

April 19, 1966

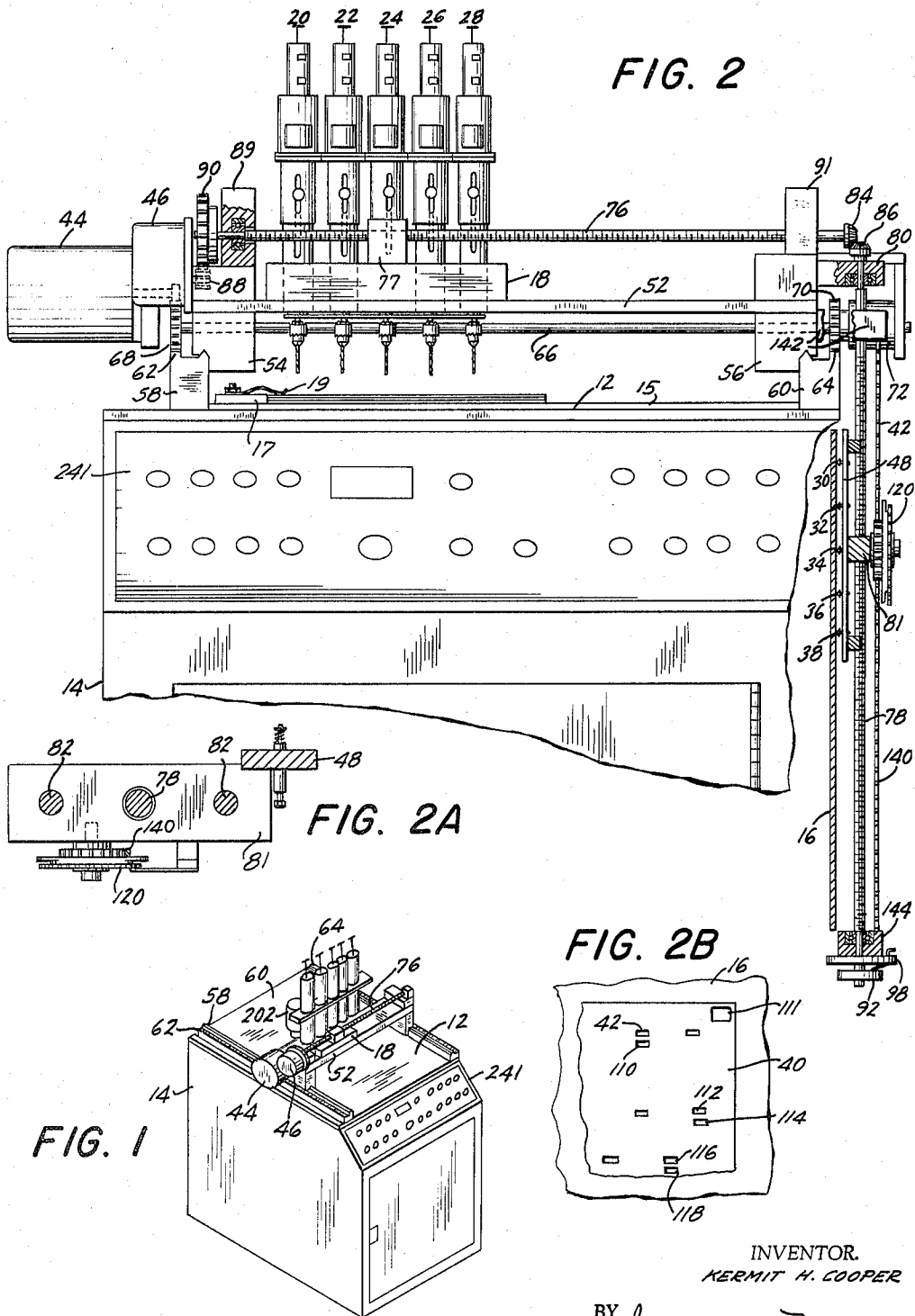
K. H. COOPER

3,246,544

MULTIPLE DRILLING MACHINE

Filed May 1, 1963

5 Sheets-Sheet 1



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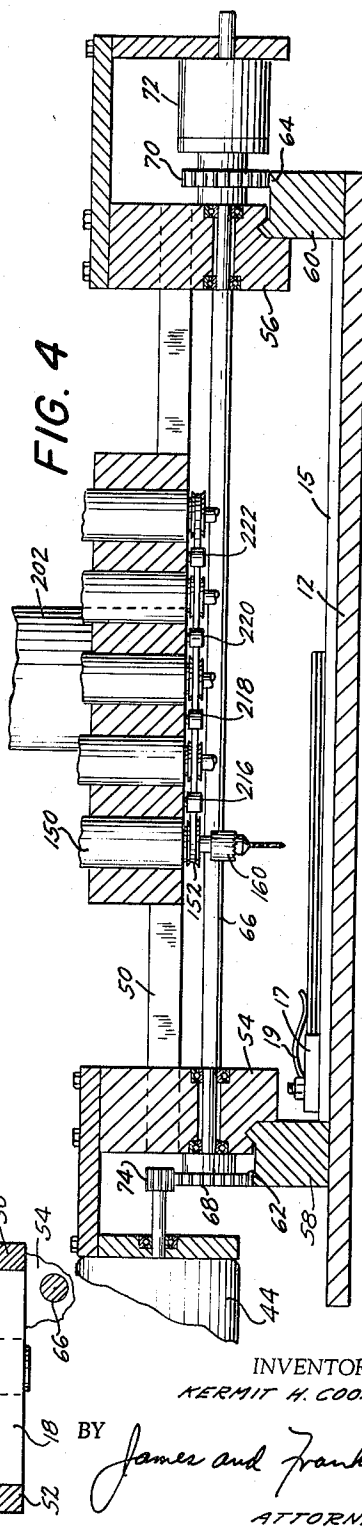
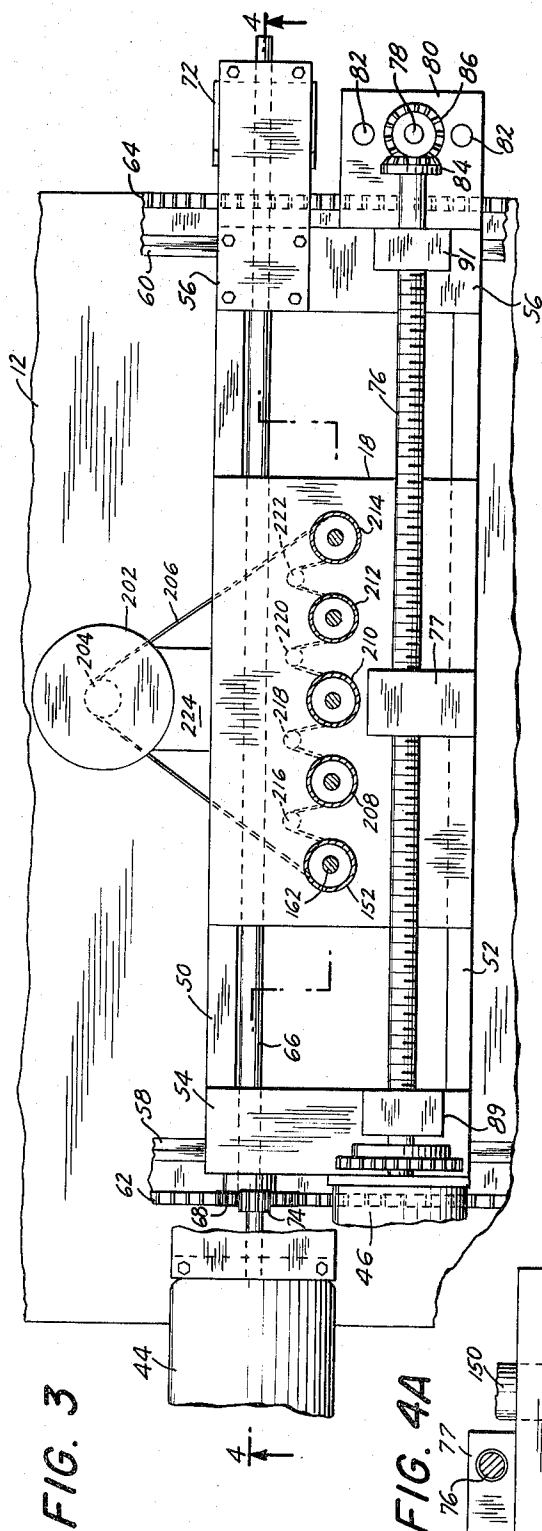
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5 Sheets-Sheet 2



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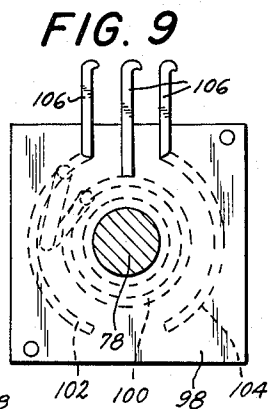
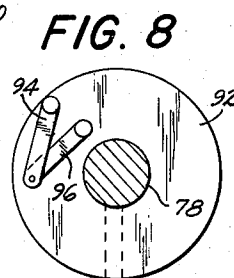
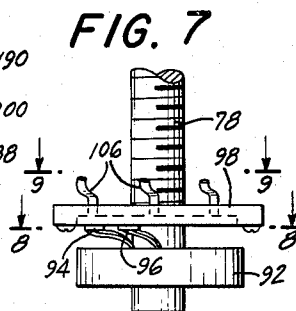
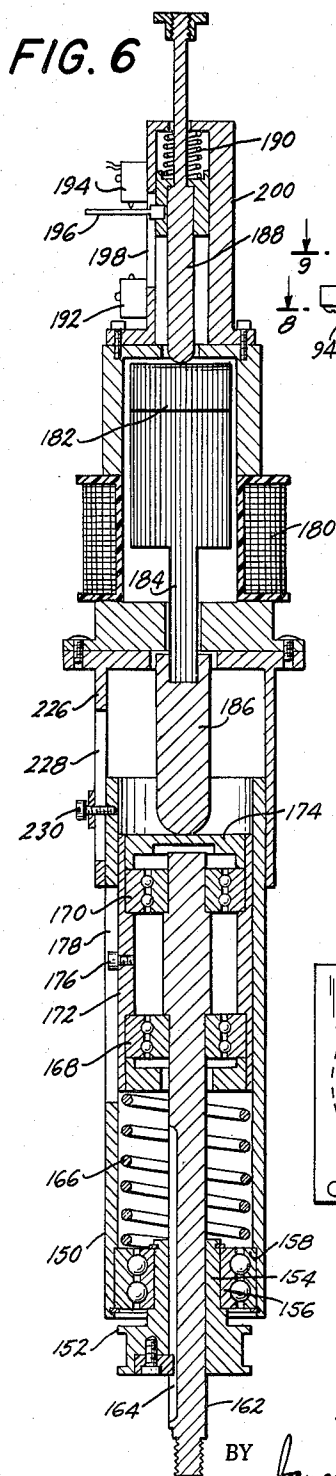
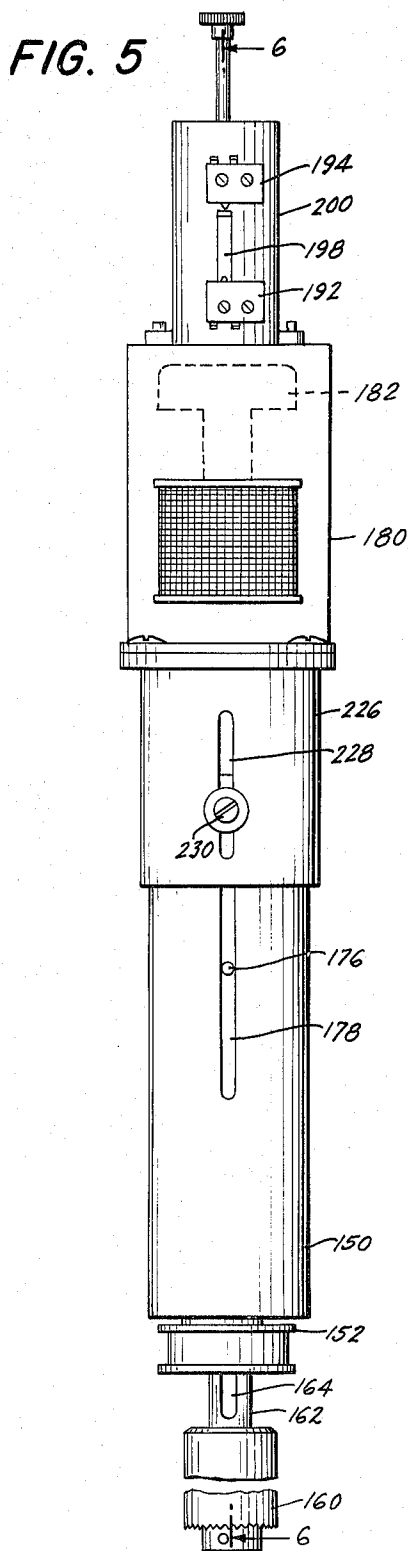
April 19, 1966

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MULTIPLE DRILLING MACHINE

3,246,544

Filed May 1, 1963

5 Sheets-Sheet 3



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3,246,544

MULTIPLE DRILLING MACHINE

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FIG. 10

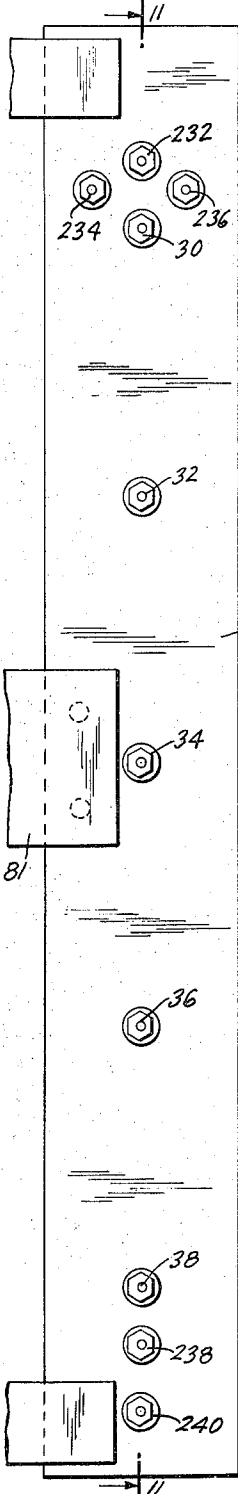


FIG. 11

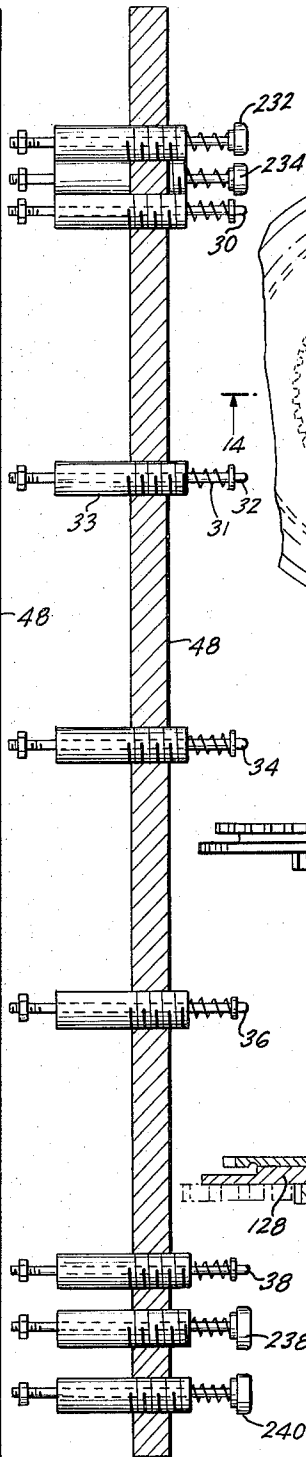


FIG. 12

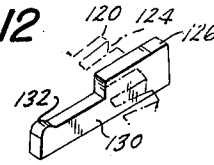


FIG. 13

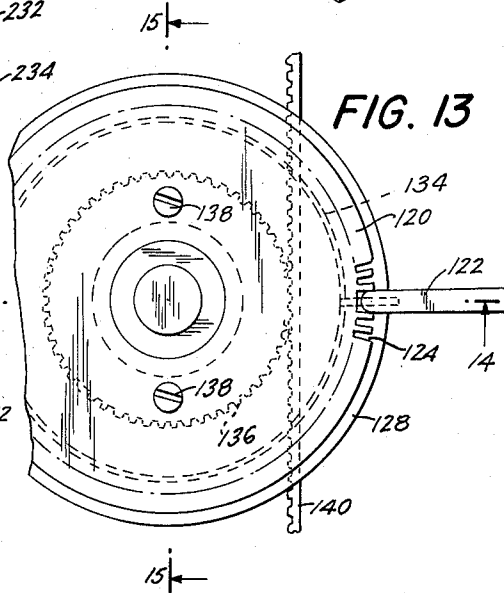


FIG. 14

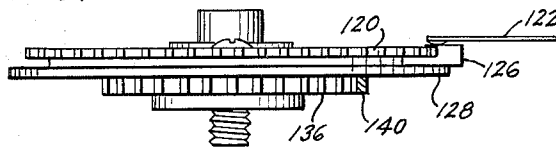
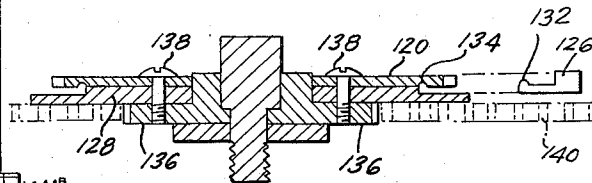


FIG. 15



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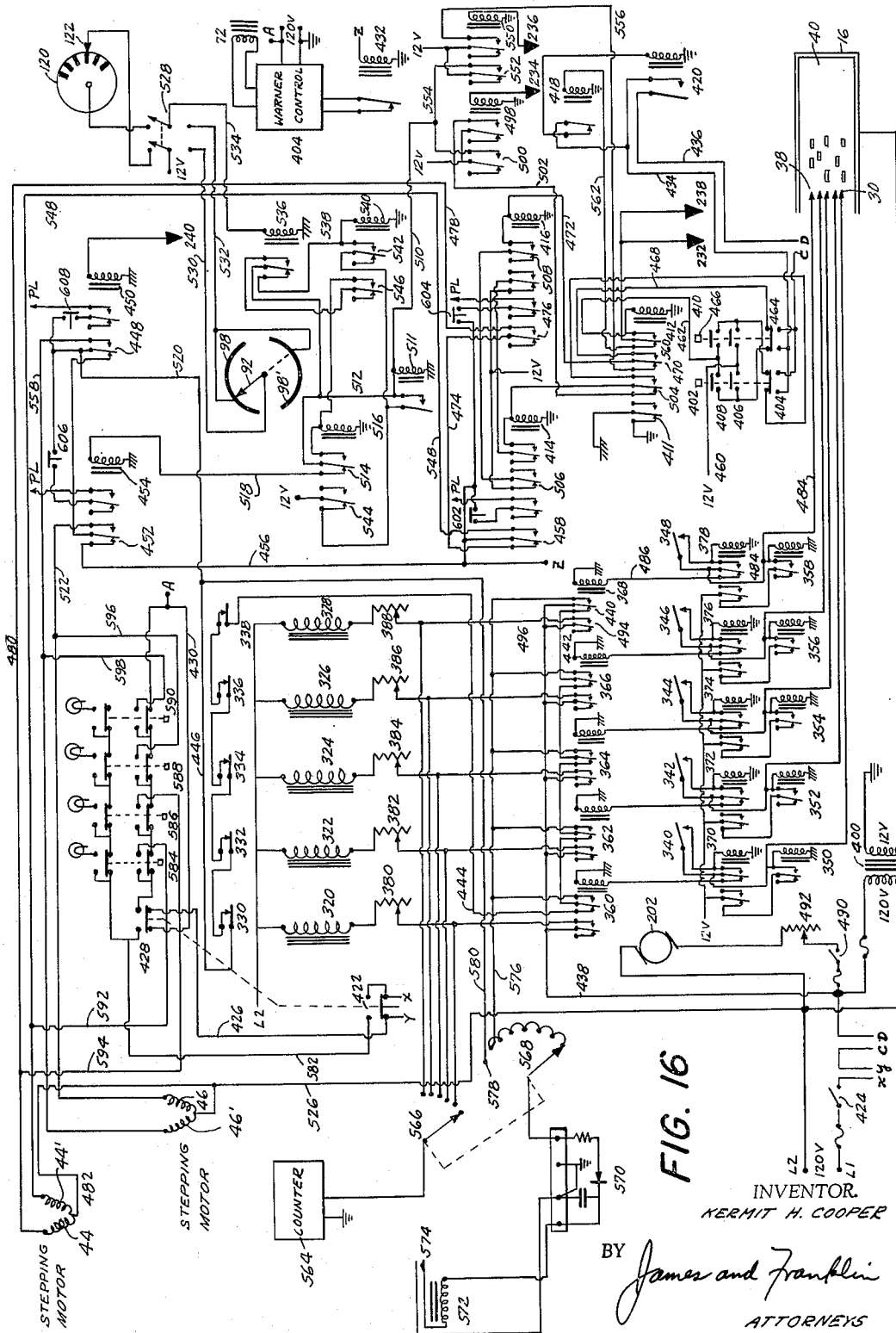


FIG. 16

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3,246,544

MULTIPLE DRILLING MACHINE

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Filed May 1, 1963, Ser. No. 277,271

25 Claims. (Cl. 77—32.1)

This invention relates to drilling machines, and more particularly to automatic pattern drilling machines.

The primary object of the invention is to generally improve such drilling machines. The present machine is well suited for but is not limited to the drilling of printed circuit boards. These require small holes at small spacing, and the pattern therefore is preferably a full size pattern, more specifically a perforated insulation sheet adhered to a metal contact plate which is co-extensive with the table of the machine. In accordance with one object of the invention, the work table and contact plate are stationary, the drill carriage being movable over the table with a scanning motion.

A further object is to conserve space while keeping both the table and contact plate readily accessible, and for this purpose the table is disposed horizontally and the contact plate is disposed vertically at one side of the frame supporting the table.

A further object is to provide improved mechanism for the scanning movement of the carriage, this mechanism being comparatively simple yet providing rapid and accurately reproducible stoppage of the carriage for precise location of the holes.

In accordance with a further feature and object, the carriage has a row of drill heads instead of one, thereby multiplying the area which is scanned. Thus in a specific case, with five drill heads spaced two inches apart, a distance of ten inches is scanned when the carriage is moved only two inches. The retraction or lift of a drill causes resumption of the scanning movement, and with multiple drill heads all of them must be retracted before scanning is resumed.

The pattern is engaged by feelers which cooperate with the pattern holes. In accordance with a further feature and object there are additional limit feelers which are much too large to enter the pattern holes and which determine the scanning travel of the carriage. Thus the scanning is efficiently limited by the pattern rather than by the table size, or even the board size. If the circuit board or other plate being worked on has a large imperforate area at one end or one side, the pattern size may be limited to the area where there are holes, so that the scanning travel is not even as great as the board area.

A further object of the invention is to cause automatic return of the carriage to starting position after completion of the drilling of a board.

A further object of the invention is to save scanning time when the pattern has large gaps between holes in lateral shift direction.

A further object is to provide an improved and simplified drill head.

Still another object is to provide a digit counter which counts the total number of holes drilled thereby checking whether the board has been properly drilled.

A still further object is to provide a machine which requires only electrical energy, so that it simply may be plugged into a wall outlet, and does not require a source of compressed air nor compressed fluid or the like.

To accomplish the foregoing objects, and other more specific objects which will hereinafter appear, my invention resides in the pattern drilling machine elements and their relation one to another as are hereinafter

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more particularly described in the following specification.

The specification is accompanied by drawings in which:

FIG. 1 is a perspective view showing a pattern drilling machine embodying features of my invention;

FIG. 2 is a partially sectioned front elevation of a part of the machine;

FIG. 2A is a fragmentary horizontal section taken at the slide 48 in FIG. 2;

FIG. 2B is a fragmentary view of one corner of a pattern sheet;

FIG. 3 is a horizontal section explanatory of the invention;

FIG. 4 is a fragmentary vertical section taken approximately in the plane of the stepped line 4—4 of FIG. 3;

FIG. 4A is a transverse section showing how the carriage is related to the cross rails;

FIG. 5 is a front elevation of one of the drill heads;

FIG. 6 is a vertical section taken approximately in the plane of the line 6—6 of FIG. 5, with the chuck removed;

FIG. 7 shows an electrical commutator which is located at and driven by the lower end of the vertical lead screw;

FIG. 8 is a detail looking approximately on the plane 8—8 of FIG. 7;

FIG. 9 is another explanatory detail taken approximately in the plane of the line 9—9 of FIG. 7;

FIG. 10 is an elevation of a slide acting as a carriage for the electrical contact feelers;

FIG. 11 is a vertical section taken approximately in the plane of the line 11—11 of FIG. 10;

FIG. 12 is a perspective view showing an insulation tab which is used in connection with a commutator wheel shown in FIGS. 13, 14 and 15;

FIG. 13 is a front elevation of a commutator wheel;

FIG. 14 is a bottom plan view of the same;

FIG. 15 is a vertical section taken approximately on the line 15—15 of FIG. 13; and

FIG. 16 is a wiring diagram showing the electrical circuitry of the machine and explanatory of the operation of the same.

Referring to the drawing, and more particularly to FIG. 1, the machine comprises a table 12 for supporting a plate to be worked on by a tool, in this case a drill. In practice, a group of boards may be superposed and drilled simultaneously, but for simplicity the description refers to a single board. A suitable frame, concealed in this case by housing 14, supports the table. A contact plate substantially coextensive in area with the table 12 is disposed in a vertical plane at the side of the frame, and in the present case the contact plate is on the side opposite that shown in FIG. 1.

Referring now to FIG. 2, the contact plate is shown at 16. A carriage 18 has a drill head 20 disposed over the table 12. There is also an electrical contact feeler 30 disposed outside the contact plate 16 for movement over a pattern (not shown in FIG. 2) made of appropriately perforated thin insulating material secured on the outside of the contact plate 16.

FIG. 2B shows a corner portion 40 of a pattern mounted on the contact plate 16, and it further shows the perforations 42 in the pattern, these preferably being slots resembling those used in business machine cards. While not essential, one way to secure the pattern to the contact plate is to employ pressure sensitive adhesive on the back of the pattern, giving it a so-called "sticky back."

The machine further comprises means, in this case a motor 44 (FIG. 2) and a motor 46, to simultaneously move the carriage 18 and the feeler 30 with a scanning

movement over the table 12 and the pattern 40 respectively. There is also electrical circuitry housed in the cabinet 14 and controlled by the feeler 30 to arrest the scanning movement and to operate the drill head 20 when the feeler 30 reaches a perforation in the pattern.

In preferred form, and in order to greatly reduce the work time required, the carriage 18 preferably carries a row of uniformly spaced drill heads, in this case five drill heads 20, 22, 24, 26 and 28. Similarly, the contact slide 48 has a row of contact feelers 30, 32, 34, 36 and 38 which control the drill heads 20-28 respectively, it being understood that the vertical spacing of the feelers 30, 32, 34 etc. is the same as the horizontal spacing of the drill heads 20, 22, 24, etc. In the particular machine here shown the spacing between drill heads and between feelers is two inches, and thus when the carriage has scanned for a lateral (side to side) distance of two inches, an effective distance of ten inches has been covered at the pattern and on the work being drilled.

Considering the mechanism further, the carriage 18 is slidable on a pair of spaced cross rails 50, 52 (FIGS. 2, 3 and 4). The rails are carried at their ends by cross heads 54, 56, which in turn are slidable on ways 58 and 60 which extend longitudinally at the sides of the table 12. There are gear racks 62 and 64 which extend parallel to the ways, and indeed which may be mounted directly thereon. A shaft 66 is disposed parallel to the rails 50, 52 and carries gears 68 and 70 meshing with the racks 62 and 64, respectively. A stepping motor 44, and a magnetic brake 72 at the other end of shaft 66, serve to control the shaft. For this purpose, a pinion 74 meshes with gear 68, and serves to drive the shaft. Brake 72 serves to stop the shaft instantly in response to a feeler contact reaching a pattern perforation. The travel here referred to is longitudinal of the table.

For lateral shift there is a lead screw 76 which extends parallel to the rails 50, 52. This threadedly engages a block 77 fixed on carriage 18. There is also a vertical lead screw 78 (FIG. 2) disposed outside the contact plate 16 and carried by the cross head 56. Referring to FIG. 3, the cross head 56 has a bracket 80 rigidly affixed thereto, and this carries upright slide rods 82 as well as the upper end of the vertical lead screw 78. The lead screws have identical pitch and are geared together by means of mitre gears 84, 86 so that they have simultaneous equal movement. The slide 48 and its block 81 (FIG. 2) are moved by the vertical lead screw 78, and thus the slide movement relative to the pattern duplicates the movement of the drill carriage 18 relative to the work-piece.

Referring to FIGS. 2A and 3, the lead screw 78 is located between the two vertical slide rods 82. These do not show in FIG. 2, but they are rigidly secured at their upper ends in the blocks 80 and 142, and at their lower ends to a block 144. This provides a rigid assembly which travels back and forth with the cross head 56. The part 140 (FIG. 2) is an upright gear rack which is fixedly mounted between the upper block 142 and the bottom block 144. The slide 48 is slidably mounted on the upright rods 82 by means of blocks to which the slide 48 is secured, and one of these blocks, block 81, is accurately internally threaded to receive the vertical lead screw 78 which causes the lateral shift movement of the slide 48. This block 81 also serves to carry a "skip-scanning" wheel assembly 120 which is described later, and which is operated by the gear rack 140.

The lead screws 76 and 78 are driven by a stepping motor 46, which in the present case drives a pinion 88 meshing with a gear 90 fixed on one end of the horizontal lead screw 76. The horizontal lead screw is carried in bearing blocks 89 and 91 affixed to the cross heads 54 and 56, respectively. The lead screws drive a commutator wheel system for stepping the stepping motor 46 after a desired increment of lateral shift. In the present case the lead screws have a pitch of $\frac{1}{8}$ ", and a lateral shift

is provided in increments of $\frac{1}{16}$ ", so that the screws are turned a half revolution for each step. One commutator for this purpose is mounted at the lower end of the vertical lead screw, as is shown at 92 and 98 in FIG. 2.

The construction is shown in detail in FIGS. 7, 8 and 9, referring to which the vertical lead screw 78 drives an insulation disc 92, which in turn carries a pair of leaf spring contacts 94 and 96 best shown in FIG. 8. Above disc 92 there is a fixedly mounted insulation plate or stator 98 best shown in FIG. 9. This has a slip ring 100 and two arcuate strips 102 and 104 with appropriate soldering lugs at 106. The contact arms 94 and 96 are electrically connected and thus connect the slip ring 100 to either the arc 102 or the arc 104. The electrical circuitry, described in detail later, is such that when contact 94 reaches arc 102 or 104 the stepping motor 46 is stopped. The lead screws are turned in half revolution steps for scanning of the pattern on scanning lines which are $\frac{1}{16}$ " apart. A different amount of rotation may be provided with different commutator arcs.

If desired, a different form of commutator wheel may be employed which makes possible a variable amount of lateral shift, or what may be termed "skip scanning." Referring to FIG. 2B, it will be seen that holes 42 and 110 are close together; that holes 112 and 114 are close together; and that holes 110 and 112 are far apart. Again the holes 116 and 118 are close together, but there is considerable space between the holes 114 and 116. Thus a loss of work time will take place if the pattern is scanned back and forth on lines only $\frac{1}{16}$ " apart. Instead a special commutator wheel may be provided with insertable tabs to prevent stoppage of the motor 46 for any desired amount of lateral shift.

Such an arrangement is illustrated in FIGS. 13, 14 and 15. The commutator wheel is shown at 120, it being made of metal and being engaged by an electrical contact 122. The wheel is peripherally notched as shown at 124, and is turned by the lead screws in such ratio that each tooth corresponds to a desired increment, say $\frac{1}{16}$ ". Insulation tabs 126 are provided which may be detachably inserted in the slots 124, and which prevent engagement with the stationary contact or brush 122. They cause a circuit break, whereas without a tab the contact engages the teeth continuously because it can straddle two teeth. The circuitry is such that this causes continued operation of the stepping motor 46 until a tab is reached, so that contact is first broken and then made again on the following metal tooth, and this arrests the lateral shift. With a full complement of tabs inserted in wheel 120, the operation is the same as previously described, that is, the scanning is in uniform small steps. Where tabs are omitted, the shift is wider.

To help hold the tabs 126, the metal wheel 120 is associated with an insulation backing wheel 128, the space therebetween corresponding to the width of the shank portion 130 (FIG. 12) of the tab 126.

Referring to FIG. 12, when a tab is inserted its working portion 126 enters the slot 124 of wheel 120 while the shank 130 is snugly confined between the commutator wheel 120 (FIGS. 14 and 15) and the backing wheel 128. To additionally secure the tab in position, the shank 130 may have a detent projection 132 which is received with a snap engagement in a mating annular groove 134 in the back of wheel 120.

To drive the wheels 120, 128 they are secured directly to a gear 136 as by means of screws 138. The entire rotatable assembly is mounted on the block 81 of the slide 48 previously referred to, and moves up and down with the slide. Gear 136 meshes with vertical rack 140 which is stationary between the upper and lower bearing blocks 142 and 144 (FIG. 2).

The rack 140 remains stationary as the slide moves, thereby imparting a movement to the commutator wheel which is proportional to the movement or lateral shift of the slide. The diameter of gear 136 is so related to the width of the slot and tooth 124 that desired increments of

lateral shift are provided. The main importance of the commutator wheel shown in FIG. 13 is in affording "skip scanning" to greatly speed the operation of the machine when a series of like boards are being drilled from a pattern with substantial skip distance, as was explained in connection with FIG. 2B. Tabs are removed to provide the desired lateral shifts.

The preferred form of drill head is described with reference to FIGS. 5 and 6 of the drawing. In those figures the stationary housing 150 carries a pulley 152 at its lower end, this being rotatable but not axially movable. For this purpose the pulley hub 154 is carried by the inner race 156 of a bearing, the outer race 158 of which is fixedly secured in housing 150. The drill is removably received in a conventional chuck 160, secured to the lower end of a drill spindle 162, which is splined at 164 to the pulley 152 for rotation thereby, while affording axial movement of spindle 162. A compression spring 166 urges the spindle away from the work. There are spaced bearings 168 and 170 which carry the spindle and which are in a cylindrical slide 172, the latter being closed by a top 174, and the assembly being vertically slidable in the housing 150. Rotation is preferably prevented by means of a stud 176 received in a slot 178.

A solenoid coil 180 is disposed above the slide 172, and influences a solenoid core 182, the lower end 184 of which acts as a pusher which pushes the spindle toward the work or downward when the solenoid 180 is energized. In the present case, the core portion 184 is extended by means of a stud 186, the lower end of which bears directly on the top 174 of the slide 172.

For control purposes there is an additional non-ferrous finger 188 above the core, and normally urged toward the core by a light compression spring 190. There is a lower or "down" limit switch 192 and an upper or "up" limit switch 194. A projection 196 from finger 188 passes through a slot 198 in a suitable housing or guide 200. The limit switches are thus responsive to the position of the drill spindle and indicate when the drill has completed making a hole, and conversely when it has returned to its retracted or up position. The circuitry, described later, is such that the down limit switch 192 de-energizes the solenoid 180 thereby permitting immediate retraction of the spindle, and the up limit switch 194 causes the carriage to resume scanning. However, the up limit switches of all of the drill heads are connected in series, so that scanning is not resumed unless all of the spindles have been retracted. The down limit switches 192, on the other hand, are individual, and each controls its own solenoid for immediate retraction on completion of its hole. It will be understood that in many cases only a selected one or more of the drill heads is operated, the others simply remaining in up position.

The spindles rotate continuously, and preferably under drive of a single motor. This is shown in FIG. 3 in which motor 202 drives a pulley 204 and a belt 206 which is threaded around the pulley 152 of the first drill head. With a series of drill heads as here shown, the belt is threaded back and forth around similar pulleys 208, 210, 212 and 214 by means of idlers 216, 218, 220, 222. The motor 202 is mounted on a bracket 224 fixedly secured to the carriage 18 so that the motor travels with the drill heads, and there is no change in the belt and pulley relation shown in FIG. 3. It will be understood that the drive of the drill spindles may be by means of sprocket gears and a roller chain, instead of pulleys and belts as here shown.

Reverting to FIGS. 5 and 6, the solenoid 180 and the limit switches etc. may be mounted on an upper housing 226, which is itself secured to the lower housing 150 previously referred to. The housing parts 150 and 226 are preferably telescopically related, thereby affording adjustment of the relation of the solenoid core to the spindle slide. In the present case the upper part 226 has a slot 228 receiving a lock screw 230 which is thread-

edly received in the upper end of the lower housing portion 150.

Referring now to FIGS. 10 and 11, the slide 48 has five feelers 30 through 38 corresponding respectively to the five drill heads. Each feeler is a conductive rod urged forward by a light compression spring 31 bearing against an insulation bushing 33 fixed in the slide 48. The contact tip is rounded, and is made of beryllium copper for hardness. A flexible conductor (not shown) is connected to the outer end of each rod.

The slide 48 carries not only the feeler contacts 30-38, but also additional limit contacts 232, 234, 236 and 240. Their general construction is similar, but these limit contacts differ importantly at their inner or contact ends in that they have large diameter heads as will be clear from inspection of FIG. 11 at the numerals 232-240. The heads are too large in diameter to enter the perforations in the pattern plate, and therefore in no way affect the drilling operation. This is to be contrasted with the inner ends of the feelers 30-38 which are very small in diameter and which readily enter the pattern perforations. The limit contacts take effect only when they pass beyond the edge of the pattern 40 (FIG. 2B) and so engage the large area contact plate 16 on which the pattern 240 is mounted. They also take effect on reaching a special large hole 111 (FIG. 2B) which marks the starting position and which is used to stop the machine after completion of the pattern and after return to starting position ready for work on another board.

At the end of the first forward scanning line, the contact 234 rides off the left edge of the pattern as viewed in FIG. 2B, that is looking toward the pattern, and this causes lateral shift for say $\frac{1}{16}$ " (or more with skip scanning) whereupon the carriage travels back longitudinally of the table and the slide moves toward the right until the limit contact 236 rides off the right edge of the pattern, whereupon there is another increment of lateral shift downward of the slide, and then another scanning travel toward the left until the limit switch 234 again rides off the left edge of the pattern, etc. It should be noted that the limit switches 234 and 236 are disposed sideward of the line of five feeler contacts 30-38, and this distance is such that the travel is arrested and reversed while the contacts 30-38 are still on the pattern, so that there will be no actuation of the drill heads. In addition, there is a safety feature whereby if a board contact 32-38 moves off the pattern the machine is stopped.

The scanning motion proceeds as described until the bottom of the pattern is reached. This is sensed by limit contact 240 at the bottom of slide 48 which preferably cooperates with a special large hole near the bottom of the pattern, the hole being like the starting hole 111 shown in FIG. 2B at the top of the pattern. When limit contact 240 reaches the large hole, the carriage and slide are returned to starting position directly, that is, by a continuous lateral shift all the way across the table and all the way up the pattern. The return to starting position is sensed by a top limit contact 232 (FIG. 10) which reaches the large hole 111 shown in FIG. 2B, at which time the machine stops.

In practice, the drilled boards are then removed from the table and are replaced by a new set of boards which are to be drilled. The table 12 may be protected, as by means of a thickness of pressboard 15 into which the drills may enter slightly. The boards are preferably located against stop bars, one of which is shown at 17 in FIG. 4. The bars may have hold-down springs 19. These parts have been omitted in other figures of the drawing except FIG. 2.

A "start" button is pressed at the panel 241 (FIG. 1) whereupon the machine goes through another complete scanning cycle. If desired, the operator may read the number of holes that were drilled in a board (or set of boards) on a suitable counter exposed on panel

241 to make sure that all holes have been drilled before removing the board.

The circuitry and operation

The circuitry may be described with reference to the wiring diagram shown in FIG. 16, and in which the plate 16 corresponds to the contact plate 16 in FIG. 2, and the pattern 40 corresponds to the pattern 40 in FIG. 2B. The contact feelers are indicated by arrow points 30-38. The motor 44 shown at the upper left corner of the diagram is the main travel motor shown at 44 in FIGS. 2-4. The stepping motor 46 corresponds to the lateral shift motor 46 shown in FIGS. 2-4. The motor 202 drives the drill heads and corresponds to the similarly numbered motor in FIGS. 3 and 4.

The magnetic brake associated with the main travel motor 44 is indicated at the right of the diagram at 72, and is preferably energized with a momentary high voltage followed by a lower voltage by means of a control box indicated at 404.

The commutator for determining the increments of lateral shift is indicated at 92, 98, this corresponding to the parts shown at the bottom of FIG. 2. The skip scan wheel is shown at 120, and the stationary contact engaging its notched periphery at 122. The five solenoids which push the drill spindles down are shown at 320, 322, 324, 326 and 328, these numbers corresponding to the drill heads 20-28 respectively shown in FIG. 2. The up limit switches for the drill heads are shown at 330, 332, 334, 336, 338, and the down limit switches for the drill heads are shown at 340, 342, 344, 346 and 348.

The feeler contacts with the large heads which act as limit contacts are indicated by large arrow points 232, 234, 236, 238 and 240 (the latter being near the top of the diagram) and correspond to the similarly numbered limit contacts in FIG. 10.

The main power supply, which may be an ordinary 120 volt 60 cycle supply, is marked L1, L2. The machine employs a large number of relays which are operated at 12 volts, and a 12 volt power supply is indicated by the step down transformer 400.

The relays 350, 352, 354, 356, 358 are holding relays triggered by the feeler contacts 30-38 respectively, and serve to maintain current supply even if the contact at the feeler is only momentary or intermittent, until completion of the drilling operation at that stopping point.

The relays 360, 362, 364, 366, 368 are power relays which control the 120 volt power supply for the main solenoids 320-328 of the drill heads. The relays 370, 372, 374, 376, 378 are intermediate relays which function as later described between the holding relays 350-358 and the power relays 360-368, and they are also related as later described to the down limit switches 340-348.

The variable resistors or variacs 380, 382, 384, 386 and 388 vary the voltage applied to the solenoids 320-328, and thus serve to adjust the drill pressure so that it may be made appropriate for the particular material being drilled.

In the diagram it will be noted that two kinds of grounds are shown, one being a normal ground illustrated by horizontal lines in triangular form, and the other being an elevated or high ground and represents wired connections which lead to ground through the contacts 411 of a relay 412. The second or high ground symbol with diagonal lines simplifies the diagram by omitting a considerable number of wires which have in common the fact that they lead to and are grounded through contacts 411 of relay 412 when the relay coil is de-energized.

A main power switch 424 is preliminarily closed. There is a manually operable switch 422 which changes the machine to either manual-electric or automatic, and which is normally in automatic position, at which time the XY terminals are closed.

The operation may be described as follows, it being assumed that the drill carriage and contact feeler slide

are at rest in starting position. At this time the brake 72 is energized, the circuit for this purpose being traced as follows.

When XY is closed at 422 voltage is supplied from L1 to wire 426 and then to the lower contacts of switch 428, which switch is in the same block and is operated with switch 422. Voltage then flows through line 430 to terminal A. Referring now to the right end of the diagram, voltage at terminal A is let into the control box 404 which energizes magnetic brake 72, the power for the brake flowing through the contacts of a relay 432, the coil of which at this time is de-energized. In general, when power is supplied to the machine the brake 72 is on whenever the carriage either is in rest position or is undergoing lateral shift.

To start the scanning and drilling operation a start button 402 (or it could be button 466 for opposite direction) is pressed momentarily. This releases brake 72 and starts motor 44. The circuitry for this may be traced as follows.

Starting at terminal C (at lower right of diagram) current flows through the lowest contacts 404 of switch 402 and thence through line 434 through the contacts of relay 418 and thence to the coil of relay 420. This energization of relay 420 closes its contacts thereby supplying voltage from wire 434 to terminal D. The effect is to close the terminals CD shown at the bottom left of the drawing. In consequence, voltage flows up wire 438 to the bank of relay contacts of relays 360-368.

At the relay 368 voltage flows through contact 440 to conductor 442 and thence through the contacts of relays 366, 364 etc. in series, emerging at conductor 444 which leads to the up limit switch 338. This is connected to the four other up limit switches in series, and the voltage then flows through conductor 446, then through contacts 448 of relay 450, and thence through contacts 452 of relay 454 to conductor 456 and terminal Z. This connects to terminal Z at the right edge of the diagram, and so energizes the coil of relay 432. Its contacts move from left to right thereby de-energizing magnetic brake 72.

Meanwhile the closing of terminals XY and CD at the lower left of the diagram results in energization of step-down transformer 400, and a supply of 12 volt power then is available for the various relays throughout the circuit. It will be recalled that start button 402 was operated, which supplies 12 volts from lead 460 through contacts 406, then through contacts 408 and lead 462 to energize the coil of relay 412, which pulls its contacts to the right.

The 12 volt supply also flows from push button switch contacts 406, through contacts 464 of companion push button start switch 466, then through wire 468 to contacts 470, and thence up through wire 472 to energize the coil of relay 416 which pulls its contacts to the right.

The circuit to power the main travel motor 44 may be described beginning from terminal Z to the contacts 458 of relay 414 and thence through wire 474 to the closed contacts 476 of relay 416, and thence through wire 478 and 480 to the forward section of motor 44, the return current flow being through wire 482 and 526 back to line L2.

This causes travel of the carriage and with it the feelers until one of the feelers encounters its first pattern hole, whereupon the travel is abruptly arrested, the circuit operation being as follows.

Assume it is feeler 38 which makes contact. A 12 volt supply runs from transformer 400 to the large contact plate 16 and thence through feeler 38 to conductor 484 and the closed contacts of relay 378 through conductor 486 to energize relay 368. When start button 402 is released the high grounds are connected to regular ground by closing of the leftmost contacts 411 of relay 412, as previously mentioned. Relay 368 therefore is energized and its contacts move to the right. It will be recalled that relay contact 440 was in its left

position to release magnetic brake 72 and movement of contact 440 back to the right re-energizes brake 72. More specifically, it opens the previously referred to series supply through relays 360-368 and conductor 444 and the series of up limit switches 330-338 and thence through relays 450, 454 to terminal Z, so that relay coil 432 at the brake control 404 is de-energized and the brake is applied. Meanwhile the travel motor 44 is de-energized, it being recalled that it was energized from terminal Z.

Meanwhile the drill motor 202 is running, it being supplied from the line L1, L2 through a manually operated switch 490 and a speed control rheostat 492. When feeler 38 makes contact, it not only stops the carriage but energizes the drill solenoid 328. The circuitry for this may be described as follows.

Feeler 38 applies the 12 volt supply to the coil of relay 358 which acts as a holding relay. For this purpose the 12 volt supply along the top of the bank of relays 370-378 runs through the left contact of relay 378 and the right contact of relay 358 and so to the coil of relay 358, which is held closed by the said voltage. The holding relay 358 is not essential but is preferred so that no difficulty will arise in the event of vibration causing intermittent contact at feeler 38 after it has made initial contact. In other words, only a pulse from feeler 38 is needed.

It will be understood that similar description applies to any of the five feelers, with relay 356 acting as a holding relay for feeler 36; relay 354 acting as a holding relay for feeler 34, and so on. A contact at any one or more feelers produces a carriage stop as previously described.

The 12 volt supply previously mentioned also flows from conductor 484 through the closed left contacts of relay 378 and thence through conductor 486 to energize relay 368. The energization of this was previously described, but the holding action now described assures maintaining this energization. The relay contacts 494 are now closed to the right, thus feeding power from line L1 and conductor 438 upward through line 496 to variac 388 and solenoid 328, the return being to line L2.

This pushes the drill spindle down and causes the desired drilling operation. Meanwhile the up limit switch 338 opens. It additionally assures that brake 72 will remain on, and motor 44 will remain off, this being so because the up limit switches 330-338 are connected in series with each other and with the control wiring previously described.

When the board has been drilled, the down limit switch 348 is closed. Voltage from feeler 38 then flows through conductor 484 to limit switch 348 and thence down through relay coil 378, the energization of which closes its contacts from left to right. This de-energizes the power relay 368 so that its contacts move back to left or relaxed position. The opening of its contacts 494 de-energizes solenoid 328, permitting the drill spindle to rise under influence of its return spring. After full rise of the drill spindle, the up limit switch 338 is closed, and this is essential before the carriage can resume its travel by release of brake 72 and starting of motor 44. Meanwhile the holding action of holding relay 358 was interrupted by the energization of relay 378 when the down limit switch 348 was closed. The action of feeler 38 is interrupted when carriage travel is resumed.

It will be understood that the action described for feeler 38 applies in similar fashion to each of the feelers and its respective drill solenoid. Thus, if feeler 30 makes contact, it acts on holding relay 350 and power relay 360 to energize solenoid 320, the limit switches then being 330 and 340. Any number of the drills may operate simultaneously if their feelers make simultaneous contact through pattern holes. If the drilling action of one head is slower than that of another, no difficulty arises because scanning travel cannot resume until all drill spindles have moved down and then up, so that all of the limit switches 330-338 are closed.

The scanning travel of the carriage is resumed until any feeler again makes contact through a pattern hole, whereupon the drilling operation previously described is repeated.

When the slide reaches the edge of the pattern, the broad faced feeler shown at 234 in FIG. 10 rides off the pattern and contacts the plate 16. Reverting to FIG. 16, the feeler 234 energizes the coil of relay 498 thereby closing its contacts to the right. This stops and reverses the motor 44 as follows.

A 12 volt supply runs through contacts 500 and then the adjacent contacts in series and thence down through conductor 502 to contacts 504 of relay 412, and thence up to relay coil 414, energizing the same. Relay 414 may be considered a "reverse" relay for motor 44, and adjacent relay 416 a "forward" relay, these two being so connected that one or the other is energized in alternation. Specifically a 12 volt supply coming through contacts 506 is opened when relay 414 is energized, thereby opening the supply to relay coil 416 through contacts 508. In other words, the holding circuit of relay 416 is opened when relay 414 is closed, and vice versa. The opening of contacts 458 of relay 414 opens the circuit through line 474, contacts 476, line 478 and line 480, to the forward field of motor 44.

The lateral shift of the carriage then begins under drive of the stepping motor 46, which is accomplished as follows. The 12 volt supply flows through contacts 500 of relay 498 (near right center of diagram), and through conductor 510, conductor 512, contacts 514 of relay 516, and thence through conductor 518 to relay coil 454, energizing the same. The 120 volt supply flows from line 446 (following the five up limit switches) through conductor 520 and contacts 448 now closed to the left, and then to contacts 452 which are now closed to the right, with a current flow through conductor 522 to the forward field of stepping motor 46. The return is through conductor 526 to line L2. Meanwhile the shift of contact 452 of relay 454 from left to right has opened the supply from terminal Z, which as previously explained applies the magnetic brake 72.

The motor 46 turns the two lead screws for lateral shift. This shift is interrupted by either of the two commutator systems previously described. That shown in FIGS. 7-9 provides a half turn of the lead screw. A choice between this commutator, and the skip scanning wheel shown in FIGS. 12-15 is obtainable by throwing a double throw switch to one side or the other, and reverting to FIG. 16, the said switch is shown at 528. For purpose of the present description, it is assumed in down position, thereby utilizing the simple commutator 92, 98 for uniform half-turn increments of the lead screw.

Assume contact 92 engages arcuate segment 98. A 12 volt supply from switch 528 flows through conductor 530, contact 92, segment 98, conductor 532, switch 528 and conductor 534 to relay coil 536, which then is energized so that its movable contact is in the right position. When rotating contact 92 leaves segment 98, relay 536 is de-energized and its contact moves to the left. The 12 volt supply through wires 510 and 512 now flows through the left contacts of relay 536 to conductor 538 to energize relay coil 540, thereby pulling its contacts to the right.

Rotating contact 92 continues to rotate until it touches the opposite segment 98'. Meanwhile relay 540 is held because of its own holding contacts 542, with voltage applied through contacts 544 of relay 516. When contact 92 engages segment 98' the relay coil 536 is again energized. With relays 536 and 540 both energized voltage flows from line 512 through the right contacts of relay 536, then to contacts 546 of relay 540, and thence to relay coil 516, to energize the same. The movement of contacts 514 from left to right opens the power supply to relay coil 454 so that its contacts move to the left. This opens the previous supply through contacts 452 and line

522 to the forward field 524 of the stepping motor 46, thereby stopping the motor and terminating the lateral shift, which in the particular case here illustrated happens after a shift of $\frac{1}{16}$ ".

Movement of relay contact 452 from right to left restores power supply from terminal Z and line 456 to the relay coil 432 at the right edge of the diagram at terminal Z, which releases the magnetic brake 72 as previously described. At the same time, the reverse field 44' of the main travel motor is energized, the power supply being from terminal Z through contacts 458, now closed to the right, and thence through line 458 to field 44' of motor 44, which drives it in reverse direction so that the carriage travels from front to rear. The return from the motor is through the common line 482 and 526 back to line L2.

The scanning movement in rearward direction continues until one of the feelers enters a hole in the pattern, whereupon the motor field 44' is deenergized, brake 72 is applied, and a drill moved down, all as previously described. After the drilling operation, when scanning travel is resumed, it is resumed in reverse direction because it is the field 44' that is being energized, instead of the field 44, each time a drilling operation has been completed.

The rearward travel is continued until the broad faced contact, shown at 236 in FIG. 10, reaches and passes off the right edge of the pattern. Reverting now to FIG. 16, when contact 236 touches the contact plate 16 the relay coil 550 is energized, pulling its contacts to the right. A 12 volt supply then flows through contacts 552 and conductor 554 to conductor 510. The flow continues through line 512, contacts 514, and line 518, to relay coil 454. This moves contact 452 to the right, which disconnects the line Z and 456, and the deenergization of terminal Z and relay 432 at the brake control box 404 applies the brake 72. 120 volt power from line 446 (following the five series-connected up limit switches 330-338) flows through contacts 448 and thence to contacts 452, now in right position, and thence through line 522, to the lateral shift motor 46, to cause another $\frac{1}{16}$ " increment of lateral shift. Meanwhile the main travel motor 44' has been deenergized by opening the line from Z and 456 when relay 454 was energized, thus cutting off power through the contacts 458 and 476 of relays 414 and 416.

The motor 46 drives the lead screws, causing movement of contact 92 over segment 98'. On leaving segment 98' relay 536 is opened, and again closed when contact 92 first touches segment 98, at which time the shift motor 46 is stopped, as previously described, by reason of deenergization of relay 454.

Again as previously described, this also reconnects the supply from terminal Z and line 456 to terminal Z and relay 432 at the brake control box 404, thereby deenergizing the brake to permit scanning travel, which this time should again be in forward direction. This is accomplished as follows.

It will be recalled that the finish of the rearward scanning line was determined by broad faced contact 236 riding off the right or rear edge of the pattern. In FIG. 16 it will be seen that this energizes relay coil 550, which causes a 12 volt supply through the right hand contacts of relay 550 to line 556 to contacts 470 of relay 412, and thence through line 472 to relay coil 416, energizing the same. It will be recalled that relay coil 416 is a "forward" relay and is interlocked for alternate operation with "reverse" relay 414. Thus when travel is resumed it will again be in forward direction.

Power is supplied to the forward field 44 of the travel motor from terminal Z as previously described for the first scanning line, the flow starting through contacts 458 of the now deenergized relay 414, and thence through conductor 474 and contacts 476 of relay 416, now closed to the right, and so to line 478 and line 480 to motor field 44.

The scanning travel continues back and forth in de-

scribed fashion until the limit contact shown at 240 in FIG. 10 reaches a large hole at the bottom of the pattern, similar to the large hole 111 shown in FIG. 2B at the top of the pattern.

Reverting now to FIG. 16, when broad faced feeler contact 240 (shown near top right of diagram) touches the contact plate 16 it energizes relay coil 450. This starts the shift motor, using its reverse field 46' instead of its forward field 46. For this purpose power supplied from line 446 (following the five up limit switches) to line 520 and contacts 448, now in right position, and thence up and through line 558 to the reverse field 46' of the motor, the return being through line 526 to terminal L2 as before. At the same time the power to terminal Z and line 456 is opened at contacts 448 of relay 450, so that the relay coil 432 at the brake control box 404 is deenergized, and the brake 72 is applied. Also, as previously described, when the Z line is opened, no power is supplied through reverse and forward relays 414 and 416 to either section 44 or 44' of the main travel motor.

The carriage and feelers then move laterally back toward starting position (the feelers moving upward) without any travel movement in fore and aft direction, that is, the return to starting position is on a short direct path, unlike the zig zag scanning movement. This lateral return movement continues until the top broad faced feeler (shown at 232 in FIG. 10) reaches the large opening 111 shown in FIG. 2B. In FIG. 16 the feeler 232 on contacting the plate 16 supplies voltage to the contacts 560 of relay 412, at this time closed to the left, and flows through line 562 to relay coil 418, energizing the same. This deenergizes relay 420, thereby opening the line at C, D. Referring to the lower left of the diagram, it will be seen that this deenergizes the 12 volt supply from transformer 100 and the 120 volt supply to the motors 44, 46 and 202. However, the 120 volt supply to the magnetic brake 72 is maintained, and the brake remains on. At this time, the drilled boards may be removed, and a new set of boards applied to the table of the machine preparatory for a new drilling operation.

As so far described, the scanning is on uniformly spaced scanning lines, because the commutator 92, 98 was used. However, by throwing the manually operable switch 528 from down to up position, the skip scanning wheel 120 is brought into the circuit, instead of the commutator 92, 98.

The operation of the circuitry remains the same as previously described in that interruption of lateral shift requires make, break, and make of a circuit at switch 528. This is obtained from contact 122 and wheel 120 when an insulation tab is inserted in a notch of the wheel, the wheel being moved a pitch distance of one tooth to the next tooth for each $\frac{1}{16}$ " in the particular example here described.

When an insulation tab is removed, the contact 122 is broad enough to straddle the notch, and contact is not broken until the next insulation tab is reached. The removal of a single tab then causes a lateral shift of $\frac{1}{8}$ ", and the removal of another adjacent tab would cause a lateral shift of $\frac{3}{16}$ "; and so on.

As an extra check to insure completion of the drilling of all the needed holes in the workpiece, the machine may include a counter which totalizes the number of holes drilled, and indicates the same on suitable digit wheels located at the front panel of the machine.

In a simpler machine having only one drilling head, any suitable counter may be employed, responsive for example to either the down limit switch or the up limit switch. In the present case the problem is complicated by the provision of five drilling heads, any one or more of which may be operated each time the carriage stops. I accordingly employ a stepping relay which works each time the carriage stops, and which sweeps an arm over five contacts which are connected one each to the drill heads, thus producing as many output pulses as there are holes drilled. These pulses in turn go to a counter with

digit wheels to show the count. This is illustrated in FIG. 16, in which the counter is shown at 564 and the stepping relay is shown with a switch bank at 566 (of which five contacts are used corresponding to the five drill heads) and another bank 568, of which the same or a greater number of contacts may be bridged as shown. The contact arms of the banks are rotated step by step by a solenoid 572 operating a pawl and ratchet, not shown. The solenoid is energized with D.C. from a rectifier 570, and at the end of each solenoid stroke, contacts 574 open for return of the solenoid core. A continuous A.C. voltage applied through a conductor 576 causes repeat stepping action until contact arm 568 leaves the bridged contacts and moves to contact 578.

The power supply on conductor 576 is obtained whenever the carriage stops and a drill spindle descends. More specifically, one or more of the power relays 360-368 must be energized for one or more drill spindles to descend. The relay contacts are therefore in right position. Suppose relay 368 has been energized. Power then flows from line L1 and line 438 to contacts 440, then in right position, and thence up to line 576 and the contact bank 568. This supplies rectifier 570 and solenoid 572 so that the stepping relay steps progressively until contact 578 has been reached. If one of relays 360-366 (instead of relay 368) is closed, the current path differs to the extent that current first flows through contacts 440, then in left position, to relay 366, to relay 364, and so on in series, until the energized relay is reached, whereupon current flows through its contacts, then in right position, up to the line 576, and the stepping relay contacts 568, as before described.

The motion at bank 568 is duplicated at bank 566, thus sweeping its contact arm over five contacts connected respectively to the five solenoids of the drill heads. The moving contact of bank 566 thus feeds a series of pulses to the counter 564, there being one pulse for each drill head the solenoid of which is energized. There will then be as many pulses as holes being drilled.

At the end of a single stepping relay action when contact 578 is reached, line 580 is dead, it being connected to line 446, which is in series with the five up limit switches 330-338, at least one of which is open. However, when the drill heads all return to up position, the line 446 comes alive, and current is supplied through line 580 and contact 578 which causes a final step of the relay for return to initial position, it being understood that the decks or banks are actually circles, with the last contact adjacent and followed by the first contact. The stepping relay rests in start position because conductor 576 then is dead.

The wide faced or limit contact 238 shown in FIG. 10 is also shown at the lower right of FIG. 16, and is simply connected in parallel with the upper limit contact 232. It will be understood that in normal correct operation the limit contact 238 remains on the pattern and would never engage the contact plate 16. However, in the event of malfunction or over travel either to the left of the pattern, or to the right of the pattern, or downward below the bottom edge of the pattern, contact 238 could touch the contact plate, and in such case, it is preferred to stop the machine altogether, which is what is accomplished by connecting contact 238 to contact 232, it being kept in mind that contact 232 does stop the machine altogether at the starting position corresponding to the large hole 111 in FIG. 2B, all as previously described, everything being dead except brake 72.

An additional relay 511 (shown below commutator 92, 98) is energized when line 510, 512 is energized, and when closed, it ensures a supply of 12 volts through contacts 544 of line 512 and contacts 514 and thence to line 518. It is a safety measure to ensure a continuous 12 volt supply regardless of possible interruption at broad faced feeler contacts 234 or 236. Here again a momentary pulse at a feeler is sufficient because relay 511

then acts as a holding relay and maintains voltage on line 512, 518 even if the feeler contact opens at 234 or 236.

For manual operation, the switch 422, 428 is moved to the up position, the switch remaining set in either position as in a toggle switch. Power then flows from the X terminal through conductor 582 through the upper terminals of switch 428 and thence to a bank of four push button switches connected in series and normally biased to down position. Current thus flows to terminal A, which corresponds to the A terminal at the brake control 404, thereby applying the brake, which is the normal condition of the machine when at rest.

Depression of button 584 supplies current through wire 592 to reverse field 44' of the main travel motor, thus causing the carriage to move from front to rear. Depression of button 586 causes current to flow through wire 594 to the section 44 of the travel motor, causing travel of the carriage from rear to front. Depression of button 588 supplies current through wire 596 to the forward section 46 of the lateral shift motor, causing movement of the carriage from left to right over the table. Button 590 supplies current through wire 598 to the reverse field 46' of the lateral shift motor, and causes movement of the carriage from right to left over the table. It should be noted that use of any of the four buttons opens the supply to terminal A and so releases the magnetic brake 72 at the same time that it energizes one motor or the other. Each time a button has been used and released the magnetic brake goes on automatically, until some button is again pressed. Note further that only one button can be effective. All following buttons lack current supply because the first button which is used opens the series circuit to the succeeding buttons.

In this manual position of the switch 422, 428, the 12 volt supply for the relays is dead, and the drill motor 202 is deenergized. The manual control is primarily to move the carriage far out of the way for servicing or maintenance work, rather than for drilling.

If desired, pilot lights may be provided to show the direction of movement of the carriage. These lights are shown above the four manual push buttons 584-590. The four wires marked "PL" lead to the same four pilot lights. The switch contacts shown at 602, 604, 606, 608 are mechanically connected to the manual automatic switch 422, 428 and are closed in automatic position to make the pilot lights operative during automatic operation. They are opened in manual position to open the circuits to the pilot lights so that the latter will respond only to the manual operation of the push buttons 584-590, and will no longer be responsive to the automatic circuitry. This precaution is needed because of the nature of the motors 44, 46 which have voltage on their back winding, and therefore would light the incorrect as well as the correct pilot light if the circuits were not isolated completely as here shown.

One feature of the machine is that the carriage and feelers will automatically find their start position after they have been moved by the travel motor 44 far back out of position manually, for maintenance work as above described. For this purpose the switch 422 is put in automatic or down position, and either start button 402 or 466 is pressed, depending on the position of the carriage. Typically, the carriage is all the way back, and it is the forward start button 402 that is pressed. The carriage travel then is arrested when the broad faced contact 232 (FIG. 10) passes the edge of pattern 40 (FIG. 2B) and enters the large hole 111, that is when its circuit is broken and again made. The machine then rests in normal starting position as though at the end of a complete drilling cycle, and another operation of the start button begins the desired drilling cycle.

To understand this, it should be recognized that when the slide is far off the pattern, the contact 232 is in continuous engagement with the contact plate 16, thereby

energizing relay coil 412 which moves its leftmost contact 411 to the right, thereby disconnecting "high ground" from "ground." By reference to the banks of relays 350-358 and 360-368 as well as the relays 450, 454, 536, etc., it will be seen that these are all disabled and therefore no attempt at drilling can take place, even though the feeler contacts 30-38 also are in continuous engagement with the contact plate 16.

However, when contact 232 reaches the edge of the pattern it is open circuited, thereby deenergizing relay 412. This connects high ground to ground and puts the circuitry in normal condition. Then when contact 232 again engages the back plate through the large hole 111, it stops the machine as though at the end of a drilling cycle.

It has already been pointed out that the drill heads are two inches apart, and after scanning laterally for two inches, a width of ten inches has been effectively covered. In some cases this may be more than adequate, and the table 12 and contact plate 16 may have a corresponding width somewhat greater than ten inches. In other cases a greater width may be desired, in which case a width of twenty inches may be provided, the carriage then being scanned for two inches, and then advanced for eight inches without scanning, preparatory to a second stage of scanning for a distance of two inches, thereby covering a total width of twenty inches. An automatic advance of eight inches may be provided by appropriate omission of tabs or appropriate design of the commutator wheel shown in FIGS. 13-15, or the desired large advance may be produced manually, if desired. In one particular case the table and contact plate were designed to handle work up to 16" in width, and in such case after the first stage of scanning the carriage is moved without scanning for a distance of four inches, whereupon the second stage of scanning is resumed. At this time the solenoids of the first and second drill heads are disabled, so that only the third, fourth and fifth drill heads are operational.

One advantage of the present machine is that the length of the table is not critical. The machine illustrated in FIG. 1 accepts work up to 27" long, but another machine may be built which is identical with that here shown in all respects except that the table may be lengthened as much as desired, up to a length of even 10, 15 or 20 feet. Such extreme length is not needed for printed circuit boards, but is useful in other fields as when perforating thin sheet aluminum parts of an airplane.

As an example, but not in limitation of the invention, in the particular machine here shown the motor 44 is a Slosyn motor made by Superior Electric Co. of Bristol, Conn., Model SS 150 RC, this being a stepping motor with permanent magnet segments. For quick uniform stopping the motor is supplemented by the magnetic brake 72, the brake being energized when the motor is deenergized and vice versa. In the present case, the brake is made by Warner Electric Clutch Company, of Beloit, Wis. The brake is preferably energized with the assistance of a Warner control, which has capacitors which feed an extra high voltage to the brake for instantaneous stopping, but after an instant the voltage drops down to a normal 90 volts.

The motor 46 for the lead screws is a Slosyn motor SS 50, and in this case there is no need to supplement the quick stop action of the motor with an additional brake. This is so because of the frictional or self locking action of the lead screws 76 and 78, in addition to which the increments of travel in lateral direction are small and do not build up inertia as does the fore and aft scanning travel, which may be in long increments, and which takes place at relatively high speed, in this case 128" per minute.

The drill heads are driven by any suitable motor, in this case a Boehm motor of ordinary brush and commutator type. It is operated at a speed suitable for the nature of the material being drilled and for the drills

being used. A speed of 3,000 r.p.m. is employed for printed circuit boards, but speeds up to 10,000 r.p.m. are available.

The pulley drive here shown employs a flat belt, but if desired the pulleys may be replaced by sprocket gears, and the belt may be replaced by a roller chain.

The stepping relay may be one made by C. P. Clare Co. of Chicago, Illinois, and the counter operated thereby may be a series E.P. made by Trimeter Co. of New York, New York.

The pattern may be an acetate sheet having a thickness of say 0.006 inch. The plastic used should not be subject to stretch. A stick back (pressure sensitive adhesive) is convenient.

It is believed that the construction and operation of my pattern drilling machine, as well as the advantages thereof, will be apparent from the foregoing detailed description.

The machine positions a group of drills over a work area, at high speed, and with a very high degree of accuracy of stopping, all fully automatically controlled. Manual electric control of the carriage is also available. The machine stops the movement of the drill carriage almost instantly, and overcomes inertia to maintain a high degree of accuracy.

Every drill spindle has its own contact feeler, thereby making each independent in the choice for drilling. Any one or multiple combination of drills can operate each time the carriage stops.

Only one motor at a time moves the carriage. This is so even during manual operation regardless of how many manual buttons are held in the "on" position. The buttons are disabled and have no effect when the machine is in automatic condition. The carriage cannot be moved at all unless all spindles are back out of the work, the scanning motor circuits being deenergized when a drill spindle is not retracted. A light on the panel indicates in which direction the machine is moving, in either automatic or electric manual drive.

The machine automatically finds the starting position if the carriage has been backed away from the starting position. The machine returns to that starting position under power, meanwhile opening all the other circuits, including of course the drill solenoid circuits, and then at the starting position the machine returns to a normal power condition for the beginning of a new scanning operation.

When the carriage returns to starting position after completion of the work cycle, all power is shut off except for the position holding brake. The machine then is ready for the next complete cycle at the touch of a start button.

The machine is in a locked or "brake on" position when the carriage is not in motion. This is so during normal automatic drilling, and also when the carriage is moved under manual control.

A digit counter enables the machine to record the total number of holes that have been drilled. The lateral traverse (from side to side) may be in uniform increments, or in non-uniform distances if in a repeat pattern. The speed of the rotating spindles is variable, so as to provide the proper speed for the material being drilled. The machine is completely self-contained, compact in size, and requires only an electrical source of power. Compressed air and hydraulic fluid are not needed.

Although the machine is shown used for drilling, it can be used for automatic reaming, tapping, punching, riveting, etc., all with the same choice of single or multiple tool selection, as well as tool carriage positioning.

It will be understood that while I have shown and described the machine in a preferred form, changes may be made without departing from the scope of the invention, as sought to be defined in the following claims. In the claims, the reference to pulleys on the drill heads

is not intended to exclude the use of sprocket gears driven by a chain instead of a belt.

I claim:

1. A pattern drilling machine comprising a horizontal table for supporting a plate to be drilled at spaced points, a frame supporting the table, a contact plate substantially coextensive with the table disposed in a vertical plane at the side of the frame, a carriage with a drill head over the table, an electrical contact feeler disposed outside the contact plate for movement over a pattern made of thin insulating material secured on the contact plate and having appropriately located small perforations corresponding to those which are to be made in the plate, means to simultaneously move the carriage and feeler with a scanning movement over the table and pattern respectively, and electrical circuitry controlled by the contact feeler to arrest the scanning movement and operate the drill head when a feeler reaches a perforation in the pattern.

2. A pattern drilling machine comprising a horizontal table for supporting a plate to be drilled at spaced points, a frame supporting the table, a contact plate substantially coextensive with the table disposed in a vertical plane at the side of the frame, a carriage with a row of uniformly spaced drill heads over the table, a slide with a row of uniformly spaced electrical contact feelers disposed outside the contact plate for movement over a pattern made of thin insulating material secured on the contact plate and having appropriately located small perforations corresponding to those which are to be made in the plate, the spacing of the feelers being the same as the spacing of the drill heads, means to simultaneously move the carriage and slide with a scanning movement over the table and pattern respectively, and electrical circuitry controlled by the contact feelers to arrest the scanning movement and operate one or more drill heads when one or more corresponding feelers reach perforations in the pattern.

3. A pattern controlled machine comprising a table for supporting a plate to be worked on by a tool, a frame supporting the table, a contact plate disposed in a vertical plane at the side of the frame, a carriage with a tool head over the table, an electrical contact feeler disposed outside the contact plate for movement over a pattern made of appropriately perforated thin insulating material secured on the contact plate, means to simultaneously move the carriage and feeler with a scanning movement over the table and pattern respectively, and electrical circuitry controlled by the feeler to arrest the scanning movement and operate the tool head when a feeler reaches a perforation in the pattern, said means including cross rails on which the carriage is slidable laterally of the table, cross heads at the ends of the rails, ways extending longitudinally at the sides of the table on which the crossheads slide, a gear rack parallel to the ways, a gear meshing with the rack, a motor and magnetic brake for driving said gear and stopping the same instantly in response to a feeler contact, a lead screw parallel to said rails for laterally shifting said carriage, a vertical lead screw outside the contact plate and carried by a crosshead, gears connecting the lead screws for simultaneous equal movement, the aforesaid feeler being moved by the vertical lead screw, a stepping motor for driving the lead screws, and a commutator wheel system driven by the lead screws for stopping the second motor after desired increments of travel.

4. A pattern drilling machine comprising a table for supporting a plate to be drilled, a frame supporting the table, a contact plate substantially coextensive with the table disposed in a vertical plane at the side of the frame, a carriage with a drill head over the table, an electrical contact feeler disposed outside the contact plate for movement over a pattern made of appropriately perforated thin insulating material secured on the contact plate, means to simultaneously move the carriage and feeler

with a scanning movement over the table and pattern respectively, and electrical circuitry controlled by the feeler to arrest the scanning movement and operate the drill head when a feeler reaches a perforation in the pattern, said means including cross rails on which the carriage is slidable laterally of the table, crossheads at the ends of the rails, ways extending longitudinally at the sides of the table on which the cross heads slide, gear racks parallel to the ways, a shaft carrying gears meshing with the racks, a motor and magnetic brake for driving said shaft and stopping the same instantly in response to a feeler contact, a lead screw parallel to said rails for laterally shifting said carriage, a vertical lead screw outside the contact plate and carried by a crosshead, mitre gears connecting the lead screws for simultaneous equal movement, the aforesaid feeler being moved by the vertical lead screw, a stepping motor for driving said lead screws, and a commutator wheel system driven by the lead screws for stopping the second motor after desired increments of travel.

5. A pattern drilling machine comprising a table for supporting a plate to be drilled, a frame supporting the table, a contact plate disposed in a vertical plane at the side of the frame, a carriage with a row of drill heads over the table, a slide with a row of electrical contact feelers disposed outside the contact plate for movement over a pattern made of appropriately perforated thin insulating material secured on the contact plate, means to simultaneously move the carriage and feelers with a scanning movement over the table and pattern respectively, and electrical circuitry controlled by the feelers to arrest the scanning movement and operate one or more drill heads when one or more feelers reach perforations in the pattern, said means including cross rails on which the carriage is slidable laterally of the table, crossheads at the ends of the rails, ways extending longitudinally at the sides of the table on which the crossheads slide, a gear rack parallel to the ways, a gear meshing with the rack, a motor and magnetic brake for driving said gear and stopping the same instantly in response to a feeler contact, a horizontal lead screw for laterally shifting said carriage, a vertical lead screw and one or more slide guide rods outside the contact plate and carried by a crosshead, gears connecting the lead screws for simultaneous equal movement, the aforesaid slide being moved by the vertical lead screw, a stepping motor for driving the lead screws, and a commutator wheel system driven by the lead screws for stopping the second motor after desired increments of travel.

6. A pattern drilling machine comprising a table for supporting a plate to be drilled, a frame supporting the table, a contact plate substantially coextensive with the table disposed in a vertical plane at the side of the frame, a carriage with a row of uniformly spaced drill heads over the table, a slide with a row of uniformly spaced electrical contact feelers disposed outside the contact plate for movement over a pattern made of appropriately perforated thin insulating material secured on the contact plate, the spacing of the feelers being the same as the spacing of the drill heads, means to simultaneously move the carriage and slide with a scanning movement over the table and pattern respectively, and electrical circuitry controlled by the feelers to arrest the scanning movement and operate one or more drill heads when one or more feelers reach perforations in the pattern, said means including cross rails on which the carriage is slidable laterally of the table, crossheads at the ends of the rails, ways extending longitudinally at the sides of the table on which the crossheads slide, gear racks parallel to the ways, a shaft carrying gears meshing with the racks, a motor and magnetic brake for driving said shaft and stopping the same instantly in response to a feeler contact, a lead screw parallel to said rails for laterally shifting said carriage, a vertical lead screw and one or more slide guide rods outside the contact plate and carried by a crosshead,

mitre gears connecting the lead screws for simultaneous equal movement, the aforesaid slide being moved by the vertical lead screw, a stepping motor for driving the horizontal lead screw, and a commutator wheel system driven by the vertical lead screw for stopping the second motor after desired increments of travel.

7. A pattern controlled machine comprising a table for supporting a plate to be worked on by a drill, a metal contact plate supporting a perforated insulation pattern, a carriage with a drill head over the table, an electrical contact feeler disposed adjacent the metal contact plate, means to simultaneously move the carriage and feeler with a scanning movement over the table and pattern respectively, electrical circuitry controlled by the contact feeler to arrest the scanning movement and operate the drilling head when the feeler reaches a perforation in the pattern, and circuitry controlled by a feeler which rides off the peripheral edge of the pattern onto the contact plate for causing the carriage to move longitudinally of the table and to then shift laterally a desired small increment and to then move longitudinally of the table in reverse direction and to then shift laterally, and so on, the back and forth longitudinal movements being repetitive, and the lateral increments being progressive.

8. A pattern drilling machine as defined in claim 7 in which the carriage has a vertical drill head comprising a pulley mounted for rotation without axial movement, a drill spindle splined to said pulley for rotation thereby, a compression spring urging said spindle away from the work, spaced bearings carrying said spindle, a slide carrying said bearings, a solenoid coil above the slide, a solenoid core arranged to push the slide and spindle toward the work when the solenoid is energized, a finger above the core and normally urged toward the core by a light compression spring, "up" and "down" limit switches responsive to said finger for indicating when the drill has completed a hole and when it has returned to retracted position, and circuitry such that the "down" limit switch de-energizes the solenoid and permits retraction of the spindle and the "up" limit switch causes the carriage to resume scanning.

9. A pattern controlled machine as defined in claim 7, said machine including circuitry for disabling automatic travel and instead providing travel under manual switch control so that the carriage may be moved out of the way for servicing, the drill head being disabled when the carriage is moved under manual switch control.

10. A pattern controlled machine as defined in claim 7, said machine including circuitry for disabling automatic travel and instead providing travel under manual switch control so that the carriage may be moved out of the way for servicing, said circuitry including additional means whereby the carriage automatically returns to start position preparatory to another drill operating cycle, the drill head being disabled when the carriage is moved under manual switch control, or is finding its start position.

11. A pattern controlled machine comprising a table for supporting a plate to be worked on by a tool, a contact plate supporting a perforated insulation pattern, a carriage with a tool head over the table, an electrical contact feeler disposed adjacent the contact plate, means to simultaneously move the carriage and feeler with a scanning movement over the table and pattern respectively, electrical circuitry controlled by the feeler to arrest the scanning movement and operate the tool head when the feeler reaches a perforation in the pattern, and circuitry causing the carriage to move longitudinally of the table and to then shift laterally a desired small increment and to then move longitudinally of the table in reverse direction and to then shift laterally, and so on, the back and forth longitudinal movements being repetitive, and the lateral increments being progressive, the means for lateral shift including a commutator wheel with insertable tabs to vary the lateral shift so that the longitudinal travel

may be skipped for a number of increments of lateral shift where desired.

12. A pattern drilling machine comprising a table for supporting a plate to be drilled, a metal contact plate substantially coextensive with the table for supporting a perforated insulation pattern, said pattern having perforations corresponding to those which are to be made in the plate, and being smaller in overall dimension than the metal contact plate, a carriage with a row of spaced drill heads over the table, a slide with a row of spaced electrical contact feelers disposed adjacent the contact plate, means to simultaneously move the carriage and slide with a scanning movement over the table and pattern respectively, electrical circuitry controlled by the contact feelers to arrest the scanning movement and operate one or more drill heads when one or more corresponding feelers reach perforations in the pattern, and circuitry controlled by a feeler which rides off the peripheral edge of the pattern onto the contact plate for causing the carriage to move longitudinally of the table and to then shift laterally a desired small increment and to then move longitudinally of the table in reverse direction and to then shift laterally, and so on, the back and forth longitudinal movements being repetitive, and the lateral increments being progressive.

13. A pattern drilling machine as defined in claim 12 in which the carriage has a row of spaced vertical drill heads, each drill head comprising a pulley mounted for rotation without axial movement, a drill spindle splined to said pulley for rotation thereby, a compression spring urging said spindle away from the work, spaced bearings carrying said spindle, a slide carrying said bearings, a solenoid coil above the slide, a solenoid core arranged to push the slide and spindle toward the work when the solenoid is energized, "up" and "down" limit switches responsive to said core for indicating when the drill has completed a hole and when it has returned to retracted position, and circuitry such that the "down" limit switch de-energizes the solenoid and permits retraction of the spindle and the "up" limit switch causes the carriage to resume scanning.

14. A pattern drilling machine as defined in claim 12, in which the electrical circuitry includes counter means to count the total number of holes drilled, said counter means including a stepping relay operated each time the carriage is stopped for a drilling operation, said stepping relay including a bank of switch contacts connected one each to the circuits of the individual drill heads to produce sequential electrical pulses, one for each drill head that is actually operated, and a counter responsive to the said pulses.

15. A pattern controlled machine as defined in claim 12, said machine including circuitry for disabling automatic travel and instead providing travel under manual switch control so that the carriage may be moved out of the way for servicing, the drill heads being disabled when the carriage is moved under manual switch control.

16. A pattern controlled machine as defined in claim 12, said machine including circuitry for disabling automatic travel and instead providing travel under manual switch control so that the carriage may be moved out of the way for servicing, said circuitry including additional means whereby the carriage automatically finds its start position preparatory to another drilling cycle, the drill heads being disabled when the carriage is moved under manual switch control, or is finding its start position.

17. A pattern drilling machine comprising a table for supporting a plate to be drilled, a contact plate substantially coextensive with the table for supporting a perforated insulation pattern, a carriage with a row of spaced drill heads over the table, a slide with a row of spaced electrical contact feelers disposed adjacent the contact plate, means to simultaneously move the carriage and slide with a scanning movement over the table and pattern respectively, electrical circuitry controlled by the

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feelers to arrest the scanning movement and operate one or more drill heads when one or more feelers reach perforations in the pattern, and circuitry causing the carriage to move longitudinally of the table and to then shift laterally a desired small increment and to then move longitudinally of the table in reverse direction and to then shift laterally and so on, the back and forth longitudinal movements being repetitive, and the lateral increments being progressive, the means for lateral shift including a commutator wheel with insertable tabs to vary the lateral shift so that the longitudinal travel may be skipped for a number of increments of lateral shift where desired.

18. A pattern controlled machine comprising a table for supporting a plate to be worked on by a tool, a contact plate supporting a perforated insulation pattern, a carriage with a tool head over the table, an electrical contact feeler disposed adjacent the contact plate, means to simultaneously move the carriage and feeler with a scanning movement over the table and pattern respectively, electrical circuitry controlled by the feeler to arrest the scanning movement and operate the tool head when the feeler reaches a perforation in the pattern, said slide having additional limit feelers which are too large to enter the perforations and which determine when the feelers have passed the boundary of the hole pattern, and circuitry causing the carriage to move longitudinally of the table and to then move longitudinally of the table in reverse direction and to then shift laterally, and so on, the back and forth longitudinal movements being repetitive, and the lateral increments being progressive, the longitudinal travel being determined by two of the limit feelers, and the total lateral shift being determined by two other limit feelers.

19. A pattern controlled machine comprising a table for supporting a plate to be worked on by a tool, a contact plate supporting a perforated insulation pattern, a carriage with a tool head over the table, an electrical contact feeler disposed adjacent the contact plate, means to simultaneously move the carriage and feeler with a scanning movement over the table and pattern respectively, electrical circuitry controlled by the feeler to arrest the scanning movement and operate the tool head when the feeler reaches a perforation in the pattern, said slide having additional limit feelers which are too large to enter the perforations and which determine when the feelers have passed the boundary of the hole pattern, and circuitry causing the carriage to move longitudinally of the table and to then shift laterally a desired small increment and to then move longitudinally of the table in reverse direction and to then shift laterally, and so on, the back and forth longitudinal movements being repetitive, and the lateral increments being progressive, the means for lateral shift including a commutator wheel with insertable tabs to vary the lateral shift so that the longitudinal travel may be skipped for a number of increments of lateral shift where desired, the longitudinal travel being determined by two of the limit feelers, and the total lateral shift being determined by two other limit feelers.

20. A pattern drilling machine comprising a table for supporting a plate to be drilled, a contact plate substantially coextensive with the table for supporting a perforated insulation pattern, a carriage with a row of uniformly spaced drill heads over the table, a slide with a row of uniformly spaced electrical contact feelers disposed adjacent the contact plate, means to simultaneously move the carriage and slide with a scanning movement over the table and pattern respectively, electrical circuitry controlled by the feelers to arrest the scanning movement and operate one or more drill heads when one or more feelers reach perforations in the pattern, said slide having additional limit feelers which are too large to enter the perforations and which determine when the feelers have passed the boundary of the hole pattern, and circuit-

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ry causing the carriage to move longitudinally of the table and to then shift laterally a desired small increment and to then move longitudinally of the table in reverse direction and to then shift laterally, and so on, the back and forth longitudinal movements being repetitive, and the lateral increments being progressive, the longitudinal travel being determined by two of the limit feelers, and the total lateral shift being determined by two other limit feelers.

21. A pattern drilling machine comprising a table for supporting a plate to be drilled, a contact plate substantially coextensive with the table for supporting a perforated insulation pattern, a carriage with a row of uniformly spaced drill heads over the table, a slide with a row of uniformly spaced electrical contact feelers disposed adjacent the contact plate, means to simultaneously move the carriage and slide with a scanning movement over the table and pattern respectively, electrical circuitry controlled by the feelers to arrest the scanning movement and operate one or more drill heads when one or more feelers reach perforations in the pattern, said slide having limit feelers which are too large to enter the perforations and which determine when the feelers have passed the boundary of the hole pattern, and circuitry causing the carriage to move longitudinally of the table and to then shift laterally a desired small increment and to then move longitudinally of the table in reverse direction and to then shift laterally, and so on, the back and forth longitudinal movements being repetitive, and the lateral increments being progressive, the means for lateral shift including a commutator wheel with insertable tabs to vary the lateral shift so that the longitudinal travel may be skipped for a number of increments of lateral shift where desired, the longitudinal travel being determined by two of the limit feelers, and the total lateral shift being determined by two other limit feelers.

22. A pattern controlled machine comprising a horizontal table for supporting a plate to be worked on at spaced points by a tool, a frame supporting the table, a contact plate disposed in a vertical plane at the side of the frame, a carriage with a tool head over the table, an electrical contact feeler disposed outside the contact plate for movement over a pattern made of thin insulating material secured on the contact plate and having appropriately located small perforations corresponding to those which are to be made in the plate, means to simultaneously move the carriage and feeler with a scanning movement over the table and pattern respectively, electrical circuitry controlled by the contact feeler to arrest the scanning movement and operate the tool head when a feeler reaches a perforation in the pattern, said carriage having a vertical drill head comprising a pulley mounted for rotation without axial movement, a drill spindle splined to said pulley for rotation thereby, a compression spring urging said spindle away from the work, spaced bearings carrying said spindle, a slide carrying said bearings, a solenoid coil above the slide, and a solenoid core arranged to push the slide and spindle toward the work when the solenoid is energized.

23. A pattern drilling machine comprising a horizontal table for supporting a plate to be drilled at spaced points, a frame supporting the table, a contact plate disposed in a vertical plane at the side of the frame, a carriage with a row of drill heads over the table, a slide with a row of electrical contact feelers disposed outside the contact plate for movement over a pattern made of thin insulating material secured on the contact plate and having appropriately located small perforations corresponding to those which are to be made in the plate, means to simultaneously move the carriage and slide with a scanning movement over the table and pattern respectively, electrical circuitry controlled by the contact feelers to arrest the scanning movement and operate one or more drill heads when one or more corresponding feelers reach perforations in the pattern, said carriage having a row of spaced vertical drill

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heads, each drill head comprising a pulley mounted for rotation without axial movement, a drill spindle splined to said pulley for rotation thereby, a compression spring urging said spindle away from the work, spaced bearings carrying said spindle, a slide carrying said bearings, a solenoid coil above the slide, and a solenoid core arranged to push the slide and spindle toward the work when the solenoid is energized, a drive motor, and a single belt extending from said motor to all of said pulleys for driving the same.

24. A pattern drilling machine comprising a horizontal table for supporting a plate to be drilled at spaced points, a frame supporting the table, a contact plate disposed in a vertical plane at the side of the frame, a carriage with a row of drill heads over the table, a slide with a row of electrical contact feelers disposed outside the contact plate for movement over a pattern made of thin insulating material secure on the contact plate and having appropriately located small perforations corresponding to those which are to be made in the plate, means to simultaneously move the carriage and slide with a scanning movement over the table and pattern respectively, and electrical circuitry controlled by the contact feelers to arrest the scanning movement and operate one or more drill heads when one or more corresponding feelers reach perforations in the pattern, said carriage having a row of spaced vertical drill heads, each drill head comprising a pulley mounted for rotation without axial movement, a drill spindle splined to said pulley for rotation thereby, a compression spring urging said spindle away from the work, spaced bearings carrying said spindle, a slide carrying said bearings, a solenoid coil above the slide, a solenoid core arranged to push the slide and spindle toward the work when the solenoid is energized, "up" and "down" limit switches responsive to said core for indicating when the drill has completed a hole and when it has returned to retracted position, and circuitry such that the "down" limit switch de-energizes the solenoid and permits retraction of the spindle and the "up" limit switch causes the carriage to resume scanning, the "up" limit switches of

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all drill heads being connected in series so that the scanning is not resumed unless all of the spindles have been retracted.

25. A pattern drilling machine comprising a horizontal table for supporting a plate to be drilled at spaced points, a frame supporting the table, a contact plate disposed in a vertical plane at the side of the frame, a carriage with a row of drill heads over the table, a slide with a row of electrical contact feelers disposed outside the contact plate for movement over a pattern made of thin insulating material secured on the contact plate and having appropriately located small perforations corresponding to those which are to be made in the plate, means to simultaneously move the carriage and slide with a scanning movement over the table and pattern respectively, and electrical circuitry controlled by the contact feelers to arrest the scanning movement and operate one or more drill heads when one or more corresponding feelers reach perforations in the pattern, said electrical circuitry including counter means to count the total number of holes drilled, said counter means including a stepping relay operated each time the carriage is stopped for a drilling operation, said stepping relay including a bank of switch contacts connected one each to the circuits of the individual drill heads to produce sequential electrical pulses, one for each drill head that is actually operated, and a counter responsive to the said pulses.

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