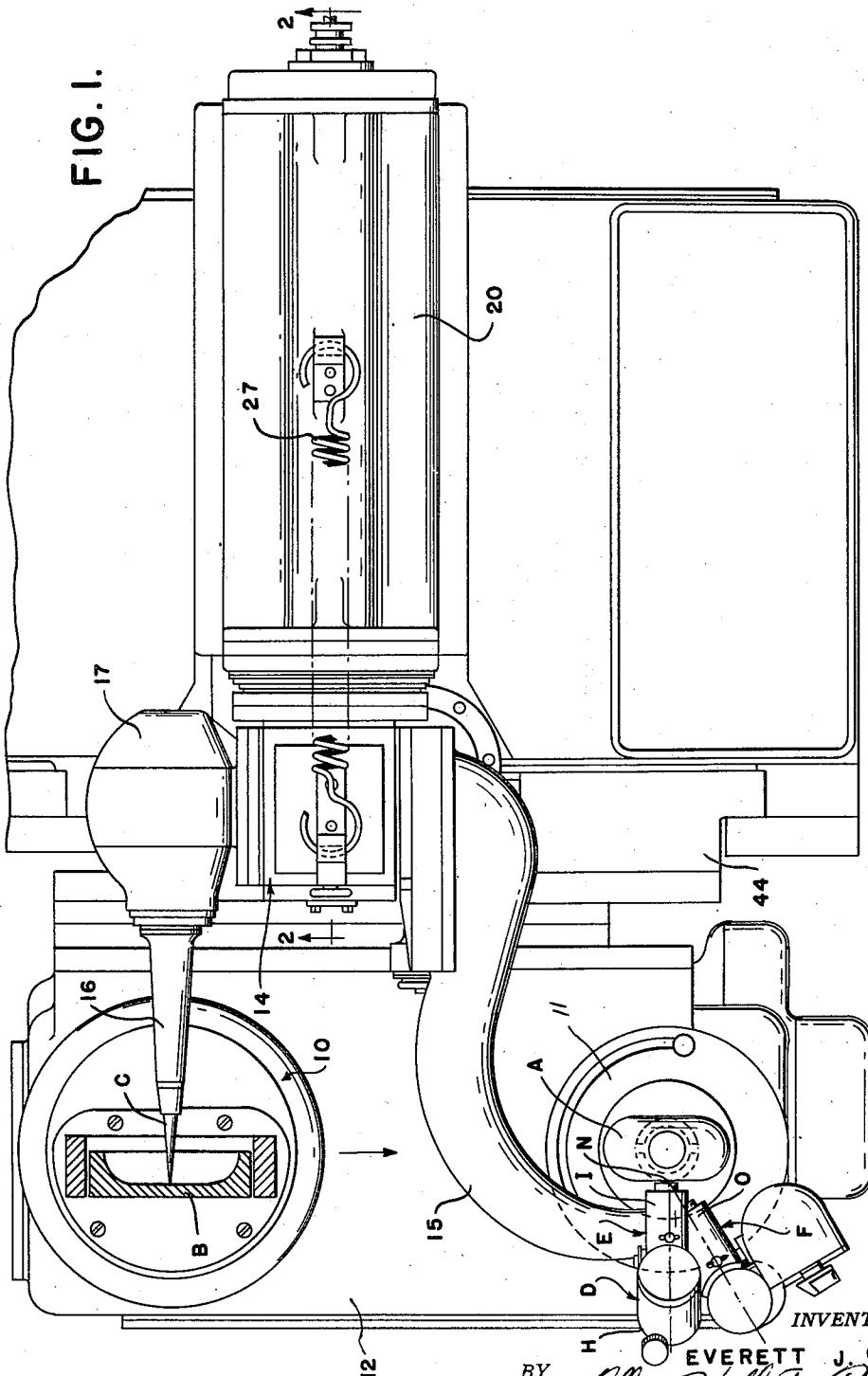
E. J. COOK

2,248,809

REPRODUCING MACHINE

Filed May 29, 1939

4 Sheets-Sheet 1



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E. J. COOK
REPRODUCING MACHINE

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4 Sheets-Sheet 2

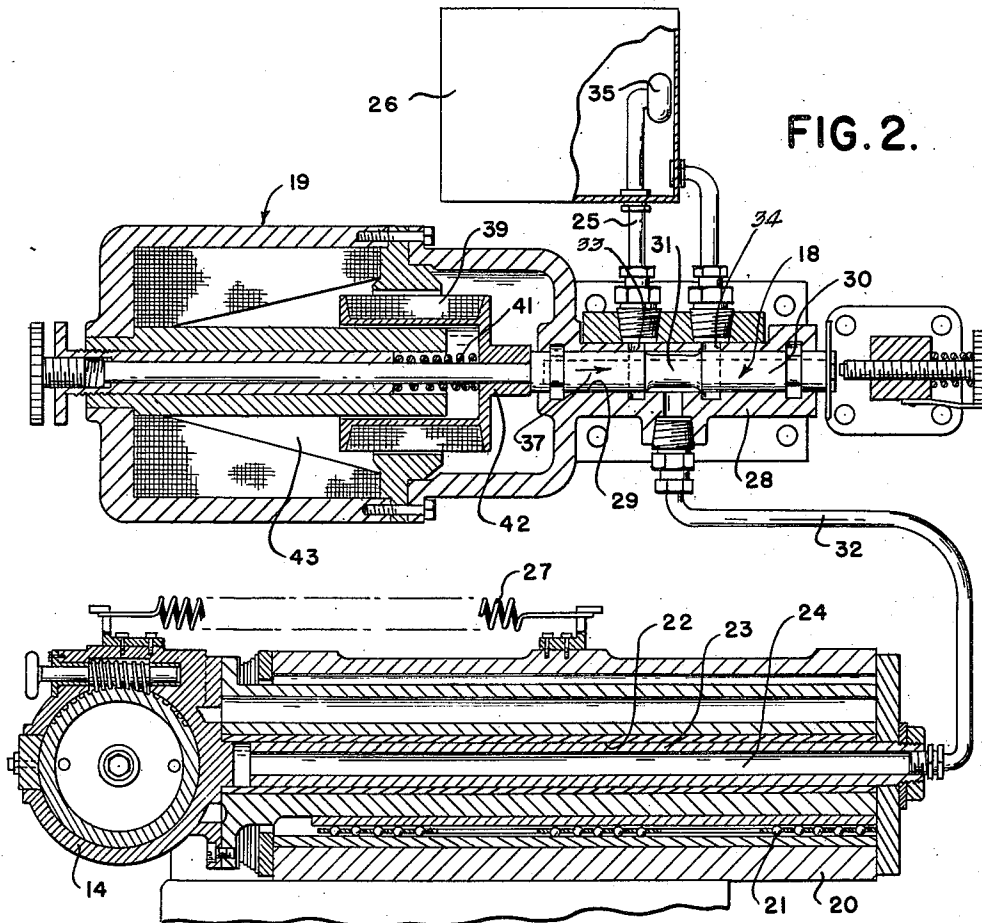


FIG. 2.

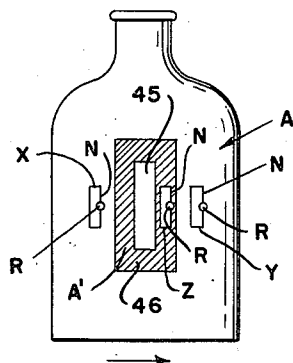


FIG. 5.

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4 Sheets-Sheet 3

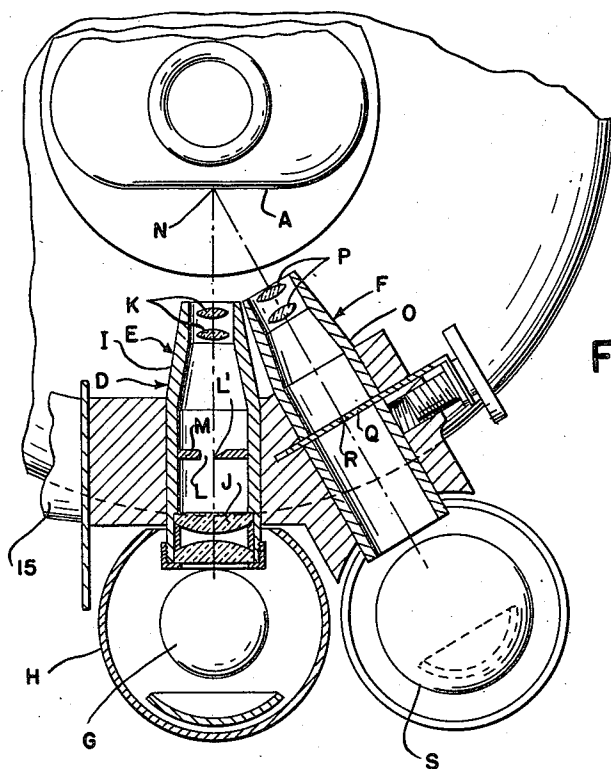


FIG. 3.

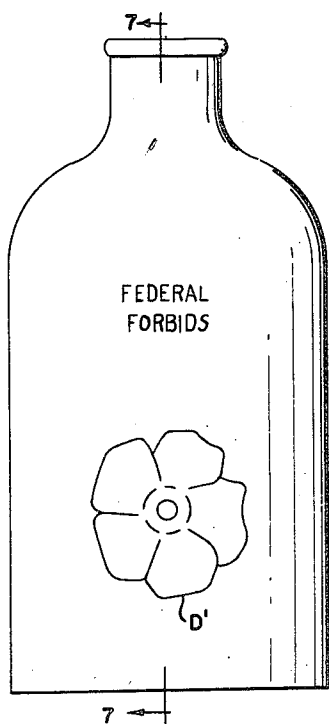


FIG. 6.

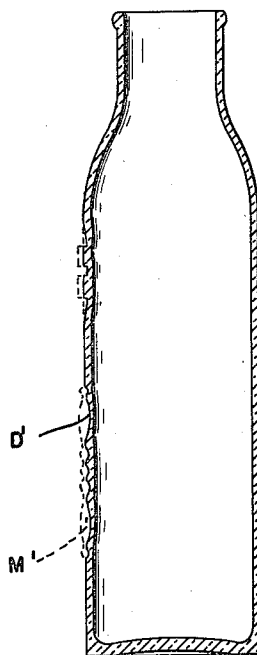


FIG. 7.

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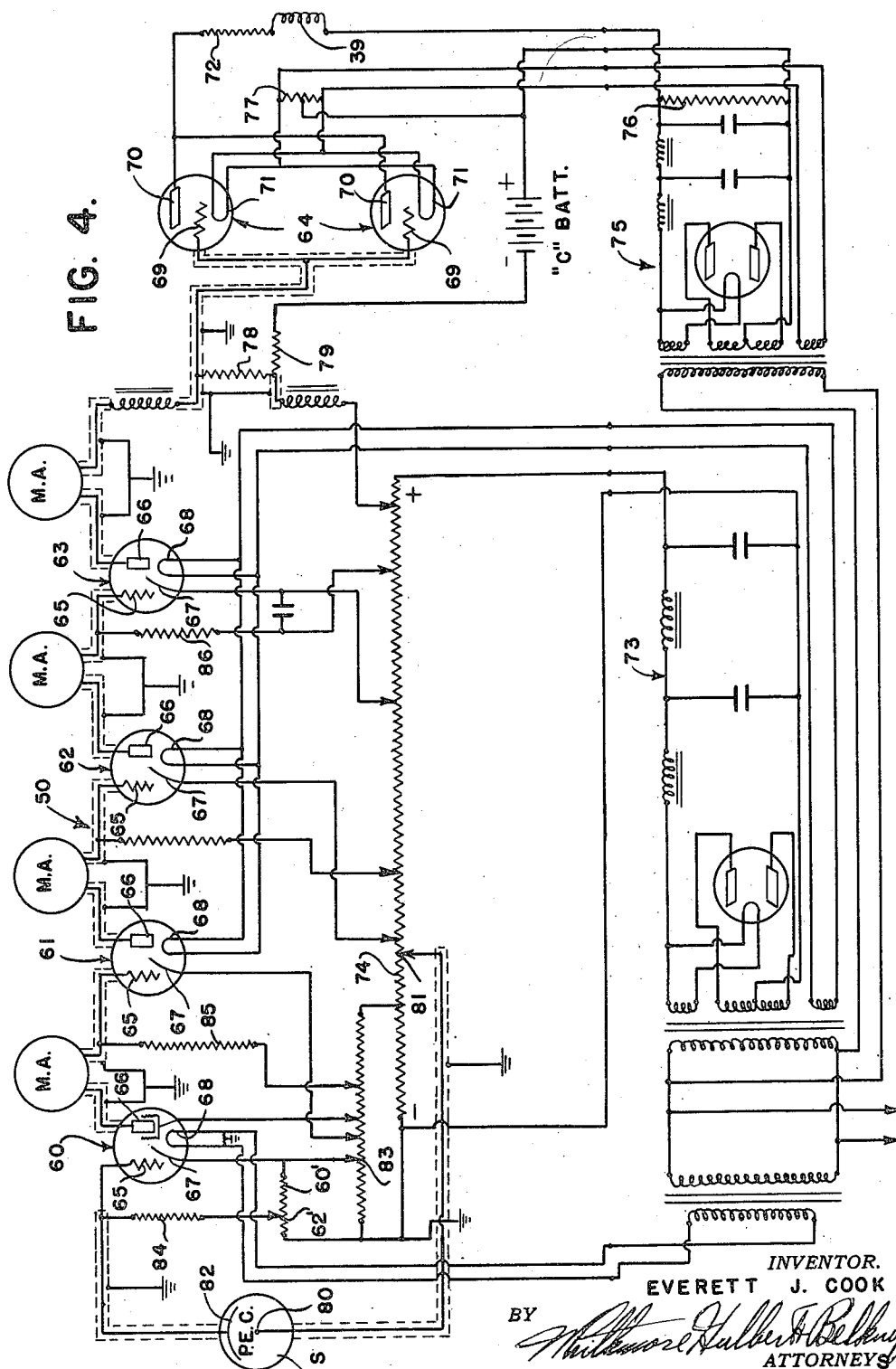
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REPRODUCING MACHINE

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4 Sheets-Sheet 4

FIG. 4.



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2,248,809

REPRODUCING MACHINE

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Application May 29, 1939, Serial No. 276,425

9 Claims. (Cl. 90—13.5)

This invention relates generally to reproducing machines of the type wherein a cutting tool and a work blank are relatively moved toward and away from each other by an optical system including a light sensitive cell scanning a record to be reproduced in the work blank.

In reproducing machines of the general type set forth, it has been proposed to scan a shaded record to be reproduced in a work blank with an optical system having a light sensitive cell responsive to variations in the intensity of light intercepted by the cell to pass an electric current which increases and decreases as the light intensity intercepted by the cell increases and decreases. It has also been proposed to control the operation of a cutting tool with an electromagnet electrically connected to the light sensitive cell through an amplifier of such design that when the light sensitive cell intercepts a shaded portion of the record, the tool is fed into the work to a depth depending upon the extent of drop in current of the electromagnet resulting from the depth of shade of the particular portion of the record scanned and when the light sensitive cell intercepts an illuminated area of the record, the tool is withdrawn from the work a distance depending upon the extent of increase of the intensity of the light intercepted by the light sensitive cell.

Inasmuch as the tool is fed into the work when the light sensitive cell intercepts a shaded area of the record, it follows that if the depth of the shaded area is greater than required, the tool will cut too deeply into the work and, in the event the source of illumination in the optical system should fail, the tool would drill the work to such an extent as to destroy the same. In order to overcome the above objections, it has been proposed in my copending application, Serial No. 261,606, filed March 13, 1939, to provide means operating automatically to withdraw the tool from the work in the event the depth of shade of the record is greater than desired and to discontinue the operation of the machine in the event the illuminating means of the optical system should fail.

With the foregoing in view, it is one of the principal features of the present invention to provide a reproducing machine wherein the danger of cutting too deeply into the work, or of drilling the latter in the event of failure of the illuminating means in the optical system is overcome without the necessity of incorporating special safety devices. In accordance with the present invention, when the light sensitive cell inter-

cepts a shaded area of the image, the tool is withdrawn from the work and when the light sensitive cell intercepts an illuminated portion of the image, the tool is fed into the work. As a result, any increase in depth of the record beyond the desired predetermined shade, or failure of the illuminating means embodied in the optical system will merely effect withdrawal of the tool from the work.

Another important advantageous feature of the present invention is realized when the reproducing machine is employed to fashion a mold cavity from a pattern corresponding to the article to be subsequently cast in the cavity. With the present invention, the shaded record on the pattern is cut in cameo on the proper surface of the mold cavity and will appear intaglio on the corresponding surface of the article cast in the cavity. As a result, the present invention offers the possibility of decorating the surface of the article without the necessity of providing any additional amount of material for the decoration.

The foregoing, as well as other object, will be made more apparent as this description proceeds, especially when considered in connection with the accompanying drawing, wherein—

Figure 1 is a top plan view, partly in section, of a reproducing machine constructed in accordance with the present invention;

Figure 2 is a longitudinal sectional view taken substantially on the plane indicated by the line 2—2 of Figure 1;

Figure 3 is an enlarged plan view, partly in section, of the optical system;

Figure 4 is a diagram of the electrical control system;

Figure 5 is an elevational view of a model having a shaded record thereon to be reproduced in the work blank;

Figure 6 is an elevational view of the article cast from the mold fashioned by the reproducing machine forming the subject matter of this invention;

Figure 7 is a sectional view taken substantially on the plane indicated by the line 7—7 of Figure 6.

For the purpose of illustrating the present invention, I have selected a reproducing machine for fashioning bottle molds from a model corresponding in size and shape to the bottle it is desired to manufacture from the mold. In Figure 6 of the drawings, I have shown a typical bottle adapted to be cast from a mold fashioned by the reproducing machine forming the subject matter

of this invention, and it will be noted that this bottle has a decoration D' cast intaglio in the outer surface thereof, as distinguished from the orthodox practice of casting the decoration in cameo. In Figure 7 of the drawings, the reference character M' designates the amount of material saved by casting the decoration intaglio in the outer surface of the bottle. While the quantity of material saved by forming the decoration intaglio, instead of cameo, will vary in accordance with the area of the surface of the bottle decorated, nevertheless, this saving is appreciable especially when accumulated over large quantity production.

The reproducing machine forming the subject matter of the following description not only renders it possible to effect the saving of material previously discussed but, inherently, embodies the feature of effecting withdrawal of the tool from the work in the event the shading of the record on the model is darker than desired, or in the event of failure of the illuminating means in the optical system for scanning the model. With the foregoing in view, attention is directed to Figure 1 of the drawings, wherein it will be noted that the bottle mold is formed of two halves and one of the halves is designated in the above figure by the reference character B. In the interest of simplicity, this half of the mold will be hereinafter referred to as the work blank.

The work blank B is shown as suitably mounted on a work support 10 carried by a traversing carriage 12 movable in the direction of the arrow in Figures 1 and 5, and also carrying a model support 11. A model A having a shaded record A' thereon corresponding to the decoration D' is mounted on the support 11 and corresponds in shape, as well as size, to the bottle it is desired to cast in the mold cavity to be formed in the work blank B. The model A is preferably formed of, or coated with a good light reflecting material and the shaded record A' may be a photograph, sketch, or print of the decoration D'.

In the present instance, the outer half of the surface of the pattern A is scanned by an optical unit D and the latter controls the movements of a tool C positioned at the inner side of the work blank B directly opposite the latter. Both the tool C and optical unit D are mounted on the forward end of a ram 14 which, in turn, is supported for reciprocation toward and away from the traversing carriage 12. The optical unit D is positioned opposite the pattern A at the outer side of the latter on an arm 15 having the inner end secured to the forward end of the ram so that movement of the ram in a direction toward the carriage 12 effects a corresponding movement of the optical unit D away from the pattern A. The tool C, on the other hand, is mounted on a spindle 16 driven by a suitable electric motor 17 which is secured directly to the ram so that movement of the latter toward the carriage 12 effects a movement of the tool C toward the work blank B. In other words, the arrangement is such that the tool C is fed into the work by the ram when the optical unit D is moved away from the pattern A by the ram.

Inasmuch as the bottle to be cast in the mold is elliptical in cross section, the work support 10 and the pattern support 11 are mounted on the traversing carriage 12 for oscillation about their respective vertical axes. As a result, the cutting end of the tool C is maintained substantially perpendicular to the surface of the work blank

being cut and the optical unit D is maintained in the same relationship to the pattern A. The means for oscillating the two supports and the mechanism for operating the carriage 12 may be the same as illustrated in my Patent #2,154,974, issued April 18, 1939.

Upon reference to Figure 2, it will be noted that the ram 14 is operated by fluid pressure in dependence upon the operation of a valve 18 controlled by an electromagnet 19. The particular construction of the ram illustrated herein is the same in construction as the one shown in my copending application, Serial No. 195,925, filed March 4, 1938, Patent 2,176,666, issued October 17, 1939, and forms no part of this invention. Briefly described, the ram is triangular in cross section and slides in a casing 20 corresponding to the ram in cross section, as shown in Figure 8. A set of needle bearings 21 is supported between the opposed parallel walls of the ram 14 and casing 20 to reduce friction to a minimum. In addition, the ram is provided with a cylinder 22 slidably receiving a piston 23, which is fixedly secured to the frame of the machine against movement and is axially bored to provide the passage 24 therethrough. The rear end of the bore or passage 24 alternately communicates with a source of fluid under pressure 25 and a fluid supply tank 26 through the valve 18. The inner end of the cylinder 22 is closed by and is secured to the head of the ram so that fluid under pressure supplied to the cylinder 22 through the passage 24 in the piston 23 effects a movement of the head together with the cylinder in a direction toward the traversing carriage 12. On the other hand, when the pressure in the passage 24 is exhausted by the valve 18, the ram is moved in the opposite direction by a suitable spring 27.

The valve 18 comprises a casing 28 having a bore 29 therethrough for slidably receiving a valve plunger 30. The valve plunger 30 is formed with a reduced portion 31 intermediate the ends thereof arranged in constant communication with the rear end of the passage 24 through the piston 23 by a conduit 32 and respectively establishes communication between the bore or passage 24 and ports 33 and 34 as the plunger 30 moves in opposite directions from the neutral position shown in Figure 2. The port 33 communicates with the discharge side of a suitable pump 35 located within the fluid supply tank 26 and the port 34 communicates with the tank 26. The arrangement is such that movement of the plunger 30 in the direction of the arrow 37 from the position shown in Figure 2 establishes communication between the passage 24 and the port 34 communicating with the supply tank 26. As a result, fluid pressure is exhausted from the ram and the latter is moved in a direction away from the traversing carriage 12 or, in other words, the tool C is withdrawn from the work and the optical unit D is moved toward the pattern A. Of course, movement of the valve plunger 30 in a direction opposite the direction of the arrow 37 establishes communication between the passage 24, through the piston 23, and the port 33 communicating with the pump 35. As a result, fluid under pressure is built up in the passage 24 and the ram is moved by fluid pressure against the action of the spring 27 in a direction to feed the tool C into the work B and to move the optical unit away from the pattern A.

In the illustrated embodiment of the invention, the valve plunger 30 is moved in a direction to feed the tool into the work by energizing a load

coil 39 of the electromagnet 19 and is moved in the opposite direction to withdraw the tool from the work by a spring 41 acting on the armature 42 of the electromagnet to resist movement of the load coil 39 into the magnetic field 43.

The operation of the electromagnet is controlled by the optical unit D in accordance with changes in shape of the surface of the pattern scanned and in dependence upon variations in shading of the record A' on the pattern A. The optical unit D comprises a light projector E and a light sensitive cell device F supported on the arm 15 in fixed angular relation to the projector. The light projector E has a source of illumination G housed by a casing H and registering with the outer end of a lens barrel I having condenser lenses J secured in the outer end thereof and having objective lenses K secured in the inner end of the same. A plate or diaphragm M is located between the two lenses and is formed with a slot L therethrough of a shape predetermined to cast an illuminated image on the surface of the pattern A having a sharply defined contour line N.

The photoelectric cell device F is also provided with a lens barrel O having its axis in a common horizontal plane with the axis of the projector lens barrel I and having objective lenses P fixed in the inner end thereof. The axis of the lens barrel O converges toward the axis of the projector lens barrel I and intersects the latter axis at a point spaced inwardly beyond the inner ends of the lens barrels for reasons to be more fully hereinafter set forth. In addition, the photoelectric cell device F is provided with a light sensitive cell in the form of a phototube S supported in a suitable light tight casing joined with the outer end of the lens barrel O to receive light passing through the latter. In this connection, it will be noted from Figure 3 that a plate Q is secured in the lens barrel O between the lenses P and the light sensitive cell S. This plate Q is provided with a restricted aperture R therethrough located substantially on the axis of the lens barrel O and may be properly termed the line of sight of the phototube S since the latter is affected only by the light escaping through the aperture R.

It has previously been stated that the axis of the projector lens barrel I and the axis of the phototube lens barrel O are arranged in fixed angular relationship. The angle between these two axes is so determined that when the tool is properly set with reference to the work blank B, the axes of the lens barrels intersect at the surface of the pattern A or, in other words, the aperture R straddles the contour line N of the image reflected from the pattern on the plate Q.

The entire surface of the pattern A to be reproduced in the work blank B is, of course, scanned by the optical unit D and exactly the same area of the work blank is necessarily traversed by the tool C. As stated above, the pattern support and work support are mounted on the traversing carriage 12. This carriage is movable back and forth by mechanism, not shown herein, and is also fed vertically by a carriage 44, generally shown in Figure 1. The carriage 44 is raised by a step by step movement and the means for accomplishing this result is not shown herein, but may be similar to the means provided for this purpose in my Patent No. 2,154,974, issued April 18, 1939. Reference has also been made to the fact that the work blank B and pattern A are oscillated about their vertical axes. This is partic-

ularly desirable in cases where the sides of the article to be formed are on a radius in that it renders it possible to maintain the tool substantially normal to the surface being cut.

It is important to note at this time that the plate M in the projector lens barrel I is positioned in such a manner that the right-hand edge L' is arranged on the axis of the lens barrel I so that the lenses K cast a light image on the surface of the model with the contour line N of the image at the left-hand side of the latter. This image is, of course, reflected from the model and is cast by the lenses P on the plate Q, in the light sensitive cell lens barrel O, with the contour line N on the right-hand edge of the image and intersecting the aperture R.

With the above in mind and remembering that the angle between the light beam and line of sight of the light sensitive cell remains constant throughout the traversing operation, it follows that as the surface of the pattern A approaches the optical unit D, the image reflected on the plate Q is shifted relative to the aperture R in a direction to increase the intensity of light passing through the aperture R to the light sensitive cell S. Such action has the effect of increasing the current flowing through the load coil 39 of the electromagnet 19 to such an extent that the valve 18 is operated to supply fluid pressure to the passage 24 in the ram 14 and effect movement of the ram 14 in a direction to feed the tool C into the work. It will, of course, be understood that movement of the tool C in the above direction causes a corresponding movement of the optical unit D away from the pattern and this movement continues until the aperture R intercepts a greater area of the shaded portion of the image. As the intensity of light passing through the aperture R is decreased by interception of the aperture R with the shaded portion of the image, the quantity of current flowing through the load coil of the electromagnet 19 is correspondingly decreased with the result that the spring 41 operates the valve 18 to permit movement of the ram 14 by the spring 27 in a direction to withdraw the tool C from the work. As a result, the aperture R is maintained in straddling relationship with the contour line N and, since this contour line represents a section of the pattern as viewed from the light sensitive cell S, it follows that an exact replica of the surface of the pattern scanned is produced in the work blank B.

Having described the manner in which the shape of the surface of the pattern scanned is exactly reproduced in the work blank B, reference will now be made to the manner in which variations in shade of the record A' affect the tool. Assuming, for the purpose of illustration, that the record is in the form of the sketch, shown in Figure 5, as having light and dark portions 45 and 46, it will be noted that when the dark or shaded portions 46 of the sketch are scanned by the light sensitive cell S, the light intensity intercepted by the cell is diminished sufficiently to effect the drop in current flowing through the cell required to permit the spring 41 to operate the valve 18 and effect movement of the ram 14 by the action of the spring 27 in a direction to cause the tool to move away from the work. On the other hand, when the light portions 45 of the sketch are scanned by the cell S, the intensity of light intercepted by the phototube S is increased sufficiently to effect the increase in current flow through the cell S required to counteract the spring 41 and operate the

valve 18 to permit movement of the ram 14' by the fluid pressure in a direction to feed the tool into the work. The arrangement is such that the decoration represented by the sketch is cut cameo in the mold while the latter is shaped to the contour of the pattern.

In order to better illustrate the manner in which the tool is controlled by both the contour of the surface of the pattern A and variations in shading of the record A', attention is directed to Figure 5, wherein three positions of the light image cast by the projector on the surface of the pattern are shown with reference to the aperture R of the light sensitive cell S. In the two positions X and Y, the tool is controlled in accordance with the contour of the pattern in the manner set forth above and in the position Z, the tool is further controlled in accordance with variations in the shading of the record A'. Assuming that the light image and aperture R are in the position Z, it will be noted that the intensity of light escaping through the aperture R onto the cell S is reduced by the shaded portion of the record and, as a result, the current passing through the photocell S is correspondingly reduced. This reduction in current relieves the fluid under pressure in the ram, permitting the spring 27 to withdraw the tool from the work to an extent depending upon the degree of shade of the record, or upon the drop in current flow through the cell S. As soon as the image and aperture R reach the position Y, the intensity of light passing through the aperture R onto the photocell S increases and causes the optical unit D to move away from the pattern A and the tool to move in a direction toward the work B in dependence upon the increase in light intensity.

The extent of movement of the tool relative to the work blank depends upon the strength of the current passing through the load coil of the electromagnet 19 which, in turn, depends upon the depth of shade of the dark portions 46 of the sketch. It follows, therefore, that movement of the tool in a direction away from the work blank B or, in other words, the height of the decoration cut in the work blank by the tool may be controlled by preselecting the shade of the dark portions 46 of the sketch. While particular care is exercised in selecting a shade which will effect the movement of the tool required to form the decoration to the proper height in the work blank, nevertheless, it is difficult to obtain a predetermined uniform depth of shade and, in some instances, portions of the shaded part of the record may be too dark. However, in accordance with the present invention, the darker portions of the record on the model will merely effect a further movement of the tool away from the work blank which may be easily corrected without destroying the work blank. Also, there is a possibility that the lamp in the projector unit may fail and render the light sensitive cell dark. With the present arrangement, such a failure would merely effect withdrawal of the tool from the work blank and, as a consequence, would not injure or impair the work blank in any way.

With the foregoing in mind, reference will now be made more in detail to the control circuit shown by the diagram in Figure 4 of the drawings. As will be observed from this diagram, the amplifier 50 comprises a plurality of amplifier tubes, designated generally by the reference characters 60, 61, 62, 63 and 64. Each of the amplifier tubes 60, 61, 62 and 63 comprises a

grid 65, a plate 66, a cathode 67, and a heating element 68 in the form of a filament. The amplifier tubes 64 in the last stage of the amplifier are connected together in parallel so that the output is greater than any one of the preceding tubes. In the embodiment of the invention shown in Figure 4, each of the tubes 64 comprises a grid 69, a plate 70, and a filament 71 which also acts as the cathode element of the tube.

The output or plate circuit of each preceding tube is conductively coupled to the grid of the succeeding tube and the plate or output circuits of the two parallel tubes 64 are connected to the load coil 39 of the electromagnet 19 through a resistor 72. It will be noted from Figure 4 that a power pack 73 of conventional design provides a low voltage alternating current for the filaments 68 of the amplifier tubes 60, 61, 62 and 63. In addition, the power pack 73 embodies a rectifier of the full-wave type which supplies a high voltage direct current across a resistor 74 and the latter, in turn, supplies the proper voltages to the plate circuits of the tubes 60, 61, 62 and 63.

Similar elements of the tubes 64 are connected together to provide multiple operation and a second rectifier 75 supplies the plate circuit of these tubes. The plate circuit of the tubes 64 comprises a resistor 76, the load coil 39 of the electromagnet 19, the resistor 72, the two plates 70, the filaments 71, and a resistor 77. Beginning at the center tap of the resistor 77, the grid circuit of the tubes 64 includes the C battery, with the polarity indicated, and resistors 78 and 79 conductively connecting the grids 69 in the plate circuit of the tube 63.

It will be noted from Figure 4 that the phototube or light sensitive cell S is electrically connected in parallel in the grid circuit of the amplifier tube 60. The anode 80 of the phototube is electrically connected to the resistor 74 at the tap 81 and the cathode 82 is electrically connected to the grid 65 of the tube 60. The grid circuit of the tube 60, starting from the cathode 67, includes a resistance 60', a resistance 84, and also the portion of the resistor 74 between the negative end of the latter and the tap 83 connecting the resistor 74 to the cathode 67. By tracing the grid circuit of the tube 60 through the resistance 84 to the tap 62' on the resistor 60', it will be noted that the grid 65 of the tube 60 is at a negative potential with respect to the cathode or plate circuit of this tube when the phototube S is dark or, in other words, when no current is flowing through the tube S.

However, when the intensity of light intercepted by the phototube S becomes sufficient to cause a current of predetermined value to flow through the phototube S, a voltage drop is effected across the resistor 84 connected in parallel in the grid circuit of the tube 60. This voltage drop is positive with respect to the cathode 67 of the tube 60 and has a counteractive effect on the fixed grid bias of this tube tending to make the grid less negative. When this condition exists, current flows through the plate circuit of the tube 60 and the flow of this current through a resistor 85 in the grid circuit of the second tube 61 causes a voltage drop across this resistor sufficient to render the normally positive grid of the tube 61 less positive. The cessation of current flow in the plate circuit of the second tube 61 causes the voltage on the normally positive grid of the third tube 62 to increase to substan-

tially the voltage at the tap 81. In other words, the grid of the tube 62 becomes more positive and causes a flow of current through the plate circuit of this tube. As current flows through the plate circuit of the tube 62, a voltage drop results across the resistor 86 rendering the normally positive grid of the tube 63 less positive and effecting a reduction in the flow of current through the plate circuit of the tube 63. A drop in current in the plate circuit of the tube 63 reduces the counteractive affect on the "C" battery and effects an increase in voltage on the grids 69 of the tubes 64, with the result that current flows through the plate circuit of these tubes. Inasmuch as the load coil 39 of the electromagnet is connected in the plate circuit of the tubes 64, it will be noted that the current flowing through the load coil will be correspondingly increased to operate the valve 18 and effect movement of the tool into the work.

When the intensity of light, intercepted by the phototube S, is decreased sufficiently to cause a predetermined drop in current flowing through the phototube, it will be understood that the grid potential of the tube 60 is reduced and, accordingly, the grid potential of the tubes 64 is correspondingly reduced. The resulting drop in current in the output or plate circuit of the tubes 64 reduces the flow of current through the load coil 39 in the electromagnet sufficiently to cause movement of the valve 18 under the action of the spring 41 to reduce the fluid pressure in the ram 13 and permit movement of the ram by the spring 27 in a direction to withdraw the tool from the work. It may be pointed out at this time that the control circuit is balanced in such a manner that the wattage through the load coil 39 in the electromagnet increases and decreases in proportion to the light intensity intercepted by the phototube S.

Thus from the foregoing, it will be observed that I have provided an improved reproducing machine of the photoelectric cell controlled type wherein the shaded decoration on the model is cut cameo in the mold so that this decoration will appear intaglio on the product cast in the mold. As previously stated, the above arrangement is an improvement over the construction set forth in my copending application Serial No. 261,606, filed March 13, 1939, in that it not only effects the saving in material designated in Figure 7 by the reference character M' but, in addition, simplifies the apparatus in that it renders it unnecessary to equip the same with safety devices for discontinuing the operation of the tool in the event the shade of the decoration should be too dark, or in the event the light in the projector should fail.

What I claim as my invention is:

1. In a reproducing machine, a pattern having a contoured surface with a shaded record thereon, an optical system for scanning the contoured surface, said optical system embodying means for casting an image on the contoured surface of the pattern with a contour line representing one section of the surface and in addition provided with a light sensitive cell responsive to variations in the light intensity reflected from the contoured pattern surface at opposite sides of the contour line and also responsive to the light intensity reflected from the shaded record, a support for a work blank, a tool positioned opposite the work blank, and means controlled by the light sensitive cell when the intensity of light intercepted by the latter is increased to

effect relative movement of the work blank and tool in directions toward each other and to effect relative movement of the work blank and tool in directions away from each other upon a decrease in the light intensity intercepted by the cell, whereby the shaded record is reproduced in cameo on the work blank.

2. In a reproducing machine, a pattern having a shaded surface portion, an optical system scanning the shaded surface and embodying a light sensitive cell responsive to variations in shading of the surface, a support for a work blank, a tool positioned opposite the work blank, and means controlled by the light sensitive cell for relatively moving the work blank and tool toward and away from each other in dependence upon variations in the light intensity intercepted by the light sensitive cell, said last named means being responsive to a decrease in the light intensity intercepted by the cell to effect relative movement of the work blank and tool in directions away from each other to an extent depending upon the degree of shade of the record whereby the latter is reproduced in cameo on the work blank.

3. In a reproducing machine, a pattern having a contoured surface with a shaded record thereon, an optical system for scanning the contoured surface and having means for casting an image on the contoured surface with a contour line representing one section of said surface, said optical system also provided with a light sensitive cell having an aperture arranged in intersecting relationship with the contour line and responsive to the intensity of light escaping through the aperture from opposite sides of the contour line, means controlled by the light sensitive cell for relatively moving the pattern and optical system toward and away from each other to maintain the aperture in intersecting relationship with the contour line, and a work blank and tool relatively movable by the last named means in directions toward each other when the light intensity intercepted by the aperture increases and relatively movable by said last named means in directions away from each other in dependence upon a decrease in the light intensity intercepted by the aperture, whereby the shaded record on the contoured surface of the pattern is reproduced in cameo on the work blank.

4. In a reproducing machine, a pattern having a contoured surface with a shaded record thereon, an optical system for scanning the contoured surface and having means for casting an image on the contoured surface with a contour line representing one section of said surface, said optical system also provided with a light sensitive cell having an aperture arranged in intersecting relationship with the contour line and responsive to the intensity of light reflected through the aperture from opposite sides of the contour line, means controlled by the light sensitive cell for relatively moving the pattern and optical system toward and away from each other to maintain the aperture in intersecting relationship with the contour line, said last named means being effective in dependence upon a decrease in light intensity to relatively move the pattern and optical system toward each other and upon an increase in the light intensity to relatively move the pattern and optical system away from each other, and a work blank and a tool relatively movable by said last named means in directions away from each other when the pat-

tern and optical system are relatively moved toward each other.

5. In a reproducing machine, a pattern having a contoured surface with a shaded record thereon, an optical system for scanning the contoured surface and having means for casting an image on the contoured surface with a contour line representing one section of said surface, said optical system also provided with a light sensitive cell having an aperture arranged in intersecting relationship with the contour line and responsive to the intensity of light reflected through the aperture from opposite sides of the contour line to pass an electrical current of a value depending upon the intensity of light intercepted by the aperture, an amplifier electrically connected to the light sensitive cell to amplify the current flowing therethrough, an electrically operated device in the output circuit of the amplifier and controlled by the light sensitive cell to relatively move the pattern and optical system toward and away from each other in dependence upon the intensity of light intercepted by the aperture, and a work blank and tool relatively movable by said electrically operated device in directions away from each other when the value of the current flowing through the output circuit of the amplifier is decreased whereby the shaded record on the pattern is reproduced in cameo in the work blank by the tool.

6. In a reproducing machine, a pattern having a contoured surface, an optical system for scanning the contoured surface and having means for casting an image on the contoured surface with a contour line representing one section of the surface, said optical system also provided with a light sensitive cell having an aperture arranged in intersecting relationship with the contour line and responsive to the intensity of light escaping through the aperture from opposite sides of the contour line to pass an electrical current of a value depending upon the intensity of light intercepted by the aperture, an amplifier electrically connected to the light sensitive cell to amplify the current flowing therethrough, an electrically operated device connected in the output circuit of the amplifier and controlled by the light sensitive cell to relatively move the optical system and pattern toward and away from each other to maintain the aperture in intersecting relationship with the contour line, and a work blank and tool relatively movable by said electrically operated device in directions away from each other when the current flowing through the output circuit of the amplifier diminishes below a certain value.

7. In a reproducing machine, a pattern having a contoured surface with a shaded record thereon, an optical system for scanning said surface and having means for casting an image on the surface with a contour line representing one section of the surface, said optical system also having a light sensitive cell supported in fixed angular relation to the light projecting means and having an apertured plate on which the image is reflected with the contour line thereof intersecting the aperture, said light sensitive cell being responsive to the intensity of light reflected through the aperture from opposite sides of the contour line and also being responsive to the variations in shading of the record on the contoured surface of the pattern, means controlled by the light sensitive cell for relatively

moving the pattern and optical system toward and away from each other to maintain the aperture in intersecting relationship with the contour line, and a work blank and tool relatively movable by the last named means in directions away from each other when the light intensity reflected through the aperture diminishes below a certain value whereby the record is reproduced in cameo in the contoured surface of the work blank.

8. In a machine for fashioning a mold cavity in a work blank with a record formed in cameo on the surface of the cavity, a pattern having a contoured surface corresponding to the surface of the cavity and having a shaded record on the surface corresponding to the record to be formed in cameo on the surface of the mold cavity, an optical system for scanning the contoured surface of the pattern and having means for casting an image on the contoured surface with a contour line representing one section of said surface, said optical system also provided with a light sensitive cell having an aperture arranged in intersecting relationship with the contour line and responsive to the intensity of light escaping through the aperture from opposite sides of the contour line and also responsive to the shading of the record on the pattern, means controlled by the light sensitive cell for relatively moving the pattern and optical system toward and away from each other to maintain the aperture in intersecting relationship with the contour line, and a work blank and tool relatively movable by the last named means in directions away from each other when the intensity of the light intercepted by the aperture diminishes below a certain value and relatively movable in directions toward each other when the intensity of light reflected through the aperture increases, whereby the shaded record on the surface of the pattern is formed in cameo on the surface of the mold cavity and is reproduced intaglio on the article cast in the mold cavity.

9. In a reproducing machine, a pattern having a contoured surface with a shaded record thereon, an optical system for scanning said surface and having means for casting an illuminated image on the surface with a contour line representing one section of the surface, said optical system also having a light sensitive cell supported to one side of the image projecting means in a position to intercept radiant energy reflected from the surface of the pattern, a plate for shielding the light sensitive cell from radiant energy reflected from the surface of the pattern and having an aperture therethrough, means for focusing a reflection of the light image on the plate with the contour line of the image intersecting the aperture and with the illuminated portion of the image extending toward the image projecting means, means controlled by the light sensitive cell for relatively moving the pattern and optical system toward and away from each other to maintain the aperture in intersecting relationship with the contour line, and a work blank and tool relatively movable in directions toward each other by the last named means upon an increase in radiant energy intercepted by the cell through the aperture and relatively movable in directions away from each other upon a decrease in radiant energy intercepted by the cell through said aperture.

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