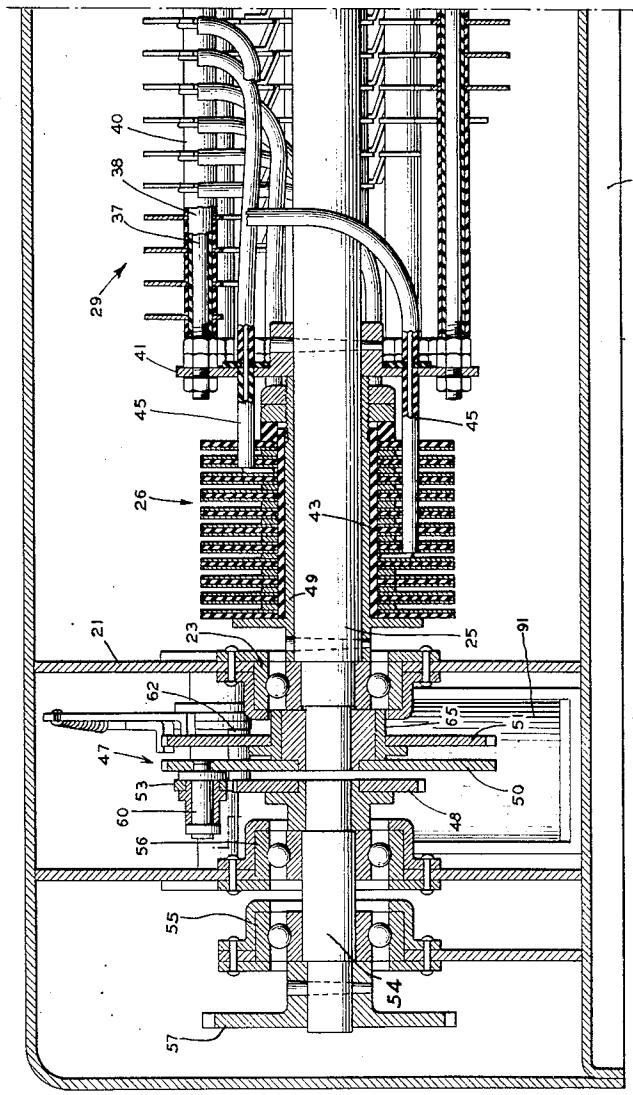
Jan. 5, 1943. H. P. MIXER 2,307,633

SEQUENCE SWITCH

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FIG. 1



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SEQUENCE SWITCH

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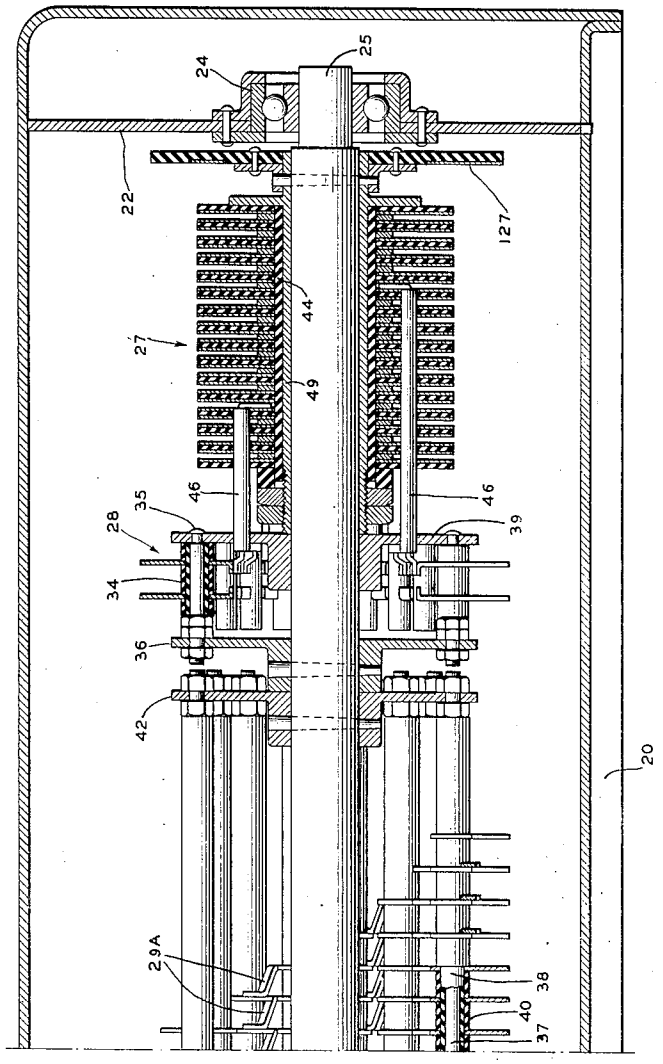


FIG.2

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Jan. 5, 1943. H. P. MIXER 2,307,633

SEQUENCE SWITCH

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FIG. 3

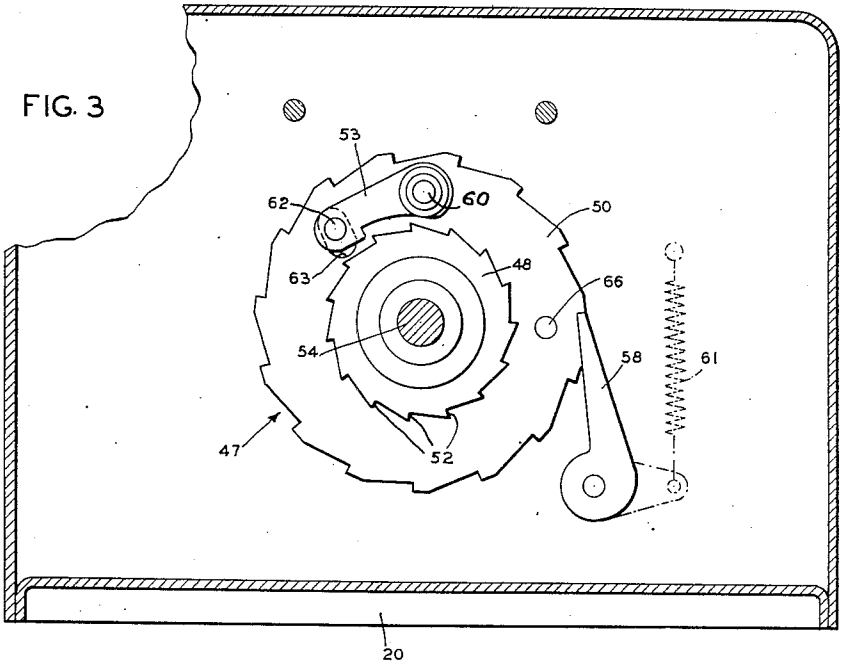
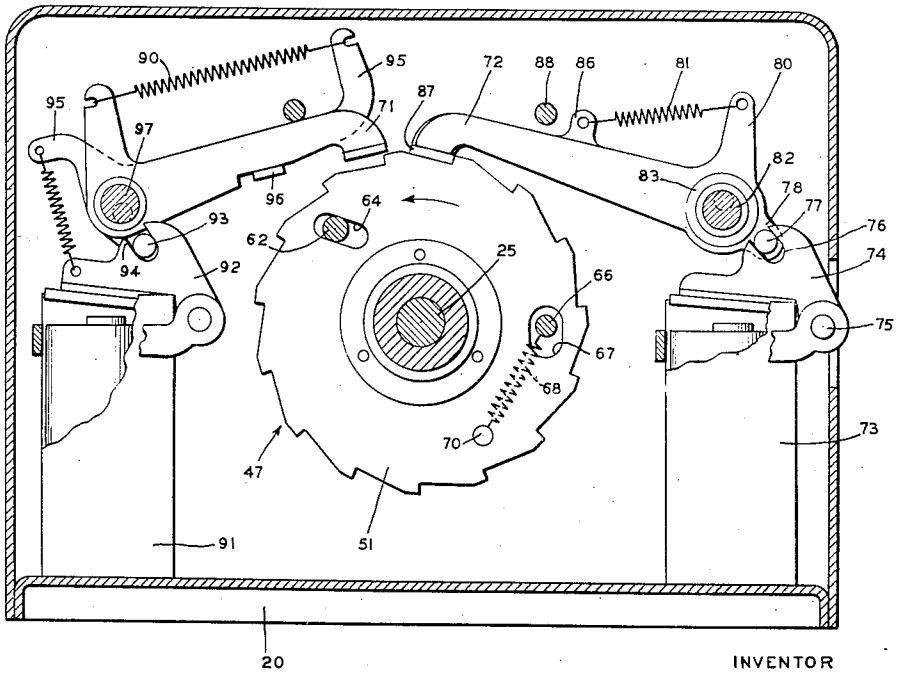


FIG. 4



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SEQUENCE SWITCH

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FIG. 5

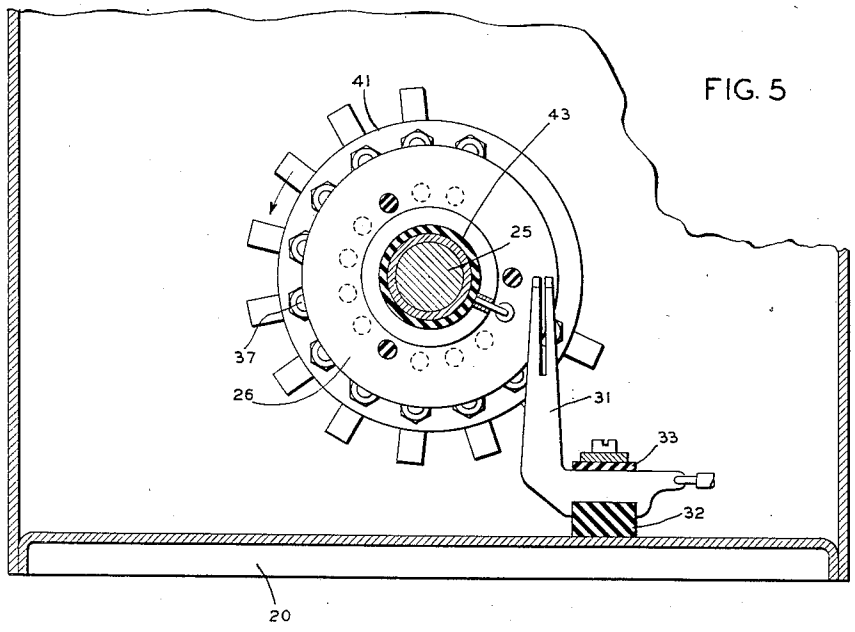
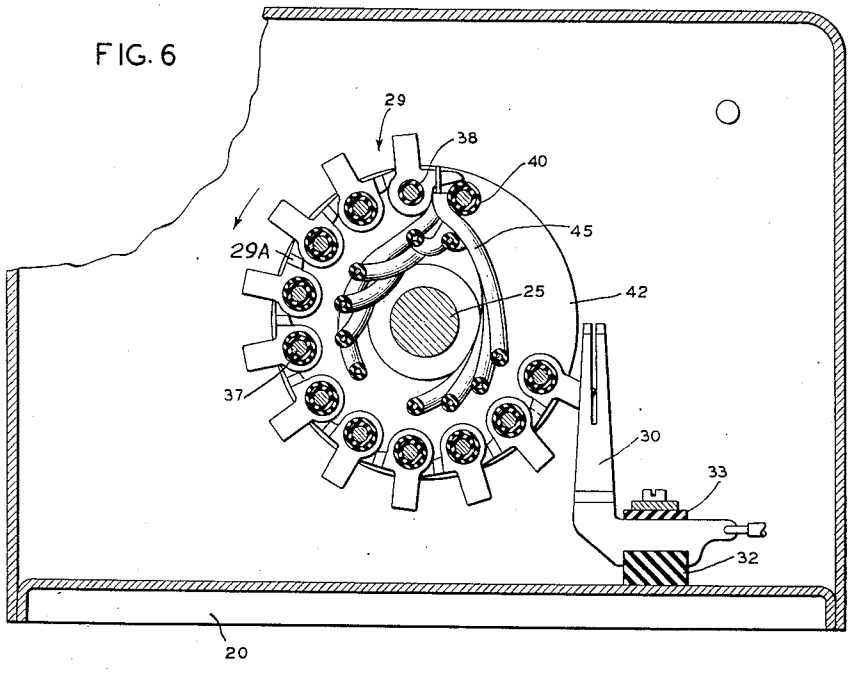


FIG. 6



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SEQUENCE SWITCH

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FIG. 7

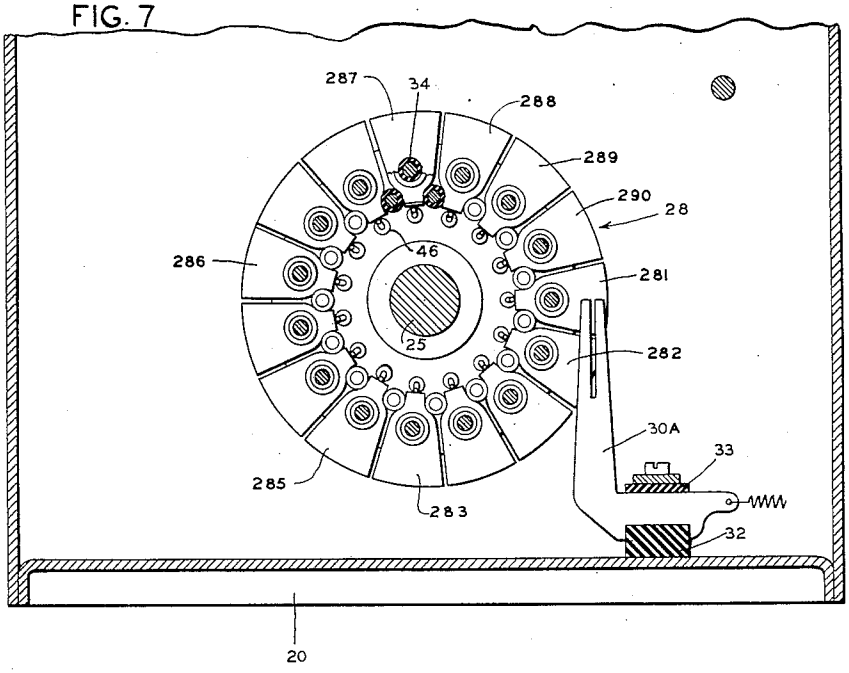
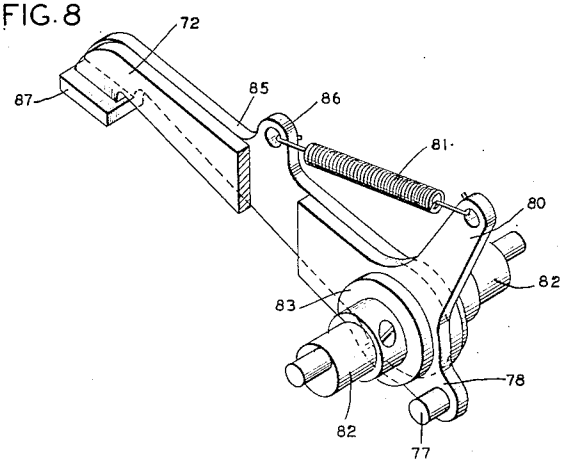


FIG. 8



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Jan. 5, 1943. H. P. MIXER 2,307,633

SEQUENCE SWITCH

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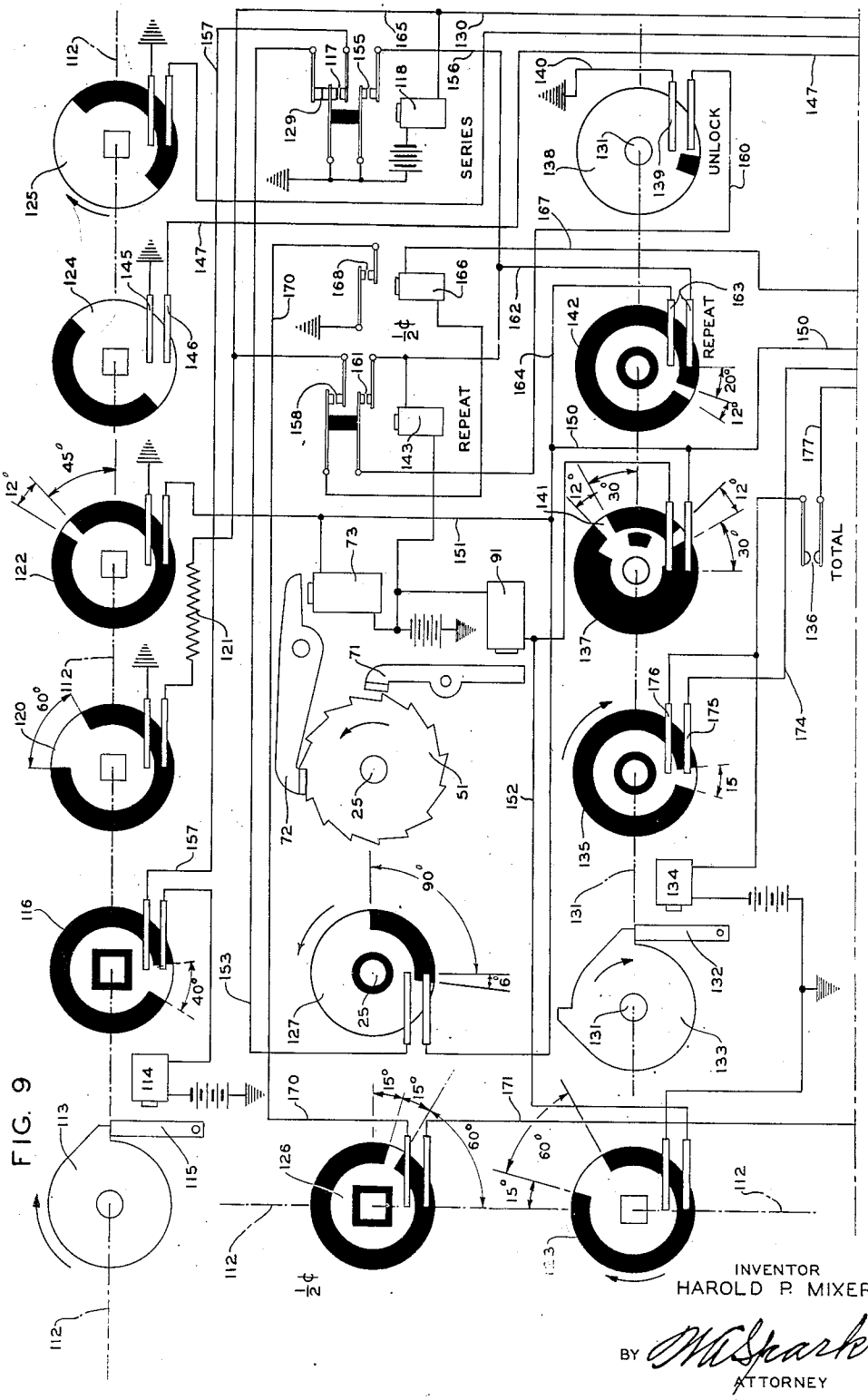


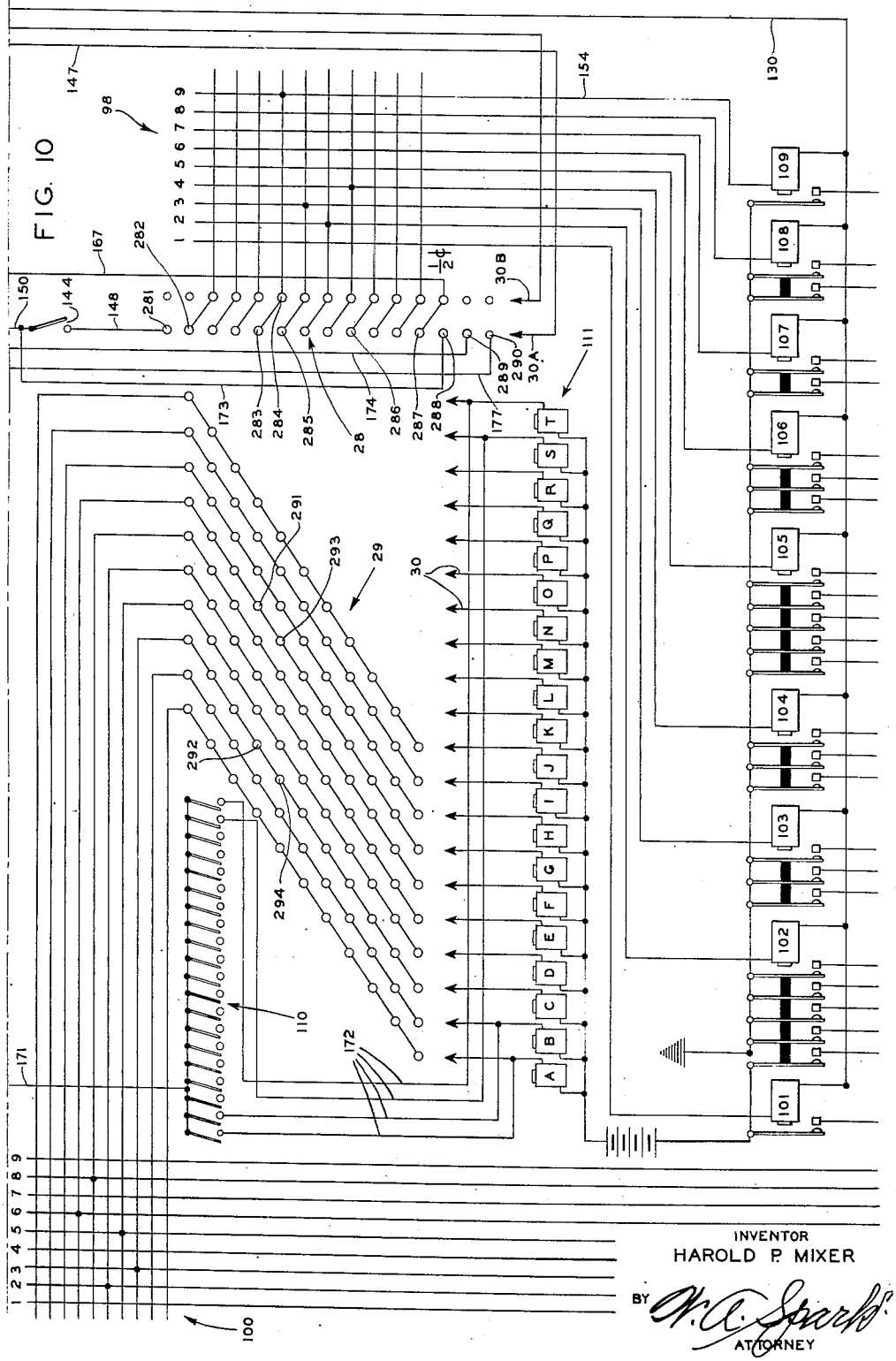
FIG. 9

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SEQUENCE SWITCH

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FIG. 10



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SEQUENCE SWITCH

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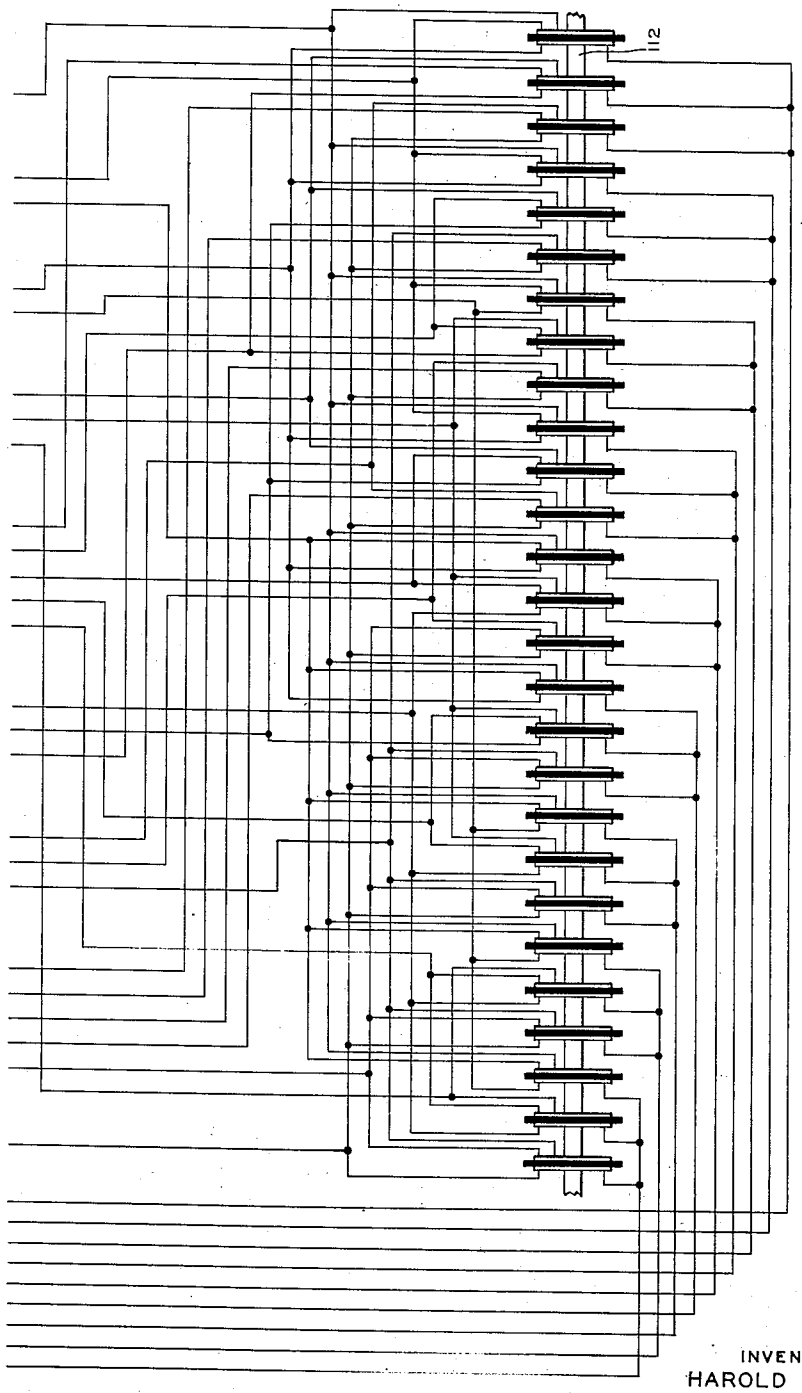


FIG. 11

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Patented Jan. 5, 1943

2,307,633

UNITED STATES PATENT OFFICE

2,307,633

SEQUENCE SWITCH

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Application October 3, 1940, Serial No. 359,468

4 Claims. (Cl. 200—6)

This invention relates to circuit controlling apparatus including what are commonly called sequence switches, whereby means are provided for automatically controlling a series of circuit changes in a definite and predetermined sequence. A particular application of this invention resides in the sequence control used in multiplying machines, one form of which is described herein.

The invention includes novel means for accomplishing sequential circuit switching whereby the number of switch contacts, previously necessary to this accomplishment, is materially diminished. The present invention includes a sequence switch which is an improvement upon the switch described in Patent No. 2,214,029, granted to H. P. Mixer on September 10, 1940.

The primary object of this invention is to improve the multiplying machine disclosed in the above patent especially with respect to the sequence switch and the electrical connections and mechanical devices directly associated with it. The switch is improved in mechanical construction. Also, the present invention includes an improved switch-operating means and some improved electrical connections outside the switch. In particular, the switch is so constructed and its operating circuits so controlled that it now requires only about half as many contacts as it did previously.

The invention resides in a sequence switching device of improved construction and in certain improvements in the means for operating the switch as well as in certain improvements in the electrical connections and circuits associated with it which will be particularly described hereinafter and pointed out in the claims.

Other objects and structural details of the invention will be apparent from the following description when read in connection with the accompanying drawings, wherein

Fig. 1 is a sectional view of one-half of the switch unit showing the clutch actuating means, the slip rings, and the rotary contact blades;

Fig. 2 is a continuation of Fig. 1 and shows, in sectional view, the control contact blades and slip rings;

Fig. 3 is a sectional view taken along line 3—3 of Fig. 1 and shows one plate of the automatic clutch for actuating the sequence switch;

Fig. 4 is a sectional view taken along line 4—4 of Fig. 1 and shows the second plate of the clutch together with two operating magnets;

Fig. 5 is a cross sectional view taken along line 5—5 of Fig. 1, and shows a stationary contact brush in contact with a slip ring;

Fig. 6 is a cross sectional view taken along line 6—6 of Fig. 1 and shows a stationary contact brush ready to make contact with the switch blades;

Fig. 7 is a cross sectional view taken along line 7—7 of Fig. 2 and shows a stationary contact brush in contact with one of the control sectors;

Fig. 8 is an isometric view of one of the stop arms showing its double arm action and eccentric shaft, and

Figs. 9, 10, and 11, when viewed together, form a diagrammatic scheme of connections of a multiplier circuit using the present sequence switch.

Referring now to Figs. 1 and 2, the switch is rotatably mounted on a base 20 having supports 21 and 22 at each end thereof. In each support there is mounted a ball bearing 23 and 24 in which a shaft 25 is journaled. At both ends of this shaft, but inside the bearing points, are two groups of slip rings 26 and 27. Between these slip rings are two groups of contact blades. One of these 28 is designed for clutch control purposes while the second 29 is used for the sequential switching operations.

A plurality of stationary brushes 30 and 31 (see Figs. 5 and 6) is secured to the base 20 by an insulator block 32. The contact members are secured in slots cut in the block 32 and are held down by a cover strip 33 which is bolted to the base 20.

The upper portions of the contact springs 30 and 31 are slotted for greater flexibility and the ends thereof are bent toward the rotating members to effect a contact along a horizontal line which passes through the center of the shaft 25.

The first group of slip rings 26 (Fig. 1) is engaged by ten stationary contact brushes 31 (Fig. 5). The first group of rotating blades 29 is engaged by twenty stationary contact brushes, 30 shown in Fig. 6. The second group of rotating blades 28 is engaged by two stationary contact brushes 30A and 30B one of which is shown in Fig. 7 and the second group of slip rings 27 is engaged by fifteen stationary contact brushes 31 in a manner similar to the first set shown in Fig. 5.

The rotating switch control blades 28 are mounted on insulating sleeves 34, which, in turn, are mounted on rods 35 secured at one end to a flange 36 which is attached to the shaft 25, and at the other end to a flange 39 free on shaft 25. There are thirty blades in all, fifteen each in two rows, but, because of certain cross connections

which will be described hereinafter, only fifteen wire connections are necessary to be brought out through the slip rings 27 and the associated contact brushes 31.

The sequence circuit control blades 29 are mounted on longitudinal rods 37 in a similar manner to blades 28. An insulating sleeve 38 is placed on the rod 37 and the blades are positioned thereon with a plurality of short spacing sleeves 40 between them. There are only ten blades on a single rod but the rods are each long enough to hold twenty because each group of blades on any one rod is progressively offset an amount equal to one blade spacing from its adjoining group.

The offset arrangement may be more clearly shown by reference to Fig. 10. In this figure the arrow points 30 indicate the stationary contact brushes and the circles 29 represent the sequence switch blades. The rods 37, shown in Figs. 1 and 2, support groups of blades which are disposed along horizontal lines in Fig. 10 parallel to the line of contact springs 30. The rotary movement of the blades around the shaft 25 would be represented in Fig. 10 by a vertical movement of the blade assembly 29 past the contact points 30.

The connection between blades 29 is also shown in Fig. 10 and is a major part of the structural unit since said connections are made by soldering together integral wing portions 29A of the blades which are bent at an angle to permit the offset connections to be made.

When completed the series of contact blades 29 form ten spiral conductors on the skeleton surface of a cylindrical drum, each spiral conductor having eleven protruding blades equally spaced along its length.

The diagonal connections described above reduce the lead-in conductors to ten, the ten slip rings 26 being employed to convey current from them to the stationary contact brushes 31.

The supporting rods 37 are secured to two flanges 41 and 42 which are pinned to shaft 25. Suitable insulating sleeves 43 and 44 are also employed to support the slip rings 26 and 27 which are collectively secured to the shaft by sleeves 49. Connections from the slip rings 26 and 27 are made to the contact blades 29 and 28 by means of wires enclosed in flexible insulating tubing 45 and 46 and conducted through holes cut in the slip rings 26 and 27 close enough to the shaft 25 to be out of the way of the contact springs.

At one end of the shaft 25, outside the ball bearing 23, is a clutch 47 (see Figs. 1, 3, and 4) comprising a toothed wheel 48 and two plates 50 and 51. Wheel 48 is the driver and contains a plurality of ratchet teeth 52 by which it engages a pawl 53 to cause rotation of the shaft 25. Wheel 48 is secured to a stub shaft 54 which is journaled in two ball bearings 55 and 56 and is driven by a sprocket wheel 57. Any means of driving the stub shaft may be employed as long as the correct speed is maintained and sufficient power is available.

Clutch plate 50 is secured to the end of shaft 25 and transmits the rotating power received from wheel 48 to the switch structure. Pawl 53 is rotatably mounted on a stud 60 set near the periphery of plate 50 and engages the teeth of wheel 48 when the clutch is engaged. An additional pawl 58 engages the ratchet teeth on plate 50 to prevent back motion and keep plates 50 and 51 in disengaged relation when the clutch is not operating. A spring 61 keeps the pawl 58 in engagement.

Secured to the free end of pawl 53 is a pin 62 which extends through a slot 63 in plate 50 and a cam slot 64 in plate 51. The hole 63 permits limited free motion of the pawl but cam slot 64 definitely positions the pawl in accordance with the relative position of the two plates 50 and 51.

As mentioned above, plate 50 is secured to shaft 25. Plate 51, however, is secured to a sleeve 65 which is free to rotate and its position is restricted only by a stud 66 (Figs. 3 and 4) which is secured to plate 50 and extends through an oval hole 67 in plate 51. A spring 68 is stretched between the stud 66 and a pin 70 on plate 51, hence there is always a tendency to rotate plate 50 clockwise in relation to plate 51.

As long as the two plates 50 and 51 are not positioned by any external means, the spring 68 will cause the relative rotation described above and the cam slot 64 will cam the pin 62 toward the shaft 25 and engage the pawl 53 with one of the teeth of wheel 48. This is the operating position of the clutch by which the sprocket wheel 57 turns the sequence switch shaft 25.

To disengage the clutch either one of two stop arms 71 or 72 may be interposed in the path of the teeth cut in plate 51. Fig. 4 shows the arm 72 in this position. Due to the inertia of the moving parts, plate 50 together with pawl 53 continues to move in a counter-clockwise direction and the pin 62 is forced away from shaft 25 by the action of cam slot 64. This draws the pawl 53 out of engagement with the teeth of wheel 48 and the sequence switch stops. The position of pawl 58 is such that it will engage one of the teeth in plate 50 when the pawl 53 is in its fully disengaged position. Therefore, the combined action of pawl 58 and stop arm 72 results in a relative displacement of plates 50 and 51 which keeps pawl 53 out of engagement.

Stop arm 72 is a complex double lever mechanism and is more fully shown in Fig. 8. The operation of the lever is effected by an electromagnet 73 which attracts its armature 74 turning on a pivot 75. A slot 76 in the armature engages a pin 77 which is secured to a short arm 78 of the stop-arm 72. Another short lever arm 80 extends upwardly and at right angles to the main arm 72. The arm 80 supports one end of a spring 81.

Stop arm 72 is formed with a boss 83 and is secured to an eccentric shaft 82 by a set screw. The reduced eccentric portion of shaft 82 is journaled in brackets 84 (only one shown in Fig. 4) secured to the base 20.

An auxiliary lever arm 85 (Fig. 8) is mounted adjacent to the arm 72 and rotates freely on the eccentric part of shaft 82. An extension 86 is provided to serve as anchor for one end of the spring 81 and a turned-over portion 87 fits under the end of lever 72 and makes contact with the teeth of wheel 51.

The operation of the stop-arm assembly is as follows: When the armature 74 is pulled down the arm 72 is rotated in a clockwise direction as seen in Figs. 4 and 8. This action, however, may not at once rotate the auxiliary arm 85 since its bent-over portion 87 is jammed tight against the edge of one of the teeth of plate 51 and this plate is stressed by spring 68 to move in a counter-clockwise direction. When the arm 72 moves clockwise, it rotates the shaft 82 with it, giving an eccentric motion to the bearing of arm 85. As may be seen from the Figs. 4 and 8, a move-

ment of shaft 85 in a clockwise direction will move the turned-over portion 87 to the left. This motion, while quite small, is made in a very short space of time and is enough to free the portion 87 from the tooth, after which it rotates upwardly under the action of spring 81 and both levers 85 and 72 are stopped by a limit pin 88.

When the stop arm 72 is raised, the clutch is engaged and the sequence switch is rotated until either of the stop arms 71 or 72 is lowered. In many operations, however, the arm 71 is lowered before arm 72 is raised, in which case the switch moves only one tooth or to the next series of switch blades 29.

Stop arm 71 is also composed of two levers joined by a spring 90. An electromagnet 91 causes the actuation of stop arm 71 by means of an armature 92, a pin 93, and a slot 94. The pin 93 is secured to a lever 95 which lies alongside stop arm 71 and has a turned over portion 96 which engages arm 71 and raises it when the electromagnet is deenergized. The spring 90 is stretched between the lever 95 and arm 71 to carry the arm downwardly to make contact with one of the teeth on wheel 51 when the magnet 91 is energized. An eccentric shaft 97 similar to shaft 82 is employed to carry lever 95 and act as pivot for arm 71. As is indicated in Fig. 4, the eccentric portion is above the center of rotation so that the arm 71 is pulled away from the engaged tooth as it is lifted.

During the operation of the sequence switch when it is being moved one step at a time, stop arm 71 is lowered in advance of the raising of arm 72 so that there will be no possibility of moving more than one space. To make such an arrangement possible the engaging portion of arm 71 is made slightly longer than necessary to overlie the next adjacent tooth, when the wheel 51 is engaged by stop arm 72.

The mechanical operation of the sequence switch may be understood from the above description. The parts are normally as shown in Fig. 4, with the arm 71 held out of and the arm 72 held in engagement by the usual armature springs. If the circuit of magnet 73 be closed momentarily, arm 72 will release the engaged tooth of disc 47, and return in time to engage the next tooth, thus turning the switch one step only. If the circuit be closed for a longer time, the switch will make a continuous rotation over a plurality of spaces, until the circuit is broken, whereupon the arm 72 will move into engagement and arrest it, the distance the switch rotates depending on the length of time the circuit is closed. When advancing step-by-step, it is preferable to use the arm 71 also. Its magnet 91 is energized an instant before magnet 73, and is deenergized an instant later than magnet 73. The ratchet is thus arrested by arm 71, even if arm 72 does not get back into engagement quickly enough. The two arms together have the action of an escapement.

As will be explained more fully hereinafter, certain of contact blades 28 are electrically connected diagonally in pairs, as shown in Fig. 10. The shaft 25 also carries at its right-hand end the commutator disc 127, the face of which is shown in Fig. 9.

The electrical operation of the switch can be best understood from the example illustrated in Figs. 9 and 10. As shown in the latter figure, each of the diagonal series of blades 29 is connected by a horizontal lead line shown at the top of Fig. 10 with the multiplicand stack 100 illustrated. In this stack the horizontal lines representing numerical denominations, the topmost line being the lowest and the vertical lines representing, respectively, the digits 1 to 9. This stack is so constructed that any one of the vertical lines may be electrically connected with any one of the horizontal lines. Thus, the fourth denominational line from the top is shown connected with the vertical line representing the digit 6.

The ten pairs of diagonally connected blades 28 are each shown connected by horizontal denominational lines with the multiplier stack 88 in which the vertical lines again represent digits, the topmost one being the lowest. When the switch is in its rest position, the row of brushes 30, 30A and 30B stand one space above the topmost row of blades 29, the brush 30A being then in contact with blade 281. The first step brings the right-hand ten of the brushes 30 into contact with the topmost row of blades 29 and brings brush 30A into contact with blade 282. In this position brush 30A is electrically connected with the units of the multiplier stack and the rightmost brush 30 is electrically connected with the units of the multiplicand stack 100. There are twenty of the brushes 30 shown connected with denominational magnets lettered A—T, inclusive, and in this position blades 29 are connected with magnets K—T, inclusive. When the switch steps down to the fourth longitudinal row of contacts 29, magnet Q is connected with the fourth denomination of the multiplicand stack, and, therefore, is set by digit 6 and brush 30A is connected with the fourth denomination of the multiplier stack, and, therefore, with the digit 9, and the multiplying machine is so constructed that in this position the units of the partial products of 6×9 will be added into an accumulator by the magnet Q. In this same position, the fifth denomination of the multiplicand stack, shown set by the digit 8, is connected with magnet P, which will cause the registration of a two, which is the unit of the partial products 9×8. The magnets O, N, and M are, respectively, connected for multiplication by 9 of 2, 5, and 3. When these units have been added, the switch makes another step and at the same time the circuit is switched from brush 30A to brush 30B. This unit step connects the fourth denominational line from the multiplicand stack, that is to say, the digit 6 with magnet P. Since the circuit has been shifted to brush 30B, the circuit still goes through the digit 9 in the fourth position of the multiplier stack. The tens of the several partial products are thus added each one step to the left of the units of the partial products. While the switch is still standing in this position, the circuit is again shifted back from brush 30B to 30A, which connects the circuit with the fifth denomination of the multiplier, in which the digit 3 is set up. The magnets then connected, that is to say, the magnets L—P, will cause the addition of the units of the partial products of the several digits of the multiplicand 35286 by 3 and so on. The multiplication proceeds in this way to the end of it. Meanwhile, while this process in multiplication has been going on, other parts of the circuit, but under the control of contact blades 28 and brushes 30A and 30B, have caused the stepping of the switch by energizing the clutch magnets 73 and 91 as has been described.

The topmost contact 281 and the last three contacts in that row, namely, 288, 289 and 290

are for control purposes, which will be understood in connection with the general description of the circuit. It may be stated at this point, however, that the commutator disc 127 also exercises a certain control over the stepping of the switch. It will be seen that the primary function of the switch is to close in sequence the various circuits of the magnets A—P under control of the multiplicand set up in the stack 100, and the multiplicand set up in the stack 98, and the commutator disc 127 also controls, according to the rules which will be explained hereinafter, the operation of the clutch and the mechanical setting of the switch.

The operation of the sequence switch in connection with a multiplying mechanism such as that disclosed in the above mentioned Patent 2,214,029, will hereinafter be described. This patent discloses complete operating details of a machine employing an older type sequence switch and an electric circuit containing commutators in which the multiplication table has been incorporated.

The present invention is designed to cooperate with the same type of multiplying circuit as described in the above mentioned patent except for certain modifications and simplifications due to the novel and improved switch operating characteristics.

Fig. 11 shows the schematic wiring of the multiplying commutators which remains unchanged from the above referred patent.

Fig. 10 shows the schematic wiring of a number of multiplying components which may be enumerated as follows: A multiplier decoding stack 98, a multiplicand decoding stack 100, a plurality (nine) of commutator relays (101 to 109, inclusive), a plurality (twenty) of half-cent carry switches 110, a plurality (twenty) of clutch magnets 111 (lettered from A to T, inclusive), the rotary switch blades 29 of the sequence switch, and the control, switch blades 28. These are all component parts of the multiplying mechanism and they will be described in greater detail hereinafter.

Fig. 9 is a schematic diagram showing two switch operating magnets 73 and 91, three relays, seven control commutators on the same shaft as the commutators shown in Fig. 11, four control commutators on the main shaft of the multiplying machine and one commutator on the shaft 25 of the sequence switch. These control units cause the rotation of the sequence switch at the proper intervals and switch in the various multiplier operating circuits when they are needed.

The multiplying commutator segments, which are indicated in edge view in Fig. 11, are secured to a square shaft 112. Seven additional commutators are secured to this same shaft but are shown in detail in Fig. 9 in order to more fully describe the switch action. An operating clutch 113 (Fig. 9) is attached to one end of the square shaft 112 at which point it has been cut cylindrical to provide a bearing means. The clutch 113 is similar to that described in the above patent and is put into operation by an electromagnet 114 which pulls an armature 115 free of a lug on one of the clutch plates and permits it to become engaged. The circuit for clutch magnet 114 is completed through commutator 116 over conductor 157 through contacts 117 to ground when a series relay 118 is operated.

The functions of the seven control commutators will now be described in detail. A starting commutator 116 has a 40° conducting portion which is in contact with the brushes at normal or starting position. After 10° of rotation, the circuit to clutch magnet 114 is broken and the armature 115 falls back to its original position ready to stop the shaft after one revolution unless the circuit is again established. To stop the shaft 112 at the end of a multiplying operation, the series relay 118 must be normalized before the conducting segment of commutator 116 is engaged by the brush.

A series relay commutator 120 is provided in order to bridge the change over from units to tens position on the blades 28. This commutator has a conducting portion which keeps the series relay operated at two points in the machine cycle. Since the winding of the series relay 118 has a low resistance, a resistor 121 of about 300 ohms is connected in series with one of the brushes to keep the current at the correct operating value.

Two stepping commutators 122 and 123 are provided to control the current through the operating magnets 73 and 91 to effect the successive rocking of stop arms 71 and 72. The conducting segment of sector 123 starts at 105° after the normal or starting position of the commutator shaft and stops 60° later. During this time the stop arm 71 is stressed against the wheel 51, ready to engage the next tooth when the wheel has been released for rotation by arm 72. Arm 72 is controlled by the conducting segment of sector 122 which starts 135° after the start of shaft 112 and lasts only 12°.

The stepping of the sequence switch at this point is made after the units of a series of partial products have been entered into the accumulator wheels and the tens of these partial products are about to be entered into the accumulator wheels one denominational order higher.

Two switching sectors 124 and 125 are secured to shaft 112 in order to transfer the sensing brushes 30A and 30B from one bank of contact blades 28 to the other bank. This transfer is made necessary by the rotation of the switch as outlined in the above paragraph and the actual switching operation should occur once while the stepping action is in progress and back again a half cycle later.

A multiplying sector 126 is also shown in Fig. 9 because the circuits associated with it are different than in previously disclosed systems. The sector 126, however, is a simple multiplying commutator constructed in the same manner as the 5 x 1 sector disclosed and described in the above patent. It is used in "rounding out" a product when a restricted number of decimal places are to be used and is generally called the one-half cent carry commutator.

The digit "5" may be added into any denominational order by throwing in any one of the switches in bank 110 (Fig. 10). In the case where a double operation is being performed, two switches may be connected, in which case a "5" is added in two denominational orders.

Shaft 25 also carries a control commutator 127 which rotates counter-clockwise as shown in Fig. 9. This commutator makes a circuit to operate the clutch at certain times when the series relay is unactuated and contacts 129 are closed. This happens at the certain times during multiplying operations when no multiplier digit or when a zero is encountered. During these periods, which will be more fully described when a sample operation is considered, the sequence switch is stepped along by the other control units.

There are four control commutators on a shaft 131 which will be called the main shaft of the machine, since most of the important mechanical results are produced by means of it. The circuits are so arranged that the two shafts 131 and 112 will never be turning at the same time. First, shaft 112 is rotated a sufficient number of times to complete the multiplying action and put the sum of all the partial products in the accumulator. Then shaft 112 is stopped and shaft 131 is rotated through an angle of 90° which puts the machine into a condition for taking a total by rectifying the accumulator wheels. As soon as the accumulator is properly set for total taking a switch 136 is closed and shaft 131 rotates through a 270° angle which prints or punches the total, normalizes the machine, and zeroizes the accumulator.

Shaft 131 is controlled in its rotation by a clutch, the control plate 133 of which is shown in Fig. 9. An armature 132 of a magnet 134 engages notches on the edge of the plate to disengage the clutch plate for the proper rotation.

Rotation of shaft 131 causes certain steps of the sequence switch by control commutators 137 and 142. The former has two brushes engaging its surface and a conducting area 141 which makes electrical contact with the shaft 131. Another commutator 138 is also mounted on and in electrical contact with the same shaft and is engaged by a brush 139 which is connected to ground by means of conductor 140. Therefore, whenever one of the brushes touching commutator 137 is brought into contact with the metal conducting area 141, the circuit associated with that brush is connected to ground. The sequence of stop arm operations during the control by commutator 137 is the same as for the action governed by commutators 122 and 123. Arm 71 is first lowered, then arm 72 is raised and lowered, and last, arm 71 is raised.

A repeat commutator 142 is secured to shaft 131 in order to cause a stepping action of the sequence switch at the very end of the machine cycle. This repeats the action as long as there are numbers available to be multiplied together. The repeat relay 143 is operated and locked in actuated condition at the start of the multiplying cycle and commutator 138, secured to shaft 131, is used to break the ground connection to the repeat relay at the end of the machine cycle, thus restoring the relay to normal.

Operation

Let it be assumed that two numbers, 35,286, and 4,239 have been entered into the machine and are to be multiplied together. The decoding stacks 98 and 100 indicate these numbers schematically by the black dots on crossed wires as is customary in the art. It makes no difference whether these connections are a result of a mechanically sensed punched card or a number set up in a keyboard as long as electrical connections are made as indicated by the dots in the two stacks 98 and 100.

The normal or starting position of the sequence switch is at blade 281 of the switch control blades (Fig. 10) with brush 30A making contact therewith.

The series of brushes 30 which connect with the accumulator magnets 111 do not make contact with any of the switch blades when the switch is in its normal position but are in the position indicated by Fig. 6, in which a single step of the switch will make contact with the first series of blades 29.

To start the multiplying action, a start key 144 is depressed. This completes a circuit which may be traced as follows: From ground to brush 145 on commutator, 124 (Fig. 9), thence to brush 146, over conductor 147 (Figs. 9 and 10), to brush 30A and switch blade 281, thence over conductor 148 to start key 144, thence over conductors 150 and 151 to the winding of magnet 73, to battery and back to ground. The result of this action is the rocking of stop lever 72 which allows the switch to be rotated. Due to the rotation, the brush soon breaks contact with blade 281, the circuit described above is broken, and the stop arm 72 falls back on the toothed wheel 51 in time to engage the next tooth. Hence, the operation of the start key moves the switch only one step.

At the end of the first step the brush 30A which was in contact with blade 281 is now engaging blade 282 but the decoding stack 98 (Fig. 10) shows that no digit has been entered in this denominational order and no contact is available. However, the first step has moved commutator 127 to a conducting position and this introduces another stepping circuit which may be traced as follows:

From ground through battery and winding of magnet 73 (Fig. 9), over conductor 151, to the brushes and commutator 127, thence over conductor 153, to contacts 129 of the series relay 118, to ground. During the time this circuit is closed stop-arm 71 is lifted and the sequence switch rotates continually until the circuit is broken.

The above circuit is broken as soon as the control brush 30A makes contact with blade 283, which is connected to the first order in which a numeral is entered, i. e., nine. A circuit is then completed which may be traced from ground, through brush 145 (Fig. 9), commutator 124, brush 146, conductor 147, brush 30A (Fig. 10), blade 283, blade 284, contact point "9" in decoding stack 98, conductor 154, winding of relay 109, conductor 130, through the winding of the series relay 118 (Fig. 9) to battery and ground.

The completion of the above circuit actuates the series relay and breaks contacts 129 but makes contacts 117 and 155, thereby completing two additional circuits, one of which may be traced from ground, through contacts 155, over conductor 156, through the winding of the repeat relay 143, to battery and ground.

This circuit actuates the repeat relay 143, which locks up over a circuit from ground, conductor 140, brush 139, through commutator 138, conductor 160, contact 161, and winding of relay 143 to battery. The repeat relay completes two circuits which will be described later.

The second of the above circuits energizes magnet 114 and starts the multiplying action with the rotation of shaft 112 by the release of clutch plate 113. The circuit which causes this action may be traced from ground, through battery and winding of magnet 114, to the brushes on commutator 116, thence over conductor 157, contacts 117 of the series relay 118 which has been actuated, and back to ground.

As shaft 112 rotates, the magnet 114 is deenergized by commutator 116 and the various commutators representing the partial products of the multiplicand and the units digit of the multiplier are connected through the accumulator magnets

111 and the products run into the accumulator wheels. A complete description of this method of multiplication has been disclosed in the above mentioned U. S. patent. It should be pointed out, however, that the multiplying action is divided into two parts, each comprising a half revolution of shaft 112 to which the multiplying commutators are secured. The first half revolution gives the units figures of the partial products and the second half revolution gives the tens figures. These two results must be entered into different denominational orders, hence the sequence switch must be advanced one step after the shaft has made its first half revolution.

As shaft 112 revolves, the multiplying sectors on the commutators cause five accumulator magnets, 111 J, K, L, M, and N to engage a series of accumulator wheels (not shown) to enter therein, the units digits of the partial products of "9" times "35,286" which are 7, 5, 8, 2, and 4. After about 120° of rotation of shaft 112 commutators 124 and 125 cooperate to transfer the ground connection from brush 30A to brush 30B, and at the same time commutator 122 acting with commutator 123 as has been explained above, steps the sequence switch to the next series of blades and the multiplying sectors cause the tens digits of the partial products to be entered into the accumulator wheels. The tens digits of the partial products, resulting from "9×35,286" are 2, 4, 1, 7, and 5, and they are moved up one denominational order by the stepping of the switch to be entered into the accumulator wheels by magnets 111 I, J, K, L, and M.

The action of entering the units and tens digits in their proper denominational orders may be better explained by reference to Fig. 10. When brush 30A is in contact with blade 283, the blades 292 to 291 and the intervening blades are connected to a number of brushes 30 which, in turn, are connected to magnets 111I to 111N, inclusive.

When the sequence switch is advanced one step and the control switched to 30B, the same multiplier digit is connected in the multiplier circuit, since brush 30B then is in contact with blade 284 and the tens digits are entered in the accumulators by way of the same wires which now are transferred from blades 292 to 294 and 291 to 293.

After the above described operations, the shaft 112 continues until it is near its normal position when the ground connection is again shifted to brush 30A by means of commutators 124 and 125 and contact is made to blade 285. Brush 30A, by virtue of the cross connections between blades 28 is now contacting the next column in decoding stack 98. If there is no connection present, there will be no current to hold the series relay actuated, its armature will drop and current will be cut off from magnet 114, which will release armature 115 into the path of the clutch plate 113; hence the shaft 112 will stop. But if there is a digit entered as shown, i. e., "3", the shaft 112 will continue to revolve and multiply the multiplicand "35,286" by the new digit sensed which is "3."

It will be obvious from the above that the sequence switch does not move immediately after the tens digits have been accumulated. There is no necessity for stepping at this point because the tens digits of one denominational order are accumulated in the same orders as the units digits of the next following denominational order multiplier.

While the transfer is being made from brushes 30A to 30B, there may be a short interval of time when both brushes are disconnected. This might open and close contacts 129 on the series relay and hence cause an extra and unwanted stepping action. To keep the armature of the series relay actuated during the change-over the commutator 120 is employed to maintain ground on the circuit for the relay as has always been described.

The multiplying action as described above will continue until the latter half of the fourth rotation of shaft 112 when ground will again be connected to brush 30A which will then be in contact with blade 286. Under these conditions there is no current available through the decoding stack and the armature of the series relay 118 will be normalized, closing contacts 129 and opening contacts 117 and 155.

The opening of contacts 117 stops shaft 112 and the closing of contacts 129 completes a circuit which may be traced from ground, through contacts 129, over conductor 153, brushes on commutator 127, over conductors 152 and 151, to the winding of magnet 73, thence to battery and ground. Shaft 25 will be rotated as long as the brushes remain on the conducting portion of commutator 127 so that the rotation steps the switch to a point just ninety degrees away from normal or on blade 287. At this point shaft 112 is again put into motion by the actuation of magnet 114 which is due to a circuit which may be traced as follows:

From ground, through battery and winding of magnet 114, to brushes on commutator 116, over conductor 157, through contacts 117, and thence to ground. This circuit is only effective when relay 118 is actuated, said actuation being due to the following circuit which may be traced from ground, through battery and the winding of series relay 118, over conductor 165, through contacts 158 of the repeat relay which has been locked up, through the winding of a "half-cent carry" relay 166, thence over conductor 167, to blade 287, brush 30A, conductor 147, brush 146 of commutator 124, brush 145, and ground.

The passage of current through winding of relay 166 actuates its armature and makes contacts 168, thereby completing a circuit which may be traced from ground, through contacts 168, over conductor 170, through the brushes on the half-cent commutator 126, over conductor 171 to the bank of half-cent carry switches 110, thence over one or more of the conductors 172 to the associated accumulator magnets 111, to battery and ground.

As explained previously, the commutator 126 is identical with the 5x1 segment in the bank of multiplying commutators, its action being to switch into the circuit an accumulator magnet 111, which will enter a five into the selected denominational order. The orders are selected by closing the proper switch in bank 110. Only four wires 172 have been indicated connecting switches 110 to accumulator magnets 111. This was done to simplify the drawings and it should be understood that each switch 110 is connected to a corresponding magnet 111.

During the operation of the half-cent carry mechanism none of the brushes 30 make contact with any of the blades 29.

If it is not desired to "round off" or use the half-cent carry, the switches 110 are all left open and the sequence switch will be stepped as usual

by commutator 122. During the second half revolution of shaft 112 there will be no multiplying action because that portion of commutator 126 is blank.

Due to the stepping action and switching of the brushes 30A and 30B, the half-cent carry operation ends with the brush 30A connected to ground through commutator 124 and in contact with blade 288. This is a blank blade and has been included in this description to indicate the manner in which other blank blades if they were added might be wired. Connection is made by means of conductor 173 from blade 288 to the top side of start switch 144 where conductor 150 is terminated. This construction causes a stepping action in the same manner as the operation of the start switch 144 when the brush 30A was on blade 281, thus bringing brush 30A to blade 289.

With brush 30A on blade 289, a circuit is completed which may be traced from ground through brushes 145 and 146 on commutator 124 (Fig. 9), over conductor 147 to brush 30A (Fig. 10), blade 289, over conductor 174, through brush 175 on commutator 135, brush 176, to winding of magnet 134, battery, and ground. This circuit causes the attraction of armature 132 and a 90° rotation of shaft 131. During this rotation, shaft 131 operates certain cams and gears (not shown) which condition the accumulator mechanism for total taking. The present mechanism has been designed to be used with a planetary geared accumulator and before a total taking operation is started the accumulator wheels must be "rectified" or the "creep" removed from the wheels. This is done by mechanism described in the above mentioned patent. Sometimes this will be done in a very short time, but if there are a number of nine digits recorded, the rectifying action will take longer. The stopping of shaft 131 at the 90° point is to permit enough time for the conclusion of this operation, and then continue with the remaining 270°.

The total contacts 136 (Fig. 9) are mounted on the machine at the left of the accumulator in such a manner as to be closed only when the rectifying action is complete. When these contacts are made a circuit is completed from battery and ground, through winding of magnet 134, through the contacts 136, conductor 177, to blade 290 to cause the shaft 131 to be rotated 270°. During the complete revolution of shaft 131 the sequence switch is stepped twice, the first step occurring during the 90° rotation and advancing the blades so that brush 30A contacts blade 290. The second step is made at the start of the 270° rotation and moves the blades to the position where brush 30A is in contact with blade 281. These two steps are made as described previously by commutator 137 in conjunction with the grounded brush on commutator 138.

With brush 30A again on blade 281, the sequence switch is again in its normal or start position. But the repeat relay has been locked in actuated position for the purpose of causing a repeat action of the sequence switch without the necessity of manual operation of the start key. The repeat circuit may be traced from ground, through battery and winding of magnet 73, over conductors 151 and 164, through brushes 163 of commutator 142, over conductor 162, contacts 161 of repeat relay 143, over conductor 160, through brushes on commutator 138, and ground. It will be obvious from a study of the angular dispositions of the conducting segments that three steps of the sequence switch are always made when the shaft 131 makes a complete revolution and the repeat relay is locked up. If the repeat relay is open the switch will stop in its normal position.

Directly after the stepping action made by means of contacts 161, the locking circuit for the repeat relay 143 is broken by the insulating segment on commutator 138. This releases the repeat relay and, if there should be no digits sensed in the decoding stack 98, the repeat relay will remain unactuated and stop the sequence switch in its normal position after a complete or "blank" cycle.

From the above it will be seen that the machine will continue to operate as long as connections are supplied to stacks 98 and 100. When no multiplier is sensed, the machine continues for one blank cycle and then stops.

It will be noted that, while the previous sequence switch shown in Fig. 16 of Patent 2,214,029 required ten series of twenty contacts each for the accomplishment of multiplication, the present switch requires ten series of only eleven contacts, these contacts being numbered 29 in Fig. 10. Thus, it is seen that the present switch is a decided improvement over the old one. Also, the old switch had to be stepped to each of its twenty multiplication contact positions, whereas the present switch has only eleven contact positions and, therefore, needs to be stepped only eleven times, or approximately half as much. This is made possible by the arrangement of the control contacts associated with brushes 30A and 30B, see Fig. 10, and the two commutator sectors 124 and 125 (Fig. 9).

While I have described what I consider to be a highly desirable embodiment of my invention, it is obvious that many changes in form could be made without departing from the spirit of my invention, and I, therefore, do not limit myself to the exact form herein shown and described, nor to anything less than the whole of my invention as hereinbefore set forth, and as hereinafter claimed.

What I claim as new, and desire to secure by Letters Patent, is:

1. In a sequence switch, the combination of a drum comprising a series of longitudinal rods having contact blades mounted thereon in longitudinal rows and circumferential tiers, said blades being electrically connected in a plurality of spiral series by a set of brushes, one for each of said circumferential tiers of contact blades; a second set of contact blades arranged in two tiers certain of the blades of one tier being electrically connected diagonally in pairs with blades of the other tier; brushes cooperating with said two tiers of blades; a commutator means to switch alternatively from one of said second set of tiers to the other set; means for conducting current from each of said pairs of blades; means for conducting current from each of the first mentioned spiral series of blades; and means controlled in part by said second series of blades and brushes for rotating said drum and blades from one contact point to another.

2. In a sequence switch, the combination of a rotatable cylindrical mounting containing contact blades on the surface thereof, said blades arranged in longitudinal rows and circumferential tiers and electrically connected in a plurality of spiral series; a set of brushes, one for each of said tiers of contact blades; a second set of contact blades also on said cylindrical mounting arranged in two tiers, certain of the blades of one

tier electrically connected diagonally in pairs with the blades of the other tier; brushes cooperating with said two tiers of blades; means controlled in part by said second tier of blades and brushes for rotating said drum and blades from one contact position to another; and commutator means to switch alternatively from one of said second set of tiers to the other set.

3. In a sequence switch, the combination of a rotatable cylindrical mounting containing contact blades on the surface thereof, said blades arranged in longitudinal rows and circumferential tiers and electrically connected in a plurality of spiral series; a set of brushes, one for each of said tiers of contact blades; a second set of contact blades also on said cylindrical mounting arranged in two tiers; certain of the blades of one tier electrically connected diagonally in pairs with the blades of the other tier; brushes cooperating with said two tiers of blades; means controlled in part by said second series of blades and brushes for rotating said drum and blades from one contact position to another; and commutator means to operatively switch alternatively from one of said second set of tiers to the other set while the drum is stationary.

4. In a sequence switch, the combination of a rotatable cylindrical mounting containing a plurality of contact blades arranged on the surface thereof in circumferential tiers; a series of brushes, one brush for each tier; the blades electrically connected diagonally with electric circuits, the contact blades of the several rows being brought step-by-step into contact with their respective brushes, and a commutator device acting to complete two electric circuits alternatively through each brush and its engaged contact blade while, in the course of the step-by-step movement referred to, said blades are held immovable in contact with said respective brushes.

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