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H. S. BEST ET AL

3,425,166

RESISTOR TAILORING MACHINE

Filed Sept. 28, 1966

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FIG. 1

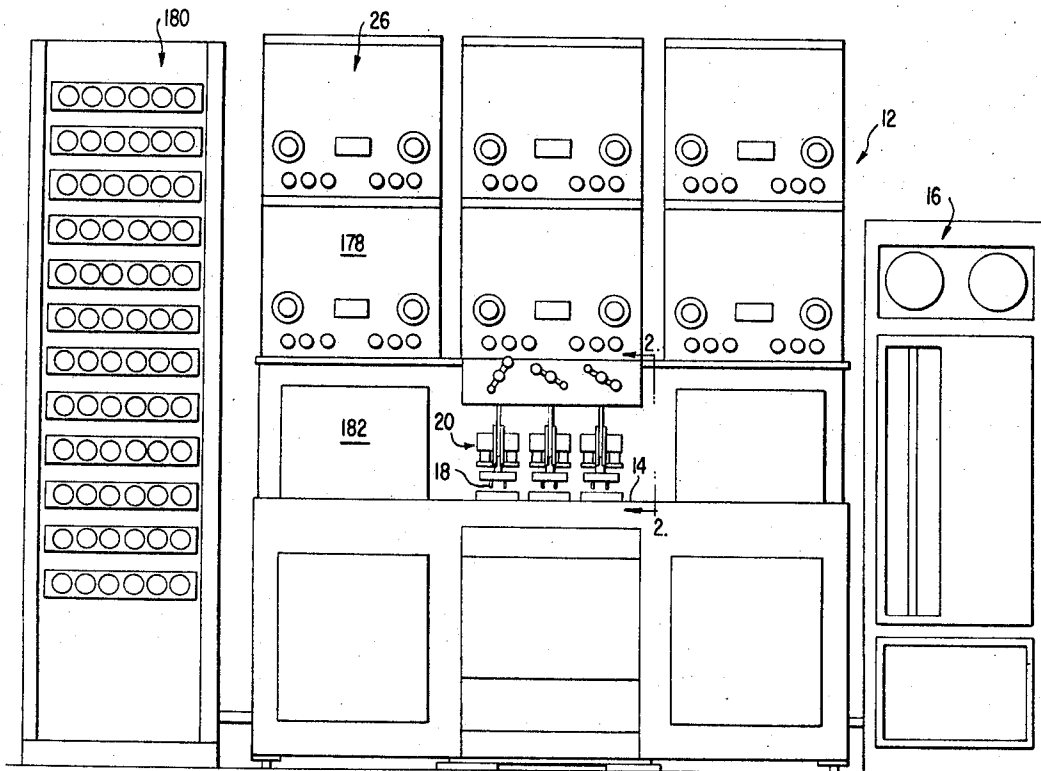


FIG. 7

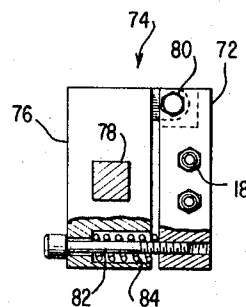
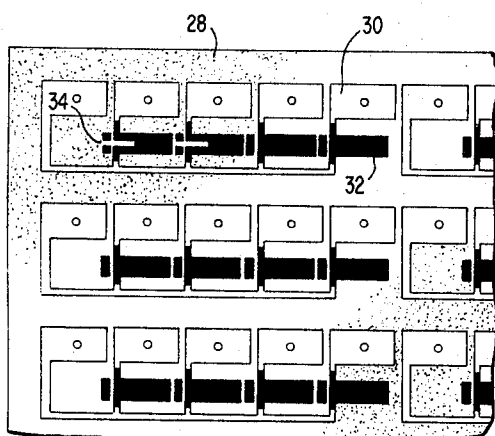


FIG. 4

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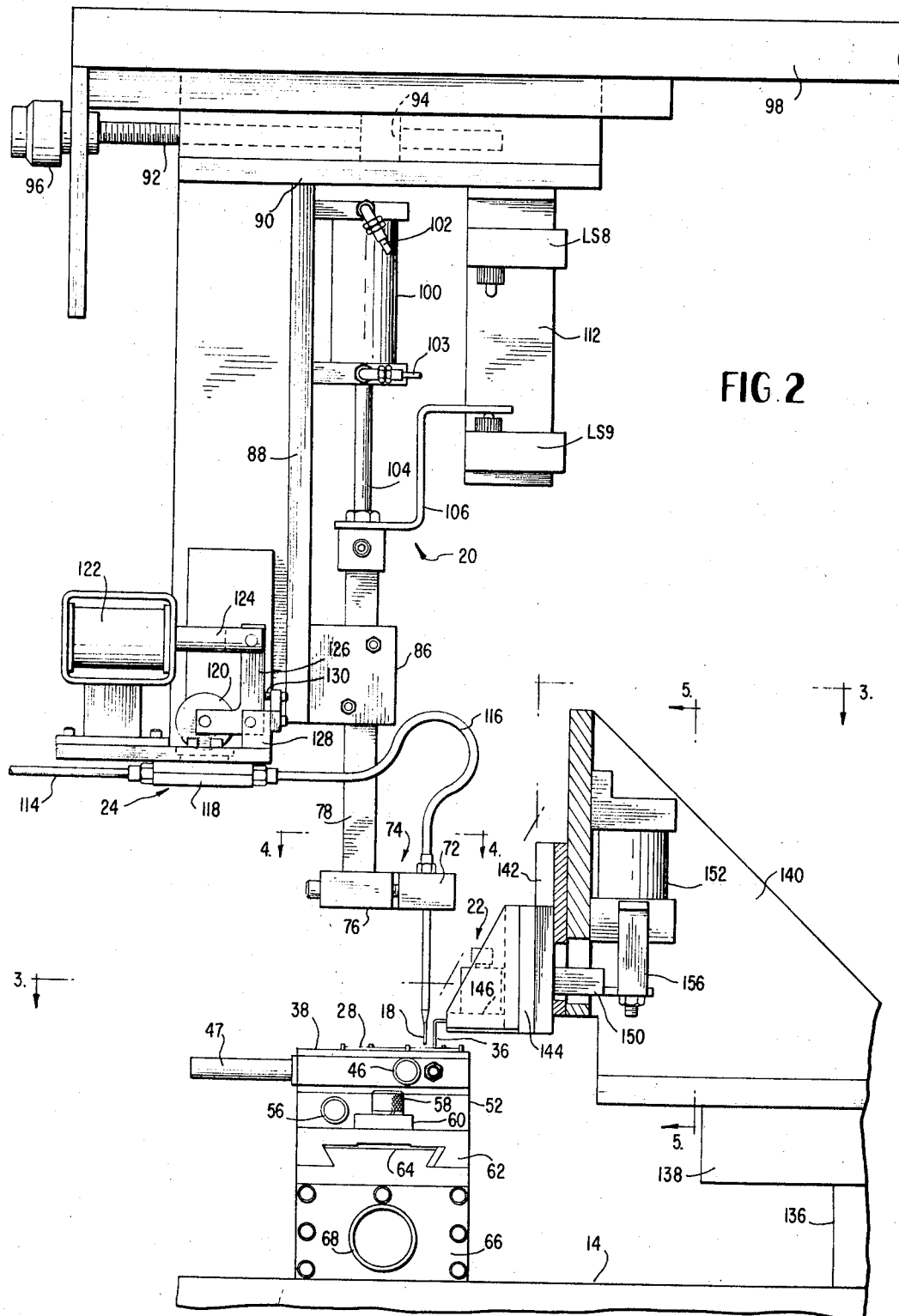
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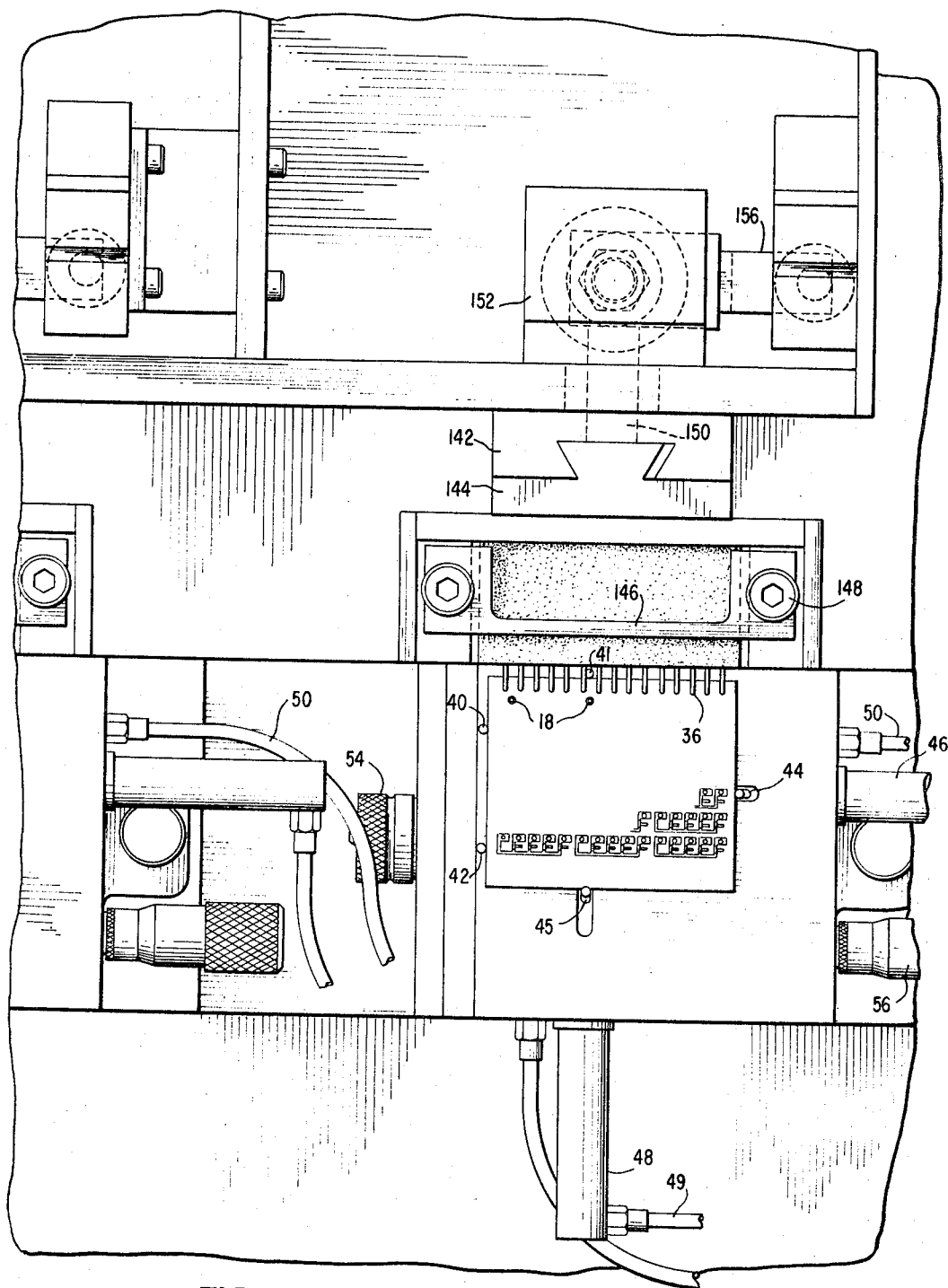


FIG. 3

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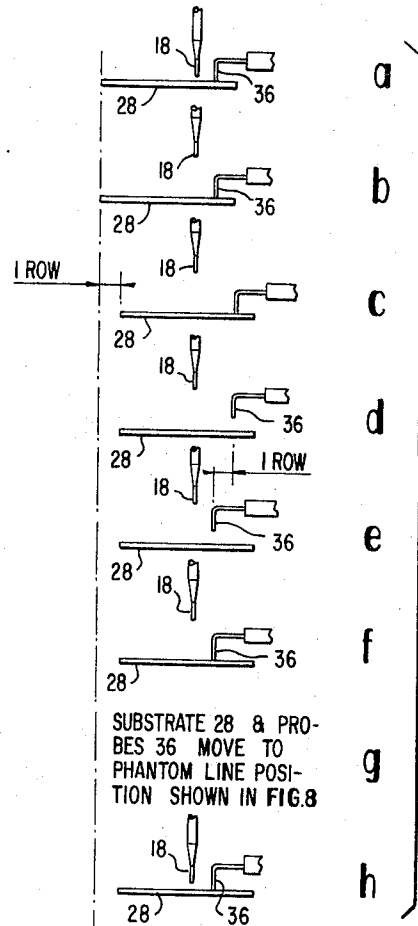
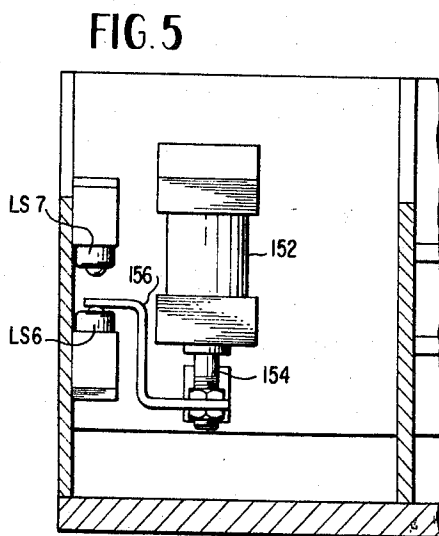
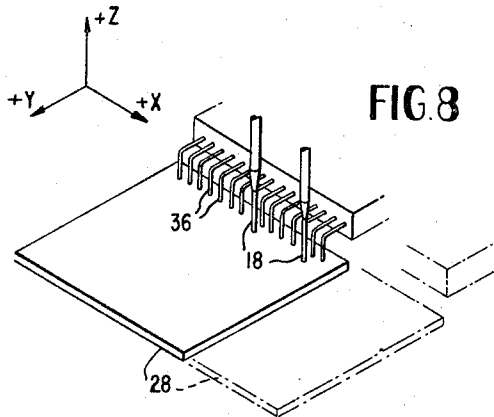
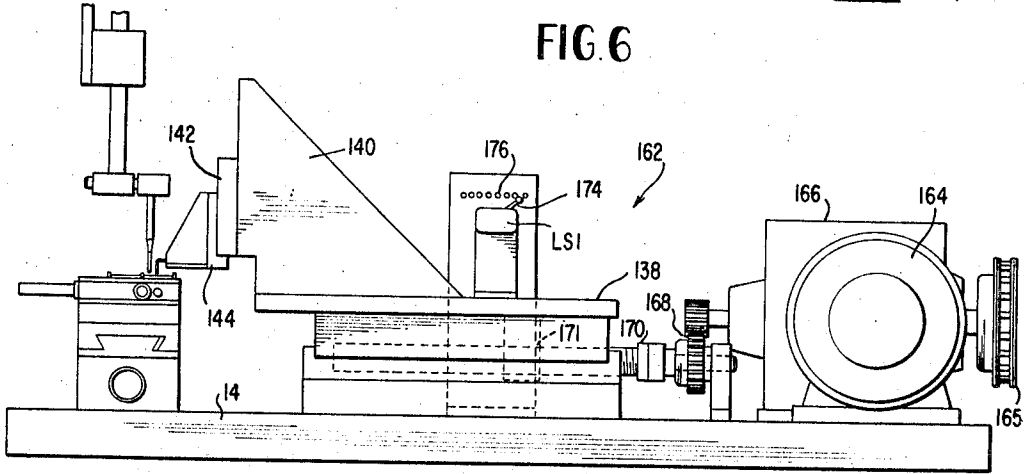
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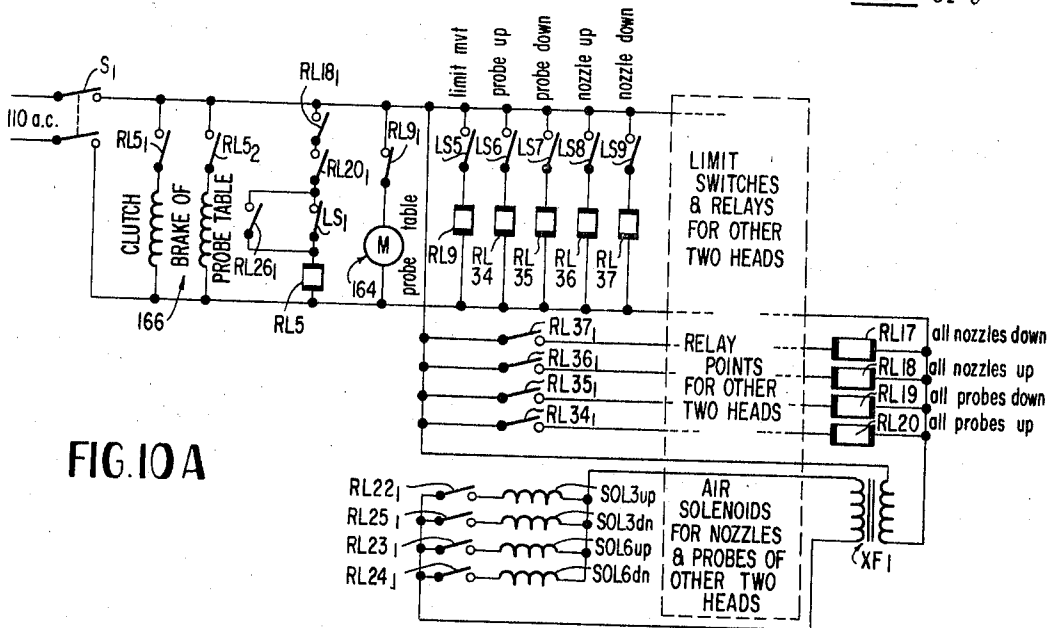


FIG. 10 A

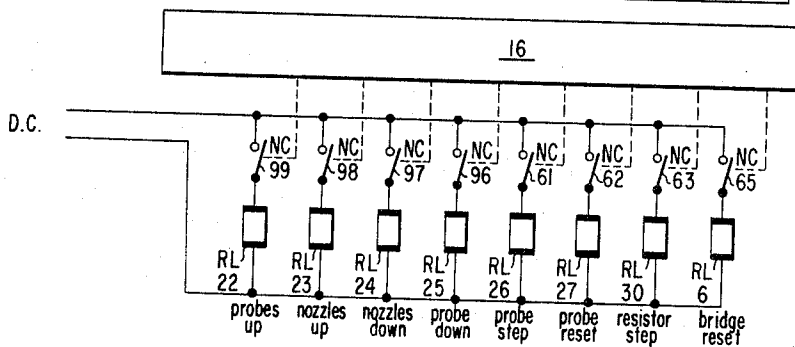


FIG. 10 B

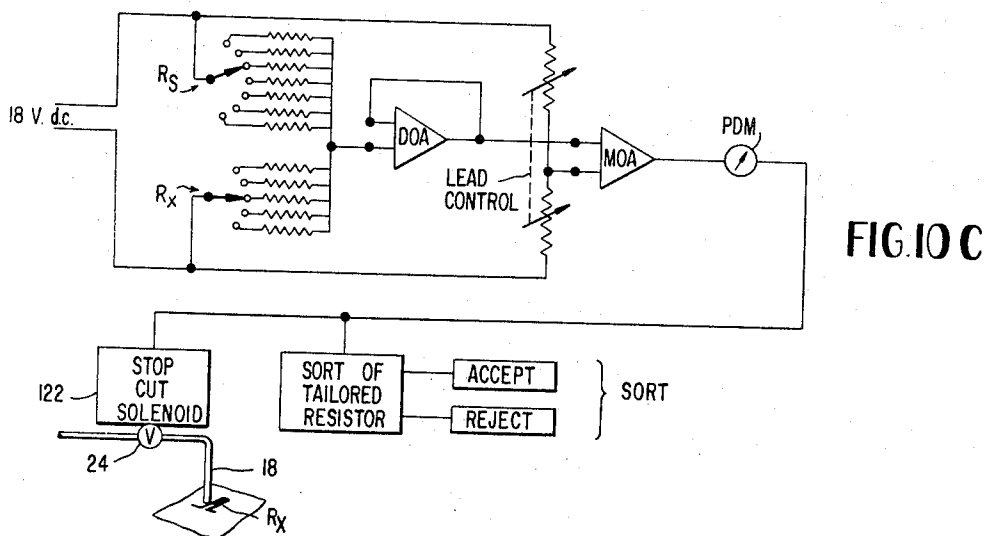


FIG. 10 C

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RESISTOR TAILORING MACHINE

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U.S. Cl. 51-14

Int. Cl. B24c 3/00

5 Claims

ABSTRACT OF THE DISCLOSURE

A resistor tailoring machine mounts resistors to be tailored on a work table moveable in horizontal plane under numerical control to precisely preselected positions under an abrasive blast nozzle fixed with relation to the movement of the work table and directed toward resistors thereon. The abrasive blast nozzle reciprocates vertically and includes a valve for selective control of the abrasive blast for resistor tailoring. Electrical intercontrols synchronize movement of the table, nozzle and abrasive application as well as electrical probes which contact the resistors on the table.

This invention relates to improvements in resistor tailoring machines.

In the manufacture of miniature electronic circuits, it is common to provide a conductive pattern on an insulating substrate together with other components including resistors. These resistors are commonly of the film type and may be placed on the substrate connecting portions of the conductive pattern. It is known that these film resistors can be tailored to a desired value by abrasive blasting of the resistor to physically remove a portion of the resistive film between the conductive portions of the circuit, thus providing the precise resistance desirable.

This invention relates to a machine for abrasive blasting of film resistors on a substrate in order to tailor the resistance value to any predetermined preset value. Since a base or substrate may have a number of resistors on it, this tailoring machine is useful for the abrasive blasting of a number of resistances, some simultaneously and some in succession.

The circuit substrates with conductive portions and resistive portions thereon are placed in a machine on a work table below a plurality of parallel abrasive blast nozzles. The work table is stepped under the control of an external programmer such as a numerical control and abrasive blasting is accomplished by abrading a longitudinal stripe as the work table is moved in a straight line and while probes are continually measuring the value of the resistance. The abrasive blast continues until a predetermined resistance is reached or until a fixed physical length of the resistive strip is removed. After tailoring one set of resistances the abrasive nozzle is removed, the probe is lifted, the work table is stepped and the probe and abrasive nozzles are repositioned for abrading another film resistor on the same substrate.

The foregoing and other features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a front elevation view of the resistor tailoring machine of this invention with three stations and associated electrical control circuits and external programmed numerical control;

FIG. 2 is a sectional elevation view of one tailoring station taken along line 2—2 of FIG. 1;

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FIG. 3 is a sectional plan view taken along line 3—3 of FIG. 2;

FIG. 4 is a sectional detail view taken along line 4—4 of FIG. 2;

FIG. 5 is a sectional detail view taken along line 5—5 of FIG. 2;

FIG. 6 is a side elevation view of one tailoring station illustrating the drive for the probe table;

FIG. 7 is an enlarged detail view of a portion of an exemplary circuit having film resistors thereon to be tailored by the machine of this invention;

FIG. 8 is a perspective view of the circuit abrasive nozzles and probes of one tailoring station illustrating the stepwise movement of the substrate carrying the film resistors;

FIGS. 9a through 9h are schematic side elevation views illustrating the stepwise operation of the machine when considered in connection with FIG. 8; and

FIGS. 10a through 10c are electrical circuit diagrams schematically illustrating the controls for the machine.

In general assembly, a resistor tailoring machine 12, is preprogrammed for tailoring film resistors on a circuit substrate by an abrasive blast. The substrate is carried by a movable work table 14 under numerical control from preprogrammed numerical control unit 16. A plurality of abrasive blast nozzles 18 are positioned stationary with respect to movement of the table 14 in a horizontal plane although these nozzles are vertically reciprocable. There are two nozzles per head in the preferred embodiment and three heads in a machine, one head per station. Means 20 are provided for mounting the head carrying the abrasive blast nozzles 18 for controlled vertical movement. For measuring the electrical resistance of the resistors being tailored, there is provided an electrical probe assembly 22 which is carried by, but movable relative to, the table 14. Valve means 24, FIG. 2, are provided for controlling the abrasive blast for tailoring the resistors, and electrical controls 26, see FIGS. 10a, 10b and 10c, are utilized to control the operation of the machine.

The machine of this invention operates to tailor a resistor which is preferably of the metal oxide film type positioned on a substrate 28. The substrate 28 as shown in FIG. 7 may include conductive portions 30 and metal oxide film resistive portions 32. As shown in FIG. 7 there are a plurality of individual resistors in three separate rows to be tailored. The table 14 carrying substrate 28 can move in a horizontal plane in both the x and y directions to position the substrate relative to the abrasive blast nozzles positioned above the substrate. During tailoring operations, the table 14 carrying substrate 28 is moved in a straight line so that a line or stripe portion of resistors 32 will be removed as shown for example by the removed portion 34 of the resistors in the upper left hand portion of FIG. 7. During the removal operations the conductive portions 30 are contacted by probes 36 which in turn are connected to bridge circuits to control and cut off the abrasive blast at the time the resistance 32 is tailored to the preset value.

Referring now to the work support for the circuit substrate 28 carried on and movable with table 14, this support includes a pad surface 38 having a plurality of fixed locating pins 40, 41 and 42, see FIG. 3, extending upwardly therefrom to locate the substrate relative to its support. Movable positioning pins 44 and 45 also extend upwardly from the surface of the pad 38 to move the substrate in against the referencing fixed locating pins. Air cylinders 46 and 48 connected to suitable air supplies such as air supply 49 for cylinder 48 are utilized to move the positioning pins 44 and 45.

A vacuum hold down is utilized to hold the substrate 28 down on the pad 38 and vacuum may be connected

to line 50 extending underneath the surface of the pad to a cavity under the substrate 28 which is not shown. The pad 38 is located upon support member 52 which in turn is adjustable relative to the table 14 in a longitudinal or x direction by means of adjusting screw 54, FIG. 3, and is clamped in adjusted position by clamping screw 58. The support member 52 may also be angularly adjusted by micrometer adjusting screw 56. Adjustment in a y or transverse horizontal direction relative to table 14 is accomplished by adjusting the nozzle support, not the work support. Clamping screw 58 is mounted on boss 60 and clamps the support member 52 to member 62 which in turn is mounted on a dove-tail rail 64 of a vacuum manifold 66 having a vacuum inlet 68. The vacuum through manifold 66 is to clear away any abrasive particles after they have been used for blasting.

The reciprocable nozzle assembly 20 is shown in more detail in FIGS. 2 and 4. The nozzles 18 are mounted in holes in a movable portion 72 of a nozzle carrier 74 which also has a fixed portion 76. A square sectioned reciprocating rod 78 is attached to the fixed portion 76. As shown in FIG. 4 the movable portion 72 of the nozzle carrier is angularly adjustable about a pivot screw 80 by means of angular adjustment screw 82 which is normally biased by spring 84 as shown in FIG. 4. In this manner, the nozzles 18 carried by the movable portions 72 may have an angular adjustment about the center of pivot screw 80.

The square sectioned reciprocating rod 78 is guided in a slide bearing 86 attached to a vertical support 88 which is part of a movable bridge 90. Bridge 90 is movable to accomplish the adjustment of the nozzles in the y or transverse horizontal direction by means of a screw 92 and nut 94; the nut being attached to bridge 90 and the screw rotatably mounted in frame portion 98 and actuatable by operating head 96.

In order to reciprocate the nozzles 18 an air cylinder 100 is provided having air inlet connections 102 and 103 to opposite ends thereof. A piston, not shown, reciprocates within cylinder 100 and is connected by piston rod 104 to the square sectioned rod 78. A switch operator 106 is connected to the piston rod to operate nozzle up switch LS8 or nozzle down switch LS9. These switches are mounted on switch brackets 112. The nozzle down switch LS9 is utilized to assure that the nozzles 18 are down before the abrasive blast is turned on and the nozzle up switch LS8 is utilized to assure that the nozzles 18 are up before the table is indexed one step.

The valve assembly for controlling the abrasive blast includes an abrasive inlet line 114 connected to a source of commercially available abrading material extending through the valve means 24 and having a further abrasive carrying line 116 connected to the top of the nozzles 18. The valve itself is a pinched tube-type valve 118 operated by a cylindrical disc operator 120 which in turn is under the control of solenoid 122 having armature 124 connected to bell crank 126 mounted on bracket 128 and stopped by screw stop 130.

The probe assembly 22 is movable with the work table 14 and is also movable relative to the work table 14. The probe assembly 22 is supported from a probe table support rail 136 which in turn supports the movable probe table 138 which is movable relative to table 14, see FIGS. 6 and 2. The probe table 138 includes a forward upstanding portion 140 having vertical ways 142 attached thereto. A probe head carrier 144 includes a clamp 146 having screws 148 for clamping a plurality of probe contacts 36 which in turn are connected to the electrical circuitry by conductors not shown. The probe carrier 144 is vertically movable to allow for lateral stepwise movement of the probe relative to the circuit substrate and the vertical movement of the carrier is through a bracket 150. An air cylinder 152 attached to portion 140 includes a piston rod 154, see FIG. 5, attached to bracket 150 for moving the probe head carrier 144 up and down in ways 142

when the probe table 138 is stepped relative to table 14. A switch actuating member 156 is attached to piston rod 154 for actuating a probe down switch LS6 and a probe up switch LS7. The probe down switches of all stations must be actuated prior to starting of the resistor tailoring operation. The probe up switch must be actuated before the probe table 138 can move relative to support table 14 to index the probe to the next line of resistors.

The probe table is driven relative to table 14 from a variable D.C. motor 164 through a chain drive 165 and brake-clutch mechanism 166 as well as a gearing couple 168 to a drive screw 170 which mates with a nut 171 attached to probe table 138. Control of the stepwise movement of the probe table 138 relative to table 14 is accomplished by a switch LS1 having actuating arm 174 contacting a plurality of positioning pins 176 which are spaced apart a distance equal to the distance between rows of resistors 32 on substrate 28 in FIG. 7.

In addition to including the electrical switches mentioned above, the electrical circuit includes bridges 178 which are balanceable by the resistor trimming operation, decade box 180 for setting the resistors and operator controls 182.

FIG. 10a shows the inner controls for indicating whether all of the probes and nozzles of all of the stations are either all down or all up and for controlling the drive of the probe table, and also showing energization of the solenoids for the air cylinders to control movements of the probes down and up.

FIG. 10b is a showing of how the numerical control operates relays to control positioning the probes down or up, stepping the probes or stepping the resistor or resetting the bridge, as well as other desired or auxiliary functions.

FIG. 10c is an illustration of how the resistor tailoring bridge circuit of this invention is utilized.

As shown in FIG. 10a, a source of 110 volt A.C. or any suitable power is connected through manual control switch S₁ to the lines shown. The clutch and brake 166 of the probe table are controlled by relay points RL5₁ and RL5₂ of relay RL5. Normally RL5₂ is closed energizing the brake so that the probe table is stopped and cannot be stepped. Relay RL5 is in series with relay points RL18₁ and RL20₁ and when relay RL18 is energized all nozzles are up and when relay RL20 is energized all probes are up, thus when points RL18₁ and RL20₁ are closed, it means that both the probes and the nozzles of all three stations, i.e., all six heads, are up and the probe table can index. This is the condition of FIG. 9d prior to the probe table indexing one row as in 9e. The energization of relay RL5 is through parallel paths including one through normally open limit switch LS1 which closes as the probe is being stepped from one point to the next. To initiate movement of the probe table the energization of RL5 is through the alternate path of relay points RL26₁ which are closed when a probe step signal energizes relay RL26 through numerical control circuit 61. As soon as movement begins LS1 closes and RL26 will be de-energized. The points of switch LS1 are the equivalent distance of one row apart so as the probe table is moved it will continue to move until the next pin 176 contacts arm 174 to open LS1. At this point relay RL5 will be de-energized thereby energizing the brake and de-energizing clutch to stop the probe table.

The probe table motor may be under the control of a plurality of limit switches one of which is shown. Relay points RL9₁ control energization of probe table motor 164. Energization of relay RL9 is under the control of limit switch LS5 which may be positioned at one end of the maximum length of travel of the probe table. There may be additional limit switches not shown.

When the probes of one head, such as shown in FIG. 9, are down as in FIGS. 9a, 9b, 9c, 9f or 9h, the probe down limit switch LS6 is closed energizing relay RL34, closing relay points RL34₁. Similarly, when the probes

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are up LS7 is closed energizing RL35, closing relay points RL35₁. When the nozzles are up, LS8 is closed, energizing RL36 and closing relay points RL36₁. When the nozzles are down, LS9 is closed, energizing RL37, closing relay points RL37₁. There are similar limit switches and relays for the other two heads, all connected in parallel. When all of the probes are up, RL34₁ and two similar sets of relay points for the other two heads in series are closed to energize RL20 which is a relay indicating that all points are up. It is noted that points RL20₁ are in series with relay RL5. Similarly, when all probes are down, relay RL19 will be energized. When all nozzles are up, RL18 will be energized and when all nozzles are down RL17 will be energized. In each case energization is through relay points such as RL37₁ and two other sets of relay points for the other two heads in series therewith, so that all nozzles of all three heads have to be down.

FIG. 10b illustrates the operation of the numerical control 16 preprogramming positioning of the probes or nozzles up or down and stepping of the probes or resistors or resetting the same or resetting the bridge after measure, or any other auxiliary function. In each case a numerical control circuit in effect closes a switch such as NC99, NC98, NC97, NC96, NC61, NC62, NC63 or NC65, to correspondingly energize a relay such as RL22, RL23, RL24, RL25, RL26, RL27, RL30 or RL6, respectively. These relays control appropriate relay points to accomplish the functional action in other portions of the circuit. For example, in the lower portion of FIG. 10a solenoid 3_{up} is controlled by relay points RL22₁. Energization of relay RL22 closes relay points RL22₁ energizing solenoid 3_{up} to apply air to raise the probes on head 144 by applying air to the bottom side of air cylinder 152. Similarly, the nozzle moving air cylinder 100 is controlled by solenoids 6_{up} and 6_{down} through relay points RL23₁ and RL24₁, respectively. Additional air solenoids for the nozzles and probes of the other two heads are in series. The numerical control 16 will not advance its tape until all components are ready and this can also be controlled by relay points in a straightforward circuit arrangement, not shown.

For controlling the application of abrasive blast through nozzles 18 to the resistive film by means of valve 24, the resistance to be measured is contacted by the conductive probes 36 and placed in a modified bridge circuit shown in the top portion of FIG. 10c. This modified bridge circuit, in addition to an unknown resistance value R_x being measured, includes a plurality of standard resistance values R_s which may be preset to a plurality of levels by a stepping switch. There is shown a plurality of unknown resistances R_x so that the device can step from one unknown resistance to another for all of the six resistances being tailored simultaneously. The bridge is fed to one input of a differential operational amplifier DOA and when the bridge approach is balanced the amplifier will come out of saturation and pass through an early balance point which is caused by a slight positive bias applied to the other input. This will stop the abrasive blasting operation just early enough so that the mechanical lag of the system will finish the cut to precisely the right resistance value. During the abrasive blasting time a meter operational amplifier MOA also follows the deviation. This amplifier is connected to a production deviation meter PDM so that the tailoring can be monitored. The lead control for energization of stop-cut solenoid 122 may be set by setting the lead control resistances feeding one input of the meter operational amplifier. After stopping the cut, a sort of the tailored resistor can be accomplished. The resistance of the tailored resistor is measured and the resistor is subsequently sorted into an acceptable or rejectable category.

It is believed the operation of the invention is apparent from the foregoing but a brief résumé will now be given. Referring to FIGS. 8, 9, 10a, 10b, and 10c, and considering the resistances to be in columns and rows as shown

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in FIG. 7, the abrasive blast nozzle 18 is positioned to abrade a stripe by removing portion 34 of resistor 32 while the probes 36 are in contact with the resistor until such time as solenoid 122 cuts off the abrasive blast through valve 24 and nozzles 18. The substrate will be moving in a horizontal x direction so that the stripe 34 of the resistor 32 can be removed. In the meantime, the probes 36 are contacting conductive portion 30 while moving with the substrate. As the measured resistance R_x balances the standard, the stop-cut solenoid 122 is energized and the abrasive blast is stopped. At the end of a line of resistors on a substrate the nozzle 18 is raised by a signal applied from the numerical control through NC98 circuit to energize nozzles up relay RL23 which in turn closes relay points RL23₁ energizing solenoid 6_{up} of FIG. 10a. At that time numerical control 16 closes NC63 to energize RL30, the resistor step relay, and correspondingly causes drive motor of table 14 to step one row of resistors by driving table 14 to the right as viewed in FIGS. 6 and 9, to the position of FIG. 9c. Next the numerical control will close NC99 energizing RL22 closing relay contact RL22₁ energizing solenoid 3_{up} to apply air to air cylinder 152 and pull the probes up to the position shown in 9d. Then the probe table is driven one step forward under the control of clutch and brake 166 and relay RL5 as well as limit switch LS1 as explained above. Then the probes 36 may be moved down again by numerical control closing NC96 which in turn energizes relay RL25 closing relay points RL25₁ and energizing solenoid SOL3_{down} to apply air to the top of cylinder 152. The nozzle 18 may be moved down similarly by the numerical control, by closing NC97. To step the resistor in the direction from one column to another after the tailoring is completed, the same operations may take place as shown in phantom lines in FIG. 8, only this time the resistor step relay RL30 is energized by numerical control closing circuit NC63 energizing the motor for table 14, not shown, to step the table one step in the x direction. Following this, the probe 36 and nozzle 18 are positioned as shown in FIG. 9h, adjacent the substrate to start the abrasive blast again as the table is slowly moved in the x direction a distance less than the space of conductive portions 30 of the circuit so that the probe stays on the circuit while the modified bridge circuit of FIG. 10a is comparing the unknown resistance R_x against the preset standard R_s .

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A resistor tailoring machine comprising; (a) a work table movable in a horizontal plane, (b) resistor mounting means on the work table, (c) means including numerical control means for moving the work table to precisely preselected locations, (d) an abrasive blast nozzle fixed with relation to the movement of the work table and directed toward the resistor mounting means on the work table, (e) means mounting the abrasive blast nozzle for controlled reciprocating vertical movement, (f) electrical probes adjustably clamped in a movably mounted probe support for controlled vertical reciprocating movement, (g) valve means adjacent the nozzle for selective control of the application of abrasive from the nozzle to accomplish resistor tailoring, and (h) electrical intercontrols for synchronizing movement of the table, movement of the probes, movement of the nozzle, and stopping the application of abrasive from the nozzle at a precisely predetermined time corresponding to the value of the resistance tailored.

2. A resistor tailoring machine as in claim 1 wherein there are a plurality of parallel abrasive blast nozzles mounted for reciprocating vertical movement together, and corresponding parallel electrical probes.

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3. A resistor tailoring machine as in claim 2 further comprising means on the work table for supporting a circuit substrate having a film resistor thereon, the means being adjustable relative to the work table.

4. A resistor tailoring machine as in claim 3 further comprising means for adjusting the position of the fixed abrasive blast nozzle relative to the position of the work table.

5. A resistor tailoring machine as in claim 1 wherein the electrical intercontrols include limit switches for indicating the upper and lower limits of movement of the probes and nozzles.

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References Cited

UNITED STATES PATENTS

587,892	8/1897	Walter	-----	51—14
2,743,554	5/1956	Dailey et al.	-----	51—15

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