

March 9, 1965

G. E. NELSON

3,172,989

ELECTRON BEAM CUTTING CONTROL

Filed July 27, 1962

4 Sheets-Sheet 1

FIG. 1

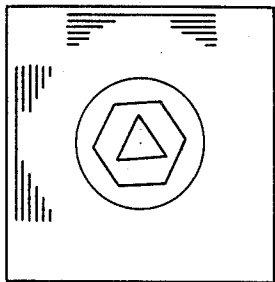


FIG. 2

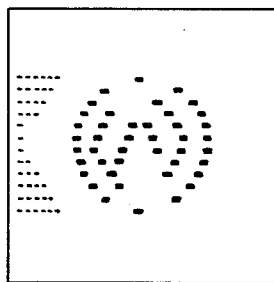


FIG. 3

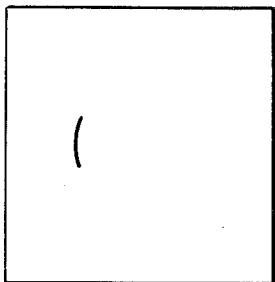


FIG. 4

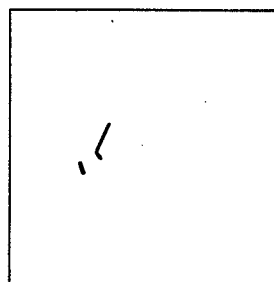


FIG. 5

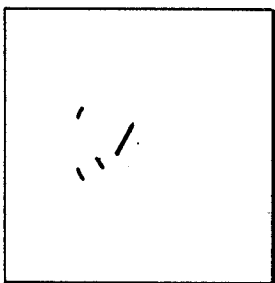


FIG. 6

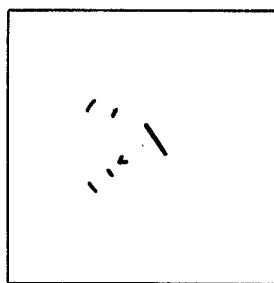


FIG. 7

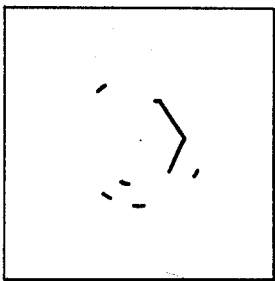
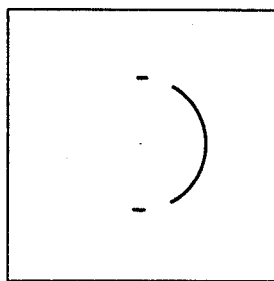


FIG. 8

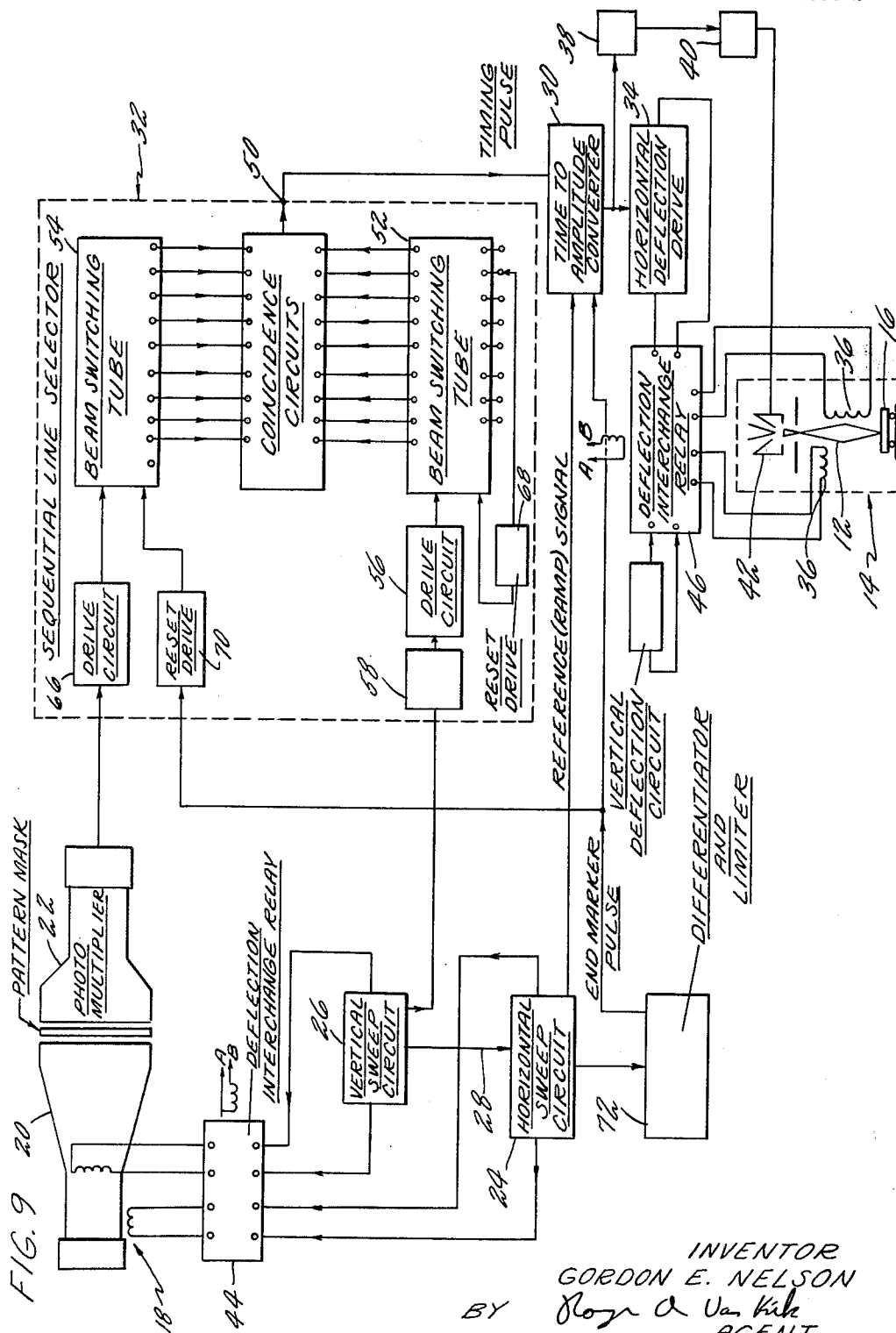


INVENTOR  
GORDON E. NELSON  
BY *Ray A. Van Kirk*  
AGENT

**G. E. NELSON**

# ELECTRON BEAM CUTTING CONTROL

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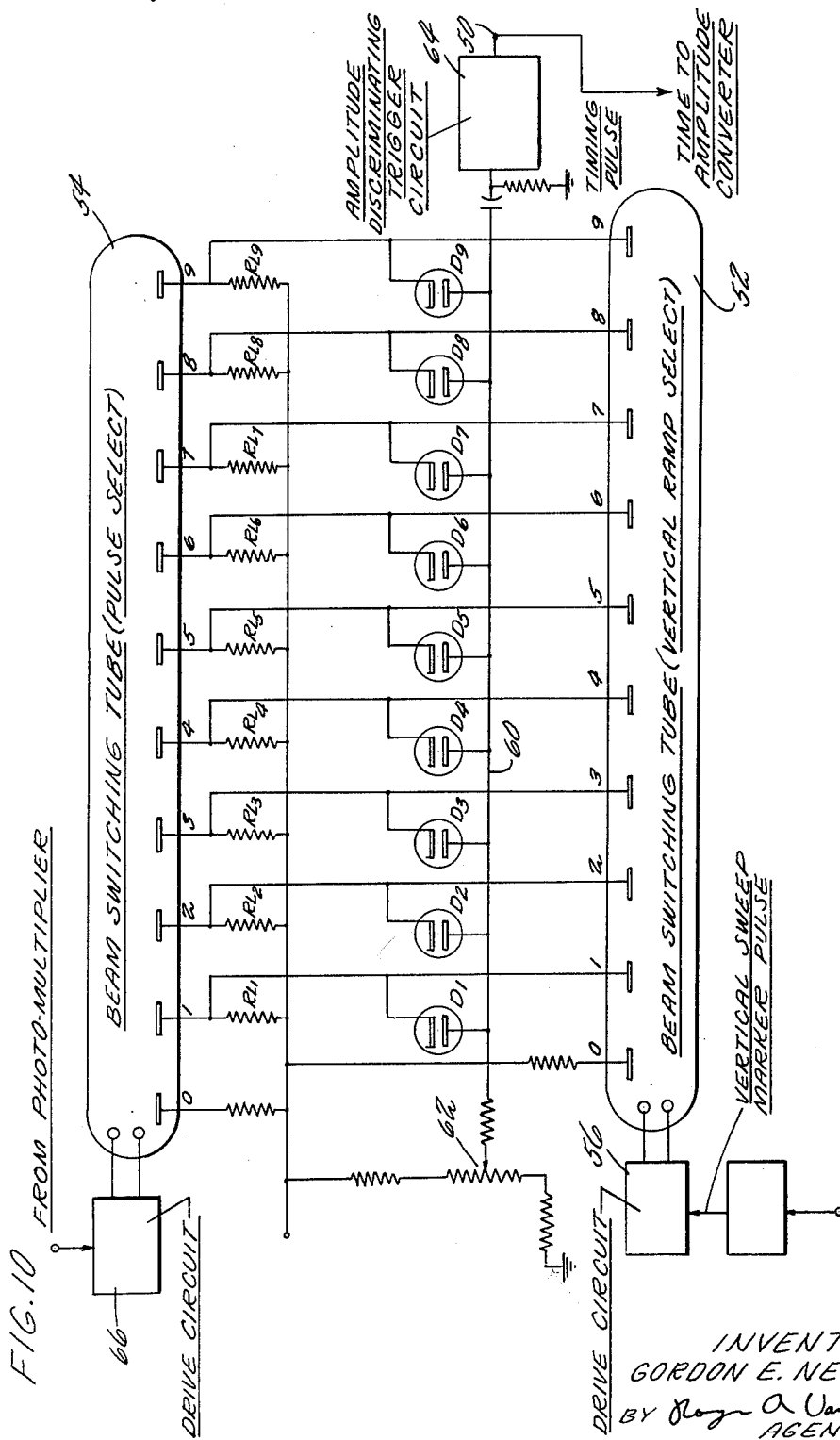
G. E. NELSON

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ELECTRON BEAM CUTTING CONTROL

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4 Sheets-Sheet 3



INVENTOR  
GORDON E. NELSON  
BY *Ray A. Van 14h*  
AGENT

March 9, 1965

G. E. NELSON

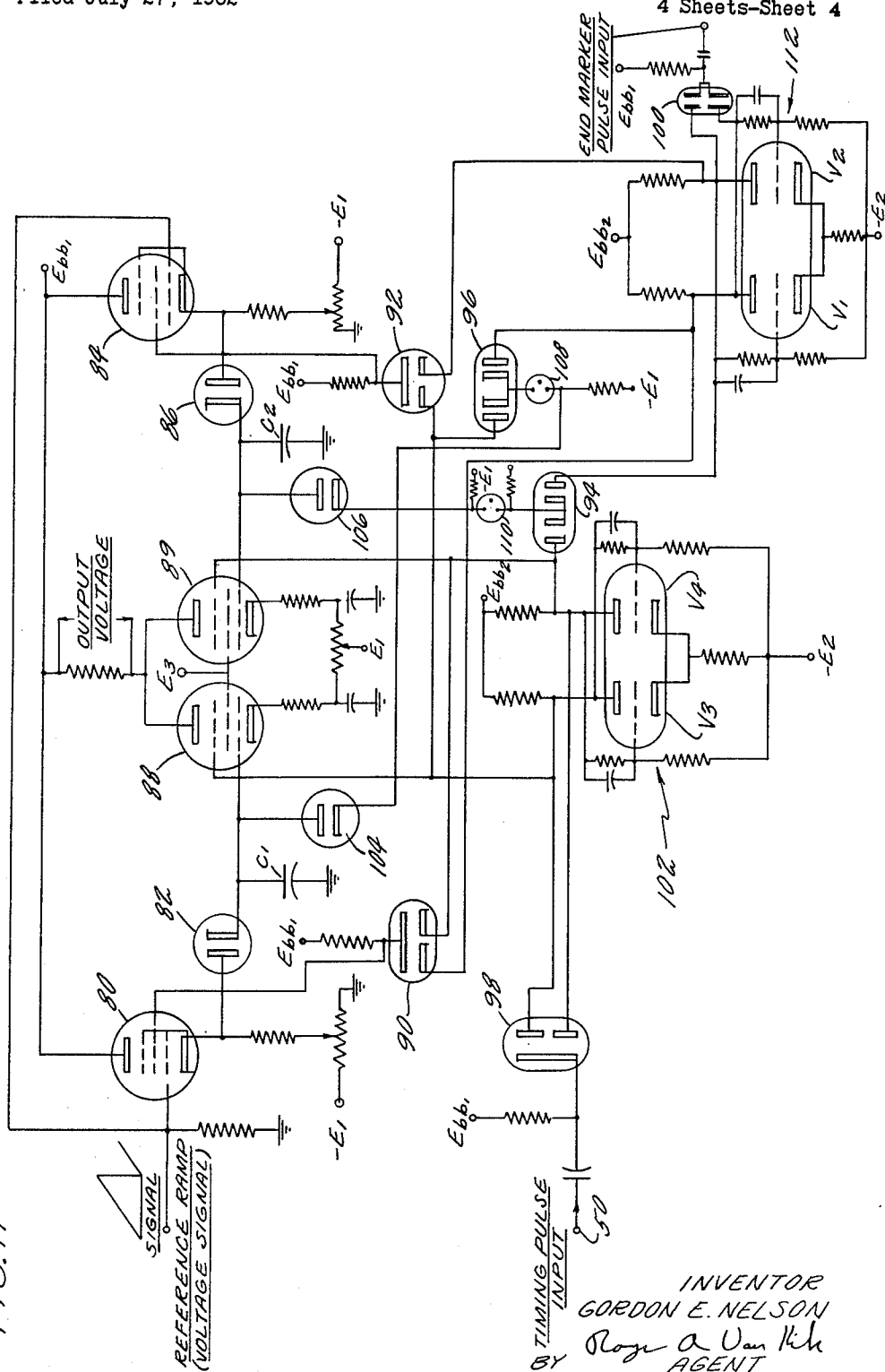
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ELECTRON BEAM CUTTING CONTROL

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FIG. 11



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3,172,989

## ELECTRON BEAM CUTTING CONTROL

Gordon E. Nelson, Tariffville, Conn., assignor to United Aircraft Corporation, East Hartford, Conn., a corporation of Delaware

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6 Claims. (Cl. 219-121)

My invention relates to programmed deflection of a beam of charged particles. More particularly, my invention relates to causing the high intensity beam in an electron beam machine to automatically trace a design carried by a remotely located pattern mask while performing a desired operation on a workpiece.

Electron beam machines, as they are generally known, are devices which use the kinetic energy of an electron beam to work a material. U.S. Patent No. 2,793,281, issued May 21, 1957, to K. H. Steigerwald, discloses such a machine. These machines operate by generating a highly focused beam of electrons. The electron beam is a welding, cutting and machining tool which has practically no mass but has high kinetic energy because of the extremely high velocity imparted to the electrons. Transfer of this kinetic energy to the lattice electrons of the workpiece generates higher lattice vibrations which cause an increase in the temperature within the impingement area sufficient to accomplish work.

To be commercially practicable, an electron beam machine must be adapted to perform the desired operation on the workpiece rapidly, accurately and automatically. The logical manner in which to accomplish this necessary automation is to provide for programmed relative movement between the electron beam and the workpiece. In order to realize this relative movement by programmed deflection of the electron beam, certain problems must be overcome. For example, steps must be taken to trigger the working electron beam only in spots where the pattern is to be cut, machined or a weld made and not when the beam is being deflected to these spots. Also, means must be provided to insure tracing the entire pattern. Most important, the beam must be rapidly deflected to the desired point and held there while the work is performed. My invention solves these problems and accomplishes the programming by providing novel apparatus for causing the electron beam to be deflected over the surface of the workpiece in accordance with a prepared pattern located exteriorly of the electron beam machine.

It is, therefore, an object of my invention to program the deflection of a beam of charged particles.

It is another object of my invention to cause a beam of charged particles to trace a pattern.

It is still another object of my invention to perform the desired operation on a workpiece with a beam of charged particles rapidly, accurately and automatically.

It is yet another object of my invention to provide an automatic control for an electron beam machine.

It is also an object of my invention to generate deflection control voltages for a device utilizing a beam of charged particles in a novel manner.

It is similarly an object of my invention to trace a pattern with a beam of charged particles by causing the beam to serially trace portions of the pattern.

It is likewise an object of my invention to convert time-spaced pulses to analogous amplitude varying pulses.

These and other objects of my invention are accomplished by novel apparatus which scans a pattern, senses the location of indicia on the pattern and generates from the indicia thus sensed beam control signals which are applied to the deflection and electron gun circuits of the electron beam generator.

My invention may be better understood and its numerous advantages will become apparent to those skilled in the art by reference to the accompanying drawings in which like reference numerals apply to like elements in the various figures and in which:

FIGURE 1 is a sample of a pattern desired to be traced.

FIGURE 2 is a representation of the pulse distribution generated during the multiple scanning of the pattern of FIGURE 1.

FIGURES 3 through 8 show the portions of the pattern which are cut or machined on the surface of the workpiece during the second through seventh scans of the pattern of FIGURE 1 in a first direction.

FIGURE 9 is a schematic drawing of the novel apparatus which comprises my invention.

FIGURE 10 is a view of a sequential line selector which may be used in the apparatus of FIGURE 9.

FIGURE 11 is a time-to-amplitude converter which may be used with the apparatus of FIGURE 9.

Referring now to FIGURES 1 and 9, FIGURE 1 shows a pattern mask containing a pattern that it is desired to have the beam 12 in an electron beam machine 14 cut or machine on a workpiece 16. In operation, the pattern mask will be positioned, as shown in FIGURE 9, so as to be repeatedly scanned by the beam of a flying-spot scanner 18. In the usual case the pattern, as shown in FIGURE 1, will appear as light lines on a photograph negative. As the flying-spot scans the screen of cathode-ray tube 20, there is provided a moving point source of light. Each time a light line on the negative is crossed or intercepted by the flying spot, a pulse of light will appear to emanate from the negative. These pulses of light are sensed by a photomultiplier 22 which converts them into electrical signals.

FIGURE 2 represents the light pulse distribution for the pattern mask of FIGURE 1 when scanned in the horizontal direction. The lines in the margin to the left and also above the pattern of FIGURE 1 enable the beam to be held "off pattern" when no pattern intercept occurs. The pattern mask is prepared so that the total number of intercepts thereon along any line in either the horizontal or vertical direction, including the pattern, will always equal a preselected maximum number.

During operation, as the flying spot scans the pattern mask, each position or the flying spot of point source of light will correspond to a definite point on a reference sawtooth deflection voltage, generated by horizontal sweep circuit 24, which is used to linearly move the spot across the screen of the cathode-ray tube 20. Whenever the occurrence of a line or other indicia on the pattern is sensed by the photomultiplier 22, a current pulse is produced. This current pulse appears at a point relative to the ramp of the reference sawtooth voltage that is linearly further up the ramp for greater intersection distances scanning from left to right. To advance the horizontal scan of the pattern to a lower position vertically, a slower or lower frequency sawtooth voltage is applied to the vertical deflection coils of flying-spot scanner 18 by vertical sweep circuit 26. The sweep voltage generated in vertical sweep circuit 26 will, obviously, be synchronized, by means not shown, with a corresponding vertical sweep voltage generated in the vertical deflection circuit which is connected, through interchange relay 46, to deflection coils 36 of machine 14. The phase relationship between the vertical and horizontal sweep voltages applied to tube 20 is maintained by applying the vertical sweep voltage via conductor 28 to the horizontal sweep circuit which, as is common in the art, includes a synchronizing circuit.

The technique described above is similar to that used with standard flying-spot scanning techniques. My invention resides in what is subsequently done with the pulses generated by photomultiplier 22. These pulses are used in conjunction with the reference ramp signal from horizontal sweep circuit 24 to generate potentials corresponding to the distances from the beginning of the sweep to the interception of the lines on the pattern. This is done by the time-to-amplitude converter circuit 30 which will be described in detail below in the explanation of FIGURE 11.

As the flying spot may intercept several lines while moving across the pattern, it is necessary to provide circuitry which will enable it to look at one line or portion of a line at a time. This is accomplished by interpositioning between the photomultiplier 22 and time-to-amplitude converter 30 a sequential line selector 32 which generates timing pulses in response to the interception of a line or indicia on the pattern which corresponds to the number of times the pattern has been scanned. That is, line selector 32 will generate a timing pulse in response to the first indicia on the pattern only during the first cycle of the vertical sweep voltage, in response to the second indicia only during the second vertical sweep and so on until the pattern has been scanned in a vertical direction a number of times equal to the maximum number of lines or indicia on the pattern that will be scanned in a horizontal direction. The circuitry and operation of a preferred sequential line selector will be discussed below in relation to FIGURE 10.

As can be seen from FIGURE 1, during the first scan of the pattern mask the electron beam 12 of machine 14 will be held off or out of the work area since for any vertical level an "off pattern" line in the left margin of the mask will be sensed during the scanning of the mask. That is, the photomultiplier 22 will sense a line on the pattern mask which occurs in time near the beginning of the build up of the sawtooth voltage generated by horizontal sweep circuit 24. The corresponding current pulses generated by the photomultiplier will be applied to sequential line selector 32 which will produce timing pulses which similarly will occur in time at a low level of the reference sawtooth voltage. The timing pulses from line selector 32 are applied to time-to-amplitude converter 30 which generates deflection control pulses which, in this case, will have a very small amplitude. These deflection control pulses generated in response to the "off pattern" indicia are applied to horizontal deflection drive circuit 34 and thence to the beam deflection means 36 of the electron beam machine 14. Because of their small amplitude, these control pulses will cause the electron beam in machine 13 to be deflected only slightly and not on to the workpiece. During the second cycle of the vertical deflection voltage, a portion of the pattern, as shown in FIGURE 3, will be cut or machined on the workpiece since there is an area on the pattern mask where the second line intercepted by the flying spot will be the pattern itself. The sensing of the pattern itself will, through the combined action of line selector 32 and time-to-amplitude converter 30, cause beam deflection control pulses to be generated, in the manner described above, having sufficient amplitude to deflect the beam to the proper position on the work piece. As shall be explained below, due to the time constants of the circuit, the beam in the electron beam machine will trace a smooth curve as shown in FIGURE 3. That is, the beam control pulses generated by time-to-amplitude converter 30 will not decrease to zero at the end of each horizontal traverse of the pattern by the flying spot and thus the beam will step or be deflected from pedestal to pedestal.

Also connected to the output of time-to-amplitude converter 30 is a differentiator 38 and gating circuit 40 which function together as a blanking circuit to provide for cutting off the beam of the electron beam machine while the deflection voltage for the machine is step changed

from an off pattern value to a magnitude commensurate with the position of the beginning of a new line to be cut as determined by the position of such line on the pattern. By differentiating the pulse output of the time-to-amplitude converter, a signal is produced which will bias the electron beam machine to cut off during the periods when the beam is being rapidly deflected. This bias voltage is applied to the control electrode 42 of the machine 14. Since, as stated above, the beam control pulses do not decrease to zero but will step from pedestal to pedestal, a blanking pulse will be produced by differentiator 38 only when there is a large variation between the pedestals or amplitudes of successive beam control pulses. Consequently, the beam will remain on once it has been triggered by gating circuit 40 until the next "off pattern" line or a spatially removed portion of the pattern causes generation of a timing pulse by line selector 32.

After the pattern mask has been scanned by the flying-spot scanner 18 the desired number of times in the horizontal direction, a pattern will have been machined or cut in the workpiece 16 which may have voids therein. These voids may result because there is a finite distance between lines scanned in the horizontal direction during the cycles of the vertical sweep voltage and also because there may be horizontal lines on the pattern which will cause generation by the photomultiplier of only a single pulse of long duration. Therefore, to insure cutting the complete pattern, after the scanning in the first direction has been completed, a pair of deflection interchange relays 44 and 46 are activated by means not shown. This causes the direction of scanning of the pattern to be rotated 90° and the direction of beam deflection in the electron beam machine to be similarly rotated 90°. This rotation also serves another purpose. Consider the outer circle of the pattern of FIGURE 1 and the last portion thereof which, as shown in FIGURE 8, will be traced on the workpiece during the seventh scan of the pattern in the horizontal direction. Since the vertical sweep voltage for the flying spot scanner increases linearly, increments of the circumference of the circle of varying size are scanned during each horizontal pass of the flying spot as the pattern is scanned from top to bottom. That is, the greater the distance the portion of the pattern being scanned lies above or below a horizontal line through the center of the circle, the longer the increments of the circumference lying between successive points of interception of the flying spot and the circle become. As these increments become longer, the beam in the electron beam machine must trace a larger arc as it steps from pedestal to pedestal and, in so doing, must move across the surface of the workpiece at velocities which vary directly with the length of these increments. The beam power density at any point is a function of the time the beam impinges on that point and is thus also directly related to the length of said increments. It will be obvious to those skilled in the art that it is desirable if not mandatory that the beam power density or work done should be the same for all points on the pattern being traced. Interchanging the deflection coils makes the total power density at each point on the workpiece the same since, after the 90° rotation of the direction of scanning, the points on the pattern which formerly were impinged upon for the longest time will now be worked by the beam for the shortest time and vice versa.

Referring now to FIGURE 10, there is shown a sequential line selector circuit which may be employed in the apparatus of FIGURE 9. This circuit functions such as to deliver a pulse at its output terminal 50 only when one of the two beams switching tubes 52 and 54 is receiving a target or anode current at the same instant the other tube is switching its beam current onto the corresponding target. Each time the pattern has been completely scanned in a horizontal direction a pulse will be delivered to the drive circuit of the ramp selector beam switching tube 52. That is, a switching pulse will be

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delivered to tube 52 by drive circuit 56 for each cycle of the vertical deflection voltage generated by vertical sweep circuit 26. The sawtooth wave produced by sweep circuit 26 is differentiated and limited by a differentiator limiter circuit 58. The circuit 58 will produce, in a manner well known in the art, a negative pulse which occurs during the flyback portion of each cycle of the vertical deflection voltage. This negative pulse is applied to drive circuit 56 for switching the tube 52. When the first pulse signifying the beginning of the first vertical scan arrives, the beam current in tube 52 will be switched from zero target to target 1. As each subsequent pulse arrives the beam will be diverted to the next target. As is well known in the art, beam current will flow in only one of the target circuits of each tube at a time. When target current is flowing, the voltage at that target is reduced by the voltage drop across its corresponding target load resistor indicated by  $R_{L1}$  through  $R_{Ln}$ . Because of the constant current characteristics of beam switching tubes, the operation of the switching circuit will be unaffected by minor variations in the target supply potential. By interconnecting the corresponding targets of the two tubes, two targets are caused to share the same load resistor. Thus, when target current is flowing to both interconnected targets, target voltage is depressed by twice the potential than would occur with a current flowing to a single target.

Diodes D1 through D9 function as a coincidence circuit and connect each interconnected pair of targets with a common or coincidence bus 60. The anodes of the diodes are connected to bus 60 while the cathodes are connected to their respective pair of interconnected target electrodes. The potential on bus 60 and thus the diodes anode voltage is adjusted by potentiometer 62 so as to be lower than the target or diodes cathode voltage when only one target of a pair is receiving current but to be higher than diodes anode potential when both targets are receiving current. As a result, the cathode of a diode becomes more negative than its anode only when both of its associated interconnected targets are receiving current. Thus one of the diodes will conduct and a pulse will be delivered to coincidence bus 60 only when both interconnected targets are receiving current. The diodes D1 through D9 isolate the coincidence bus from each of the target circuits at all other times. The pulses on bus 60 are supplied to trigger circuit 64, which may be any one of a number of pulse shaping circuits known in the art, and the resultant constant amplitude pulses are supplied to the time-to-amplitude converter 30.

The output pulses from photomultiplier 22 are supplied to drive circuit 66, and are thus used to switch tube 54. Therefore, it can be seen that line selector 32 will deliver a timing pulse to time-to-amplitude converter 30 only when the number of times the pattern has been scanned corresponds to the number of indicia on the pattern sensed by the photomultiplier as the pattern is scanned in a horizontal direction.

Referring back to FIGURE 9, it is, of course, necessary to provide for resetting the beam switching tubes 52 and 54. Reset drive circuits for these tubes are well known in the art. The reset drive circuit 68 for the vertical ramp select beam switching tube 52 is activated in response to current flow in a selected target circuit of the tube itself. That is, the triggering signal for the reset drive 68 is derived from the target circuit of the target corresponding to one more than the maximum number of times it is desired to scan the pattern in the horizontal direction. The triggering voltage for reset drive 70 for pulse select beam switching tube 54 is derived by differentiating and limiting circuit 72 which operates on the voltage generated by horizontal sweep circuit 24. This differentiation and limiting of the saw-tooth horizontal deflection voltage will produce a negative pulse during the fly-back portion of each cycle of this voltage which pulse is used to trigger reset drive 70.

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The line selector described above is meant to be representative only and it would still be within the scope of my invention to substitute other coincidence circuits for the diode arrangement shown or to use devices other than beam switching tubes. For example, a pair of decade scaling or counting circuits might be substituted for the beam switching tubes while "and" gates could be utilized in place of the above discussed coincidence circuit without departing from the spirit of my invention.

Referring now to FIGURE 11, there is shown a schematic of a time-to-amplitude converter circuit. This circuit basically functions such as to convert the time interval between two successive pulses into a voltage or current that is proportional to this time interval. The time proportional signal is stored and appears at the output terminals of the circuit until the following two pulses have arrived at which time the output voltage will step change to a second voltage plateau or pedestal which is proportional to the time interval between these two succeeding pulses. The foregoing is accomplished by allowing a gated vacuum tube to "look at" or measure the potential across a capacitor which was charged by a ramp voltage which began increasing at the beginning of a scan of the pattern. Charging of the capacitor is initiated by a pulse signifying start of a scan and is stopped when a second pulse commensurate with the interception or scanning of indicia on the pattern is received. This charging phase is taking place while a second gated tube is looking at the charge stored in a second capacitor on the previous cycle. In FIGURE 11, the pentodes 88 and 89 alternately look at the charge stored on capacitors C1 and C2 respectively while cathode followers 80 and 84 alternately charge capacitors C1 and C2 respectively through charging diodes 82 and 86.

The gate and restoring pulses supplied to the circuit to enable it to perform as described above are generated by a pair of bistable multivibrator circuits 102 and 112 and are supplied to the proper circuit element at the appropriate time by signal coincidence diodes 90, 92, 94 and 96. Whenever a timing pulse is received from line selector 32 at the input or steering diode 98, bistable multivibrator 102 will switch from one state to the opposite state and will return to its original state when a second timing pulse arrives at diode 98. The negative pulse which is generated by differentiator-limiter 72 and which occurs during the fly-back portion of the horizontal scan sawtooth voltage cycle is applied to the cathode of diode 100 thereby causing this diode to switch bistable multivibrator 112 from one state to the other. When the next fly-back pulse occurs this multivibrator will return to its original state.

To understand operation of this circuit, assume an initial condition with V4 of multivibrator 102 conducting and V3 nonconducting. At this instant, V1 of multivibrator 112 is conducting and V2 is nonconducting. A timing pulse arriving at diode 98 from line selector 32 will turn V4 off resulting in a rise in the plate voltage of V4 and a decrease in the plate voltage of V3. By proper selection of the circuit supply voltages, the plates of the conducting sections of the multivibrators assume a negative potential relative to the cathodes of the read-out pentodes 88 and 89. V1 and V3 are both conducting and thus both have relatively negative plate voltages. This results in both plates of coincidence diode 96 dropping in potential so that the cathode potential of diode 96 will drop to a point where restoring diode 104, the cathode of which is connected to the cathode of diode 96, will conduct. Conduction of diode 104 will discharge capacitor C1 and, since the plate voltage on V3 is relatively negative with respect to the cathode of read-out pentode 88 which has its suppressor grid connected to the plate of V3, pentode 88 will be cut off during this restoration phase. Cathode follower 80 is also held off during this phase because the relatively negative plate voltage of V1 initially results in the plate voltage of coincidence diode

90, which has its cathode connected to the plate of V1, being low. Since the plate of diode 90 is connected directly to the screen grid of cathode follower 80, this tube will be biased off. The foregoing is true even though the plate voltage on V4, which is also applied to a cathode of diode 90, is positive since only one diode cathode need have a negative voltage to depress the diode plate potential. During the portion of the cycle that pentodes 80 and 88 are cut off, read-out pentode 89 is conducting since the plate voltage of V4, which is applied to its suppressor grid, is positive and C2 is in a charge holding state.

When a negative fly-back pulse appears at the cathode of diode 100, it results in a switching of bistable multivibrator 112 to a state in which V1 is nonconducting and V2 is conducting. Since the plate voltage of V1 is now positive and since the plate voltage of V4 remains positive in this phase, the plate voltage of coincidence diode 90 will rise since both cathodes of this diode are now positive. The cut-off bias is therefore removed from the screen grid of cathode follower 80 just as the reference ramp voltage begins the rise. C1 is then charged by charging diode 82 as the voltage at the grid of cathode follower 80 rises. Restoring diode 104 is cut off during this phase because the positive plate voltage of V1 is connected to one of the plates of coincidence diode 96 thereby resulting in a rise in the cathode voltage of diode 96 and hence a rise in the cathode voltage of diode 104. Thus the cathode voltage of restoring diode 104 is raised to the cut-off level.

Capacitor C1 is then charged until another timing pulse arrives at the input to multivibrator 102 resulting in a switching of that multivibrator such that V4 becomes conducting and V3 is cut off. This results in the screen grid voltage of cathode follower 80 being reduced to the point where the tube is cut off because the cathode of diode 90 is connected to the plate of V4 which is now conducting and thus assumes a relatively negative potential. Since V3 is now cut off, its plate voltage rises and thus the negative bias is removed from the suppressor grid of read-out pentode 88. Thus, when cathode follower 80 was cut off, C1 stopped charging and pentode 88 now observes the charge being held on C1.

While the charge stored in C1 is being observed, diode 106 is in the restoration phase and is discharging C2 because the plate voltages of V4 and V2 are relatively negative resulting in the cathode of coincidence diode 94 going negative and bringing with it the cathode of diode 106 so that this diode conducts. Cathode follower 84 is biased off at this time because the plate of V2 is relatively negative rendering the plate of coincidence diode 92 negative. When the next fly-back pulse arrives at the steering diode 100, multivibrator 112 is switched to the state where V1 is again conducting and V2 is cut off. The plate voltage of diode 92 thus rises and turns cathode follower 84 on. The cathode follower 84 then charges capacitor C2 through charging diode 86. Upon arrival of the fly-back pulse, restoring diode 106 was cut off because the rise in the plate voltage of V2 caused a rise in the cathode potential of diode 106. When the next timing pulse arrives at steering diode 98, the plate of V3 again becomes relatively negative and the plate of V4 positive. The negative plate voltage of V3 depresses one of the cathodes of coincidence diode 92 causing the plate of this diode to also be depressed thus cutting off cathode follower 84 and charging diode 86. The positive potential on the plate of V4 turns on read-out pentode 89 so that it may observe the charge on C2. The negative plate of V3 depresses the suppressor grid voltage of read-out pentode 88 to cut off this tube and diode 104 restores C1 again to complete the cycle.

To summarize the above, when a first timing pulse is received V3 will be switched on and V4 off while V1 will remain on and V2 off. Capacitor C1 will thus be discharging while the charge stored in capacitor C2 is

being read out. The read out will continue until another timing pulse is received. When the fly-back portion of the sweep voltage cycle occurs, V3 will remain on and V4 off while V1 will be switched off and V2 on. Capacitor C1 will thus begin to recharge while the charge on C2 is still being observed. Upon receipt of a second timing pulse, V3 will be switched off and V4 on while V1 will remain off and V2 on. Capacitor C1 will then stop charging and the charge stored therein read out while capacitor C2 will be discharged. Upon the completion of the horizontal sweep, another fly-back pulse will be received which will cause V1 to be switched on and V2 off while V3 remains off and V4 on. Capacitor C2 then begins to recharge while capacitor C1 is still being read out. When a third timing pulse is received the cycle of operation will begin to repeat by the discharge of capacitor C1 and the read out of capacitor C2.

As can be seen from the above, the output of the time-to-amplitude converter does not decrease to zero after each horizontal sweep of the flying spot. Thus, a rapid change in beam deflection control voltage of sufficient amplitude to cause the differentiator 38 of FIGURE 9 to generate a pulse of sufficient amplitude to activate gating circuit 40 to cause the beam in machine 14 to be biased off will only occur when successively sensed indicia on the pattern mask are spatially removed from one another.

Referring again to FIGURE 11, connected between the cathodes of coincidence diodes 94 and 96 and the restoring diodes 106 and 104 which they respectively control are voltage reference elements 108 and 110. These voltage reference elements may be voltage regulator tubes or neon lamps which are operated in the normal glow region. It has been found necessary to use the elements 108 and 110 to provide for different D.C. potentials at the cathodes of the two interconnecting diodes, for example diodes 96 and 104, while permitting the A.C. control signals to pass unimpeded. If these elements are not used, the D.C. voltages applied to the restoring diodes from the multivibrators plate circuits would be too large.

It may also be desirable to insert a gating circuit between the timing pulse input 50 of the time-to-amplitude converter and the multivibrator 102. Such a gating circuit would be connected to pass timing signals from line selector 32 to the multivibrator 102 only when the two multivibrators were properly phased and would thus guarantee proper operation of the circuit.

While a preferred embodiment has been shown and described, various modifications and substitutions may be made without deviating from the scope and spirit of my invention. Also, while my invention has been discussed largely with respect to cutting or machining a pattern or design on a workpiece, it would be equally advantageous for use in a welding operation where either butt or spot welds are to be made. Thus, my invention is described by way of illustration rather than limitation and accordingly it is understood that my invention is to be limited only by the appended claims taken in view of the prior art.

I claim:

1. Apparatus for causing an energized beam to reproduce a remotely located pattern comprising:
  - means for generating an energized beam,
  - means for deflecting said beam in a first direction,
  - means for deflecting said beam in a second direction normal to said first direction,
  - means spatially displaced from said beam generating means and carrying a pattern to be reproduced by said beam,
  - pattern scanning means positioned adjacent said pattern carrying means,
  - scanning signal generator means coupled to said pattern scanning means for causing said pattern scanning means to scan the pattern in response to generated scanning signals,
  - means responsive to the scanning of the pattern for

generating signals commensurate with the appearance of indicia thereon,  
 means responsive to said indicia occurrence signals and said scanning signals for generating control signals varying in amplitude in accordance with the elapsed time between the beginning of a scan of the pattern and the generation of an indicia occurrence signal, and  
 means for supplying said control signals to said means for deflecting the beam in a first direction.

2. The apparatus of claim 1 wherein said scanning signal generator means comprises:  
 means for generating signals which will cause the pattern to be repeatedly scanned in a first direction at a first frequency and,  
 means for generating signals which will cause said pattern to be repeatedly scanned in a second direction normal to said first direction at a frequency differing from said first frequency.

3. The apparatus of claim 2 wherein the means for generating control signals comprises:  
 means responsive to said first direction scanning signals and to said indicia occurrence signals for generating timing pulses whenever the number of times the pattern has been scanned in a first direction coincides with the number of indicia on the pattern as scanned in the second direction, and  
 time to amplitude converter means responsive to said timing pulses and to said second direction scanning signals for producing beam control signals varying in amplitude with the elapsed time between the beginning of a scan of the pattern in the second direction and the sensing of indicia on the pattern.

4. The apparatus of claim 3 wherein the time to amplitude converter means comprises:  
 means responsive to said second direction scanning signals for storing a signal equal to the instantaneous value thereof,  
 means responsive to said timing pulses for electrically isolating said storing means from said means for generating second direction scanning signals upon the occurrence of a timing pulse, and  
 second means responsive to said timing pulses for reading the stored signal out of said storing means and applying said stored signal to said means for deflecting the beam in a first direction whereby said stored signal is utilized to control beam deflection.

5. An electron beam welding and cutting apparatus comprising:  
 means for generating an intense beam of electrons,  
 means for deflecting said beam in a first direction,  
 means for deflecting said beam in a second direction normal to said first direction,

a flying spot scanner,  
 a deflection voltage generating means for supplying first and second scan control signals to said scanner, sensing means responsive to the scanning of a pattern by said scanner for generating signals commensurate the occurrence of indicia on the pattern,  
 means responsive to signals generated by said sensing means and to said scan control signals for generating signals varying in amplitude in accordance with the elapsed time between the beginning of a scan of the pattern in a first direction and the generation of a signal by said sensing means, and  
 means for supplying said amplitude varying signals to said beam deflection means for deflecting the beam in a first direction whereby the beam is caused to reproduce the pattern on a workpiece.

6. The apparatus of claim 5 wherein the means for generating amplitude varying signals comprises:  
 means responsive to said second scan control and said indicia occurrence signals for generating timing pulses whenever the number of times the pattern has been scanned in a first direction coincides with the number of indicia on the pattern as scanned in a second direction,  
 means responsive to said first scan control signals for storing a signal equal to the instantaneous value thereof,  
 means responsive to the occurrence of a timing pulse for isolating said storing means from said deflection voltage generator, and  
 second means responsive to the occurrence of a timing pulse for reading the stored signal out of said storing means and applying said stored signal to said means for deflecting the beam in a first direction whereby said stored signal is utilized to control beam deflection.

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RICHARD M. WOOD, *Primary examiner*.  
 JOSEPH V. TRUHE, SR., *Examiner*.