

March 10, 1959

W. KEISTER

2,877,019

AUTOMATIC GAME-PLAYING MACHINE

Filed Nov. 30, 1950

7 Sheets-Sheet 1

FIG. 1

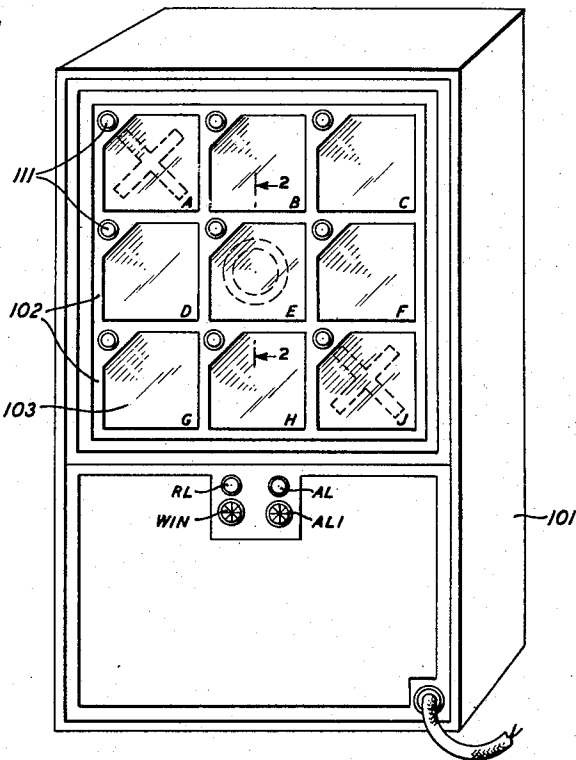


FIG. 2

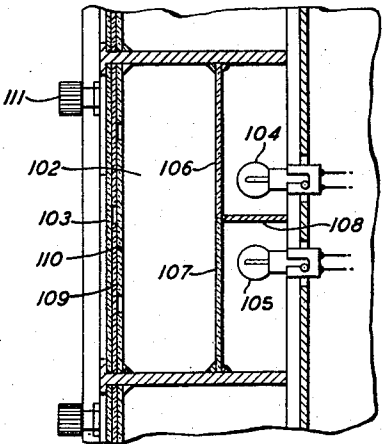


FIG. 9

FIG. 3	FIG. 4	FIG. 5
FIG. 6	FIG. 7	FIG. 8

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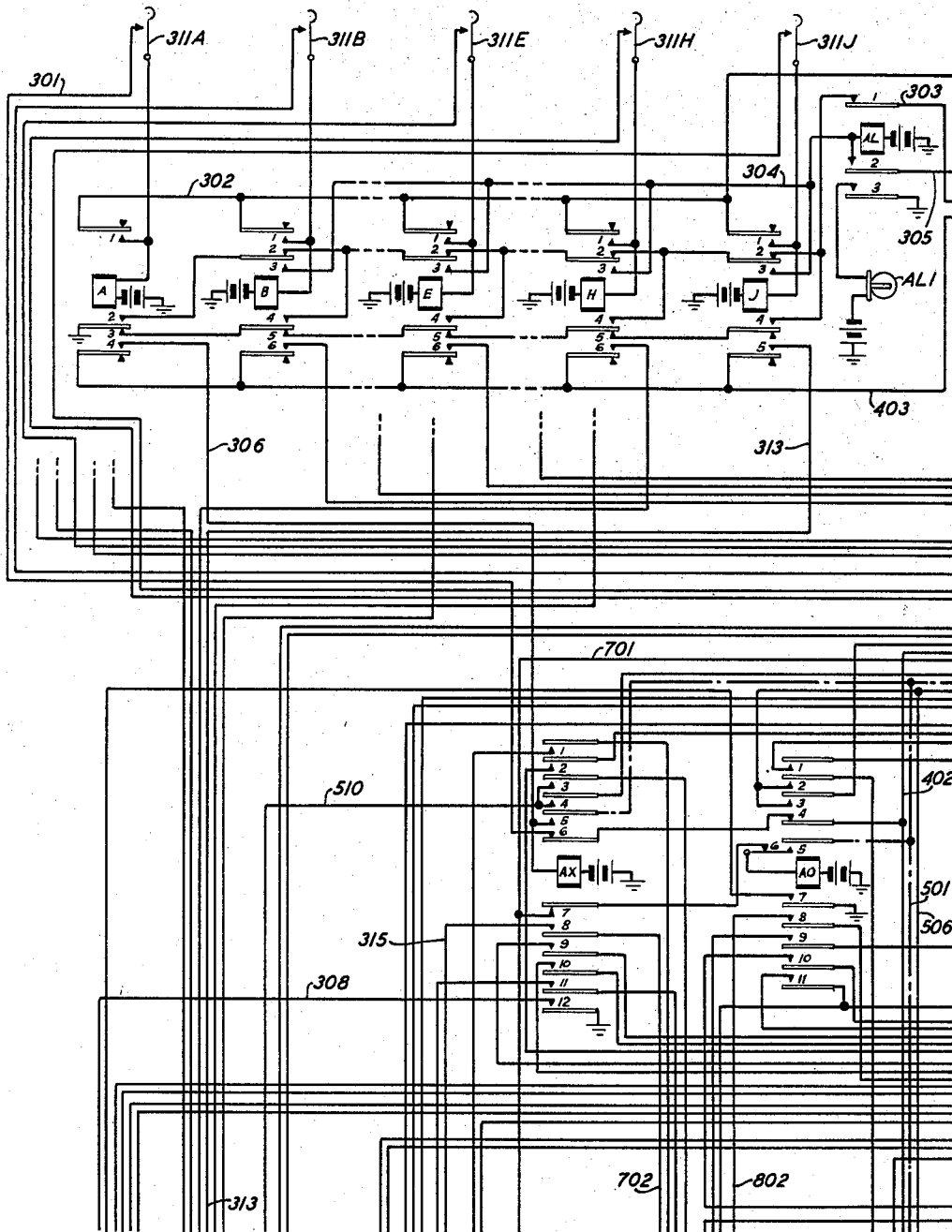
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FIG. 3

LOCK OUT CIRCUIT



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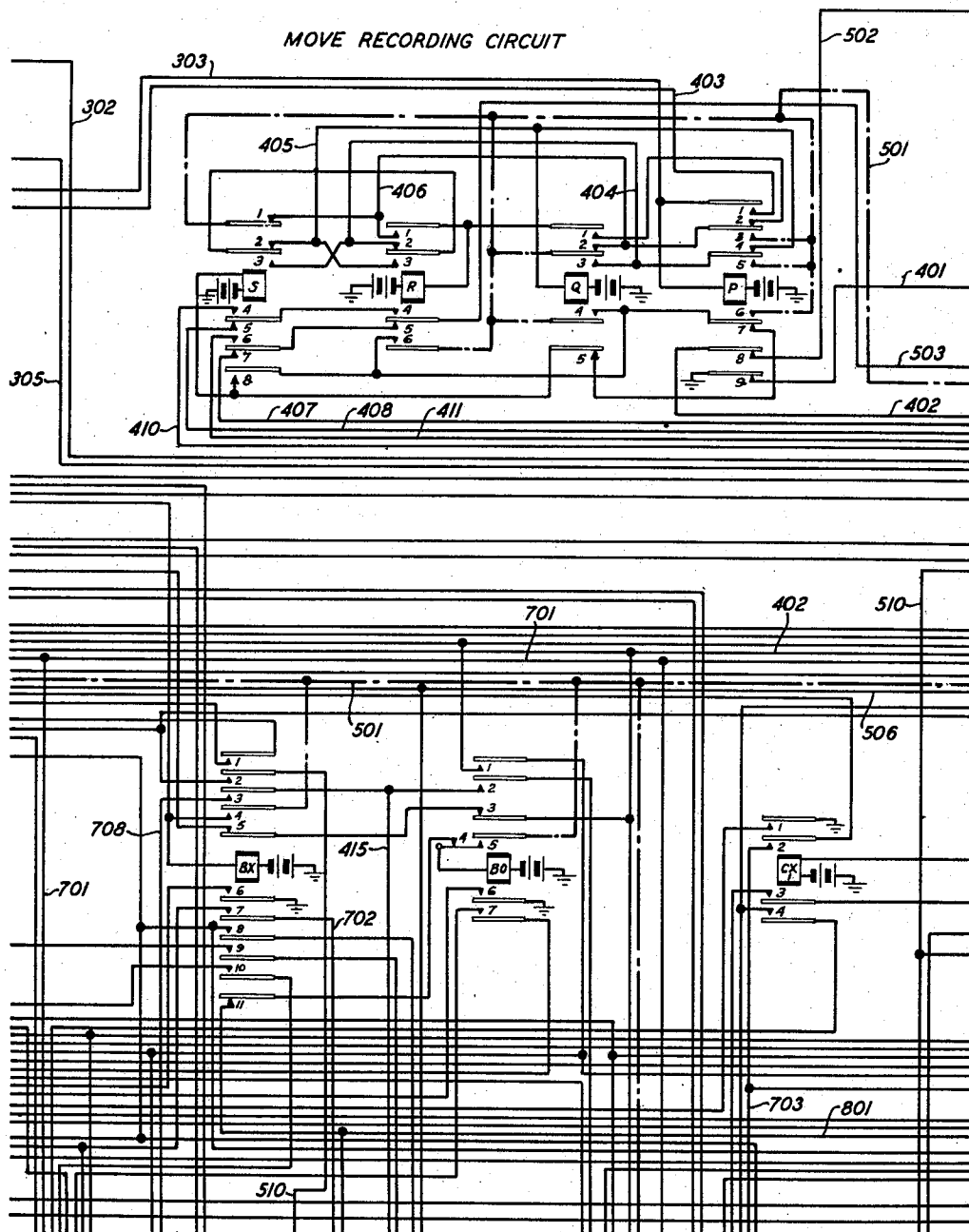
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FIG. 4



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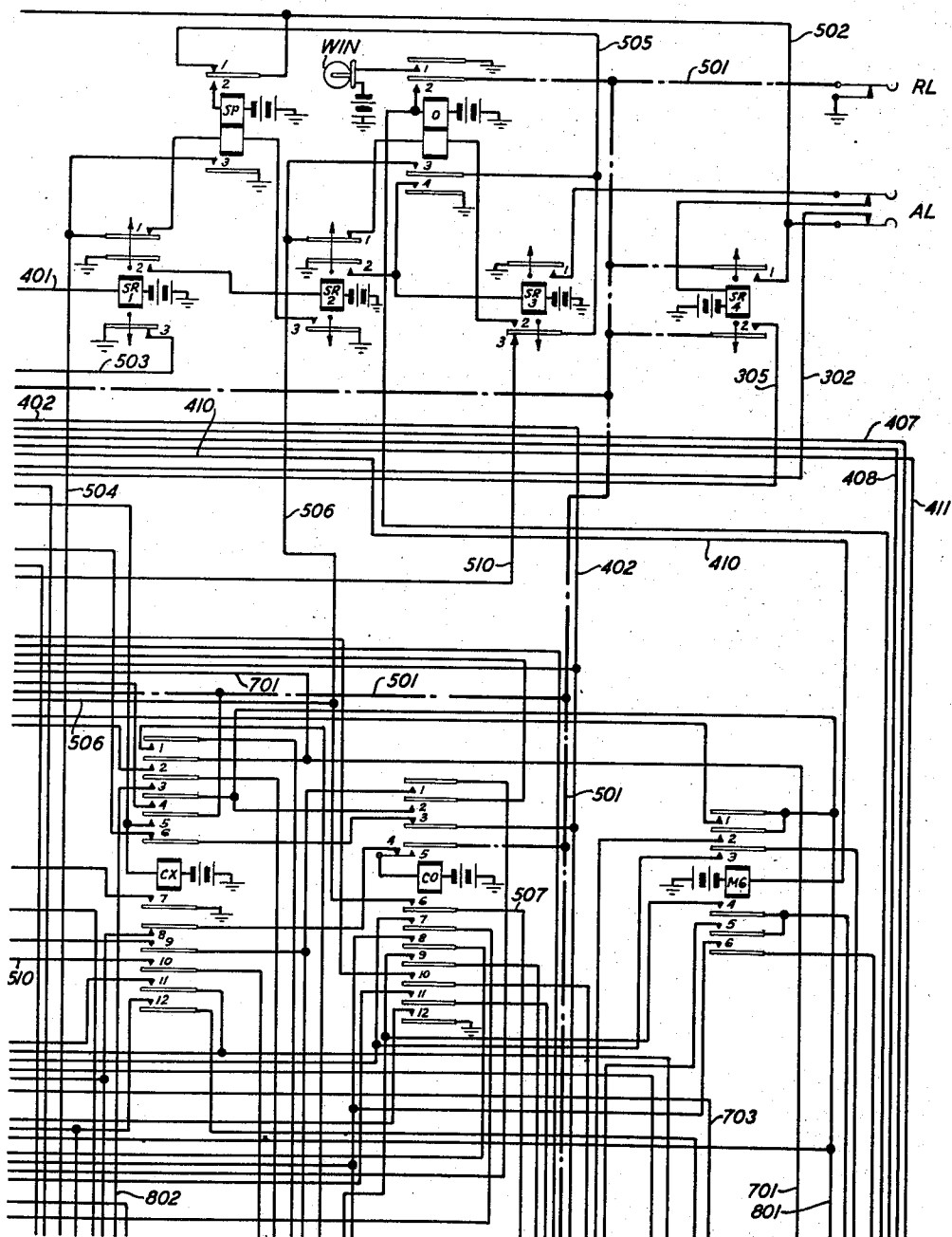
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SEQUENCE CIRCUIT

FIG. 5



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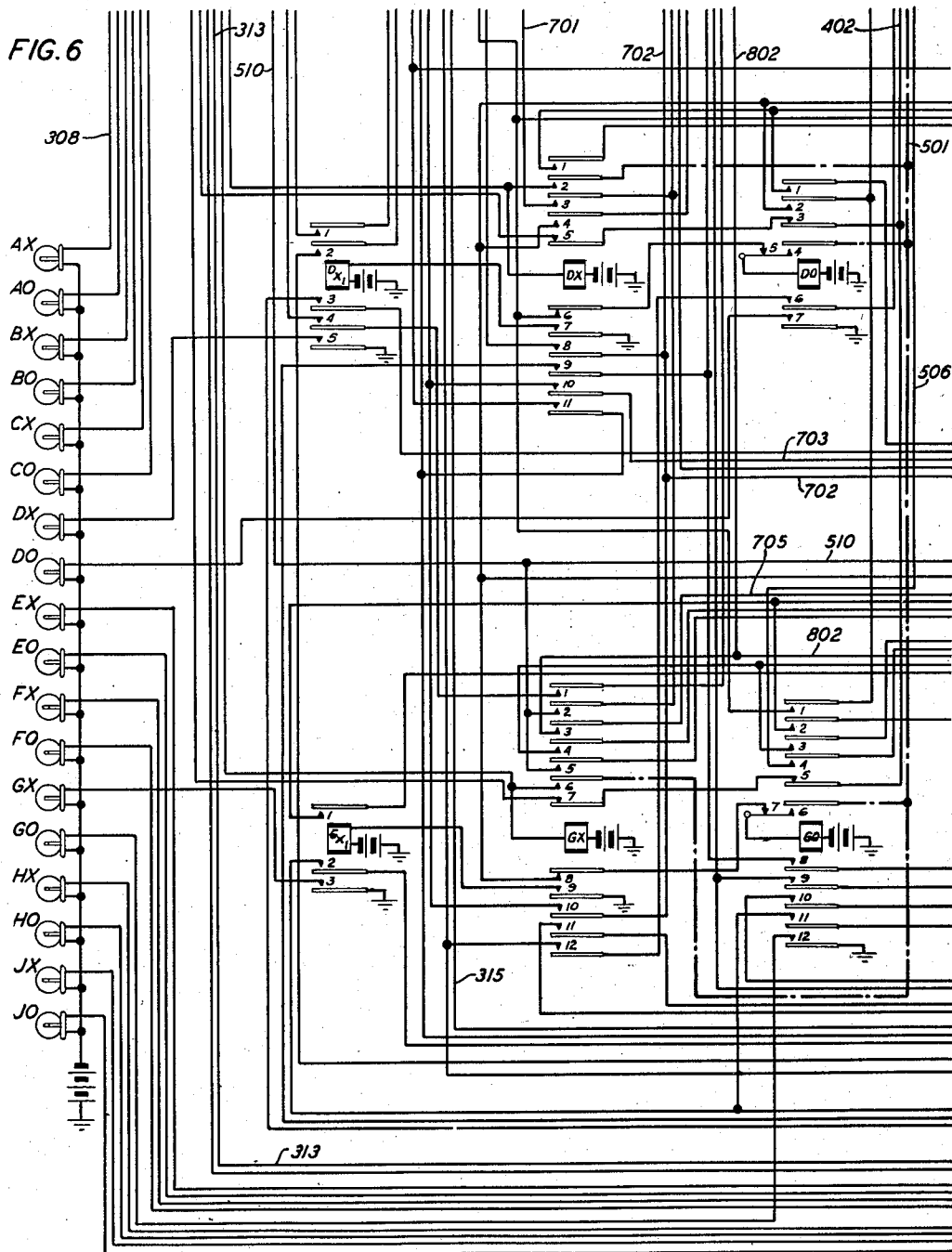
2,877,019

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FIG. 6



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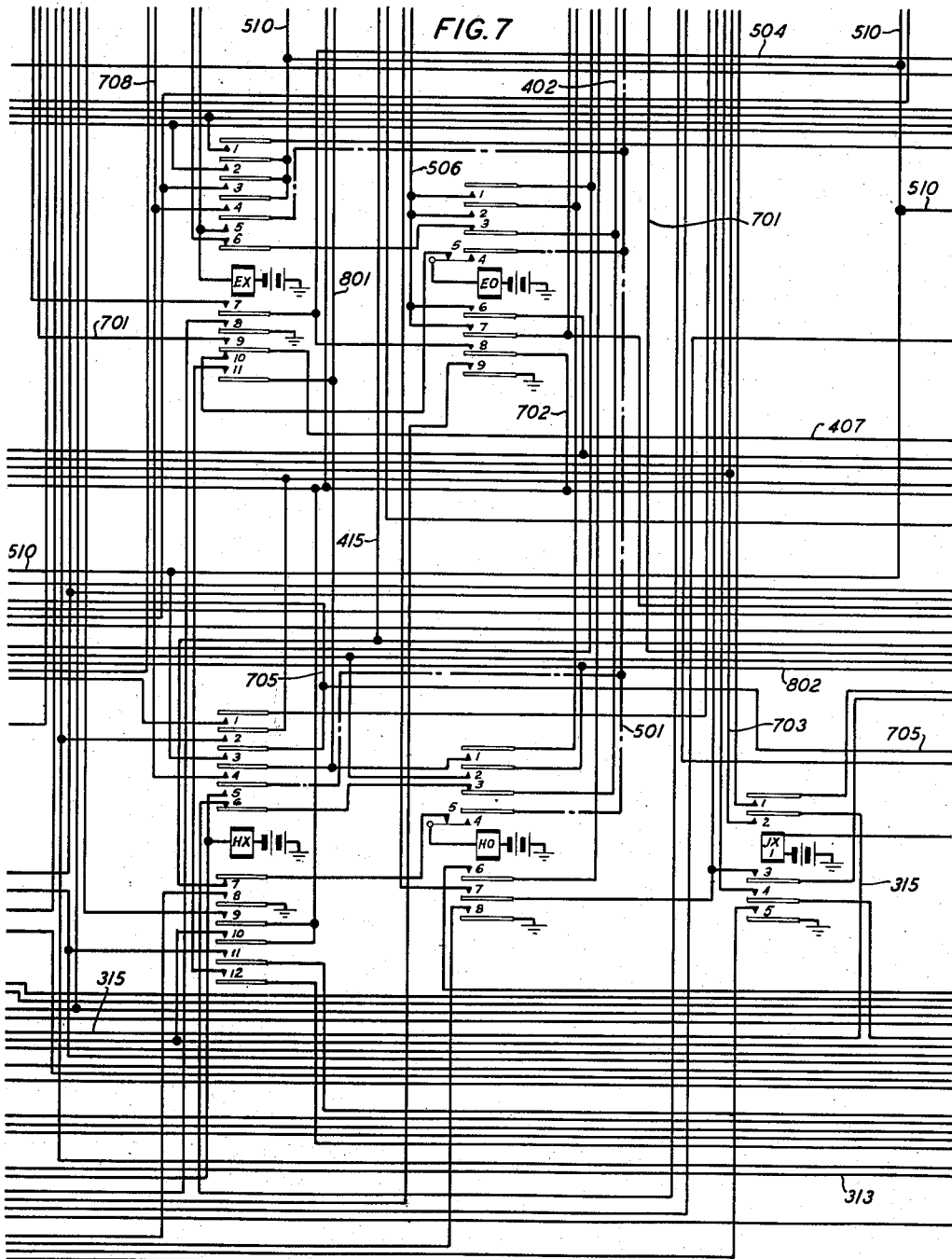
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Filed Nov. 30, 1950

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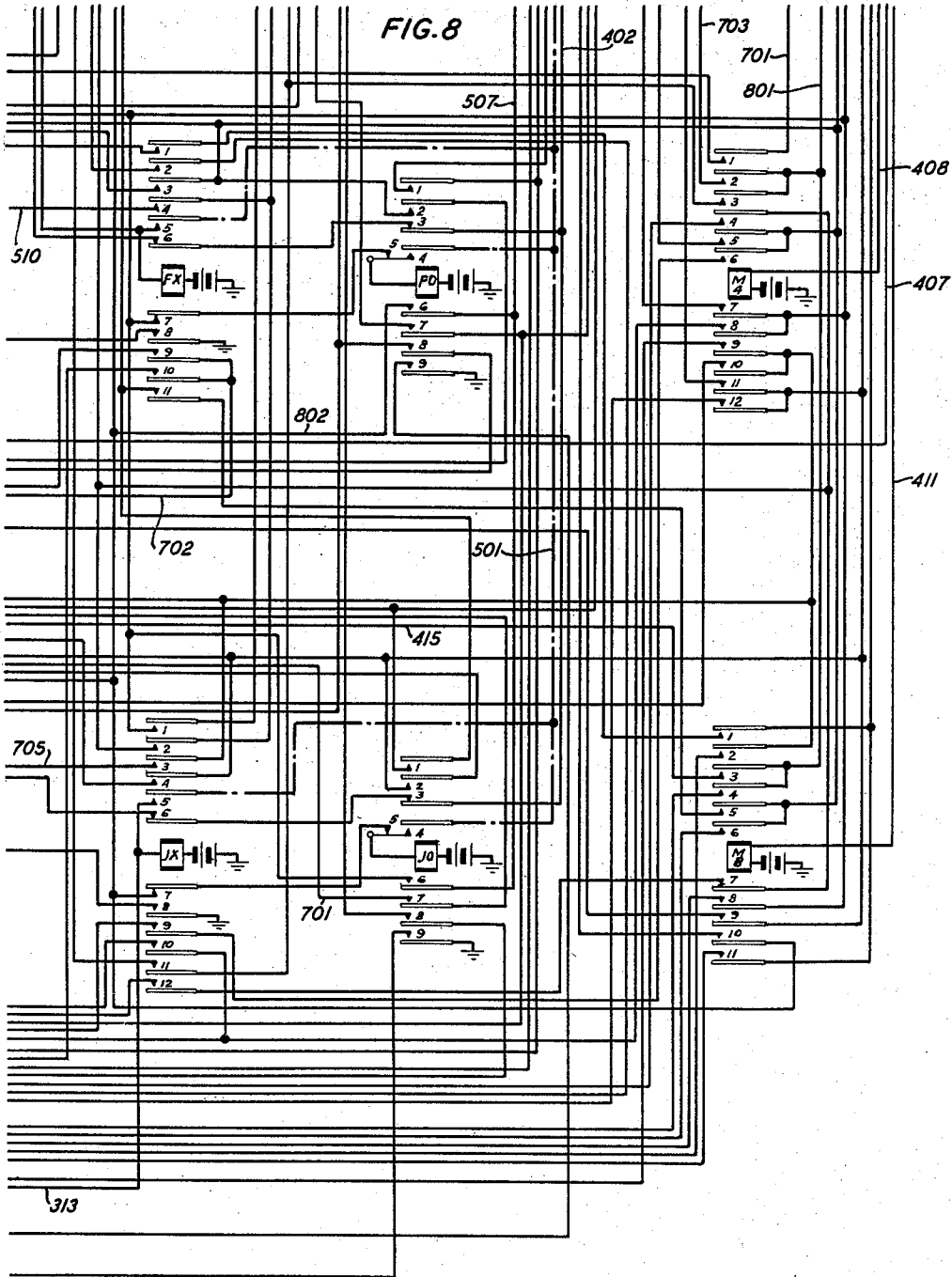
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Filed Nov. 30, 1950

7 Sheets-Sheet 7



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AUTOMATIC GAME-PLAYING MACHINE

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Application November 30, 1950, Serial No. 198,277

8 Claims. (Cl. 273—130)

This invention relates to electrical apparatus and more particularly to a machine for playing a game.

An object of this invention is to perform automatically the functions of one of the two players in the game variously known as "Tick-Tack-Toe," "Tit-Tat-Toe," "Tick-Tack-Too," "Tit-Tat-Too," "Three-in-a-Row" or "Noughts and Crosses."

A feature of this invention is a multicell display board with means for displaying both the player's and the machine's selections.

Another feature of this invention is a pair of electro-mechanical devices, such as relays, individual to each of a plurality of display board cells.

Another feature of this invention is manually operable switch means individual to each of one of the relays in each cell.

Another feature of this invention is means for preventing the player from making two simultaneous moves or selections.

A further feature of this invention is means operative after a player has made a selection for preventing any further effective selection by the player until the machine has made a selection.

Another feature of this invention is means for preventing either the player or the machine from selecting a cell that has previously been occupied.

A further feature of this invention is means comprising networks of the cell-relay contacts for continuously indicating the condition of diverse combinations of the cell relays.

Another feature of this invention is means for counting the moves made by the player.

A further feature of this invention is means for selecting those of the cell-relay contact networks which should be tested at any given stage of the game.

A further feature of this invention is means for testing the cell-relay contact networks to ascertain if a "winning" play exists and for making the appropriate move if such a play is indicated.

Another feature of this invention is means for testing the cell-relay contact networks to ascertain if a "defensive" play exists and for making the appropriate move if such a play is indicated.

Another feature of this invention is means for testing the cell relay contact networks to ascertain if any play other than a "winning" or a "defensive" play, i. e., a "singular" play, exists and for making the appropriate move if such a play is indicated.

Another feature of this invention is means for causing these tests successively to be performed in a preselected sequence.

Another feature of this invention is means to disable the machine to make further tests if an affirmative answer is received in response to any one of the tests.

A further feature of this invention is means for indicating that the machine has won the game and for preventing the making of any plays thereafter.

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A further feature of this invention is means for restoring the apparatus to normal.

An understanding of the manner in which the object of the invention is attained and a more complete understanding of the above-mentioned and other features of the invention may be obtained from the following discussion of the theory of operation of the apparatus and from the ensuing detailed description of a preferred embodiment of the invention, when read with reference to the accompanying drawings in which:

Fig. 1 shows a perspective view of the exterior of the preferred embodiment of the invention;

Fig. 2 is a section taken upon a plane indicated by the line 2—2 in Fig. 1 and shows the construction of one of the cells;

Figs. 3 to 8 are circuit diagrams representing the construction of the preferred embodiment of the invention; and

Fig. 9 is a diagram showing the proper arrangement of Figs. 3 to 8.

GENERAL DESCRIPTION

In general, the game variously called "Tick-Tack-Toe," "Tit-Tat-Toe," "Tick-Tack-Too," "Tit-Tat-Too," "Three-in-a-Row" or "Noughts and Crosses" is one in which two players alternate in marking crosses and cyphers, respectively, in the nine spaces of a figure formed by two pairs of crossed parallel lines, each player striving to fill three spaces in a row (column, row or diagonal) with his mark. The apparatus constructed in accordance with the principles of this invention performs the functions normally accomplished by one of the two players. The player is allowed the first play and his selection is displayed. The machine then responds to make a selection, and its selection is also displayed. The player and the machine then proceed alternately to make their selections until one or the other wins or until a "draw" game has been reached. The circuits may be and preferably are arranged so that the machine always wins or draws. The circuits may also be arranged so that if the opponent accidentally or deliberately operates two or more keys at once the play will not be recorded and an alarm bell or lamp will be operated. A key is provided to release the alarm and play may then be resumed. A master release key is provided which will restore the machine to normal at any time.

Let it be assumed that the player or opponent uses the mark or designation "X" and the machine uses the designation "O," and let it be assumed, for simplicity of theory and circuitry, that the player always plays first. In determining what play the machine should properly make at any stage of the game, the status of the game must be analyzed at that time. In some cases the proper play can be selected without considering all occupied cells. When two cells of a "row" (which shall herein be deemed generic to "row," "column" or "diagonal") are occupied by the player's X's and the third cell is empty, a "defensive" play is made by placing an O in the empty cell. When two cells in a row are occupied by the machine's O's and the third cell is empty, a "winning" play is made by placing an O in the empty cell. With these as controlling principles, the following decisions must be made at any given stage of the game:

(1) Choice of play when there are no winning or defensive plays,

(2) Choice between a winning and a defensive play,

(3) Choice between two defensive plays.

In the decision of type (2), the obvious choice for the machine is the winning play. In the decision of type (3), the game is lost and this situation will never occur if the decision of type (1) is always made properly. Plays involving a decision of type (1) will herein be

called "singular" plays since several alternatives of play are presented at this stage in the game.

The general scheme of operation for a machine may be predicated upon this analysis. The equipment is arranged to recognize and play all "singular," "winning" and "defensive" plays. When the machine's turn to play arrives, the machine may function in up to three stages of operation. The machine first tests for a singular play. If there is no singular play the machine next tests for a winning play and if there is no winning play it proceeds to test for a defensive play. When any play is made the remaining tests are not performed. It will be seen that as a result of this sequential operation, a winning play is given preference over a defensive play.

DETAILED DESCRIPTION

In the drawings, the several circuit elements will either be designated by a three-digit number having its hundreds digit corresponding to the figure number, or will be identified by a functional designation followed by the number of the figure in parentheses, viz., the relay bearing the letter "A" in the upper left-hand portion of Fig. 3 will hereinafter be referred to as relay "A(3)."

Referring to Figs. 1 and 2 of the drawings, the face of the case 101 is provided with nine "cells" 102 in a coordinate array. Each cell comprises a face portion 103 of translucent material and two lamps 104 and 105. In proximity to each of the lamps is a sheet of light polarizing material 106 and 107. A suitable partition 108 is provided so that the light from either lamp 104 or 105 will only be transmitted through its associated polarizing medium. The two polarizing screens 106 and 107 are positioned ninety degrees out of orientation one with the other, e. g., screen 106 may be oriented to pass only the vertical component of the rays emanating from lamp 104 while screen 107 may be oriented to pass only the horizontal component of the rays emanating from lamp 105.

Two more sheets of polarizing material 109 and 110 and the translucent face portion 103 are juxtaposed. One of these sheets, such as 109, is oriented in the same direction as sheet 106 and the other sheet 110 is oriented in the same direction as sheet 107. A portion of the material of sheet 109 is excised to form an "X" and a portion of the material of sheet 110 is excised to form an "O." When, therefore, lamp 105 is lit, the horizontally polarized rays therefrom will be unaffected by horizontally oriented sheet 110 but will be blocked by vertically oriented sheet 109. Since an "X" has been excised in sheet 109, however, an "X" will appear on the face 103 of the cell 102. Conversely, if lamp 104 is lit, an "O" will appear on the face of the cell.

Certain control switches and indicating lamps appear on the exterior of the case 101. A key or button 111 is placed adjacent each cell and the player may select any unoccupied cell by depressing the one of the switches 111 associated therewith. Indicator lamp WIN(1) is arranged to light when the machine wins the game and indicator lamp AL1(1) is arranged to light if two of the switches 111 are operated simultaneously. Key or switch RL(1) may be depressed to clear the machine if there is no "win" and key or switch AL(1) may be depressed in conjunction with switch RL(1) to clear the machine at the end of the game if there be a "win." If lamp AL1(1) lights indicating an improper play by the opponent, that play may be canceled and lamp AL1(1) extinguished by depressing switch AL(1), after which play may be resumed.

Referring now to the circuit diagrams of Figs. 3 to 8, when power is applied to the system, relay SR1(5) operates over a path from ground, No. 9 contact of relay P(4), conductor 401, winding of relay SR1(5) to battery. Relay SR1(5), in operating, connects ground through its No. 2 contact to operate relay SR2(5); relay SR2(5), in operating, connects ground through its

No. 2 contact to operate relay SR3(5); and relay SR3(5), in operating, connects ground through its No. 1 contact, upper contact of key AL(5), winding of relay SR4(5) and to battery whereby relay SR4(5) is operated.

The player's keys, buttons, or switches, identified by the designation 111 in Figs. 1 and 2, are shown in Fig. 3 as switches 311A to 311J. At the beginning of the game with all equipment in its normal condition, the player makes the first play whereby an "X" is placed in the one of the nine squares A to J (Fig. 1) which the player selects. He makes his selection by operating one of the nine keys 311A to 311J. Let it be assumed that the player desires to place his first "X" in the upper left-hand or "A" square (Fig. 1) and therefore that he depresses key 311A. A circuit is thereby completed from battery, winding of relay A(3), operated key 311A, conductor 301, No. 6 contact of unoperated relay AX(3), No. 4 contact of unoperated relay AO(3), conductor 402, No. 8 contact of relay P(4), conductor 502, No. 1 contact of operated relay SR4(5), conductor 501 (represented by a dot-dash line) and to ground through the contact of switch RL(5). Relay A(3) is therefore operated over a circuit which includes back contacts of both the player's or "X" relay AX(3) and the machine's or "O" relay AO(3) individual to that square A(1) which the player has selected. As will hereinafter be seen, if the player had already selected this square, relay AX(3) would have been operated and if the machine had previously selected that square, relay AO(3) would have been operated. In either case, the above-traced operating circuit for relay A(3) would not have existed and the player therefore could not have selected square A(1). It will be noted that corresponding operating paths are provided for each of the other relays B(3) to J(3) including the contacts of the associated keys 311B to 311J, back contacts of the two associated cell relays BX(4) and BO(4) to JX(8) and JO(8), conductor 402, No. 8 contact of relay P(4), conductor 502, No. 1 contact of relay SR4(5), to ground on conductor 501. Since each of these operating paths includes a back contact of relay P(4) and since relay P(4) is operated both throughout the time that the circuits are responding to the player's selection and throughout the time that the circuits are operating to make and record the machine's selection, as will be described hereinafter, no additional relays A(3) to J(3) may be operated during those periods. The player is thereby prevented from taking two non-simultaneous moves and is also prevented from interfering with the operation of the machine while it is performing the operations incident to the selection and recordation of its move. The means for preventing the player from effectively making two moves simultaneously will be described hereinafter.

Relay A(3) locks operated through its No. 1 contact, conductor 302, lower contact of switch AL(5), No. 1 contact of relay SR4(5) and to ground on conductor 501. It may be noted that the other relays B(3) to J(3) are provided with similar locking paths. Relay A(3), in operating, connects ground through its No. 2 contact and through the No. 2 back contacts of all of the other relays B(3) to J(3), No. 1 contact of alarm relay AL(3), conductor 303, winding of relay P(4) and to battery whereby relay P(4) is operated. It will be noted that relay P(4) will also be operated if any other one of the relays A(3) to J(3) is operated, in a similar fashion.

If any two of the relays A(3) to J(3) are operated simultaneously, ground will be connected through contacts of the two operated relays to operate alarm relay AL(3). For example, if the player operates relays A(3) and B(3) simultaneously, ground will be connected through the No. 2 contact of relay A(3), No. 3 contact of relay B(3), conductor 304, winding of relay AL(3) and to battery. Relay AL(3), in operating, disconnects, at its No. 1 contact, conductor 303 from the

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contacts of relays A(3) to J(3) to prevent the operation of relay P(4) and also closes a circuit through its No. 3 contact to light lamp AL1(3). Relay AL(3) locks operated through its No. 2 contact, conductor 305, No. 2 contact of relay SR4(5) and to ground on conductor 501. Since the energizing circuit for relay SR4(5) includes a contact of switch AL(5), the alarm condition can be corrected by operating switch AL(5). The operation of switch AL(5) removes locking ground from conductor 302 so that all of the relays A(3) to J(3) which are operated will be released. The operation of switch AL(5) also disrupts the energizing circuit for relay SR4(5), but that relay is slow to release to ensure that all of the relays A(3) to J(3) will have had time to release. The release of relay SR4(5) releases relay AL(3) to extinguish lamp AL1(3). When key AL(5) is released, relay SR4(5) will reoperate.

Assuming that only relay A(3) has been operated and that relay P(4) in the move recording circuit of Fig. 4 has operated in response thereto as above described, the ground on conductor 303 will be extended through No. 1 contact of operated relay P(4), conductor 403 which is multiplied to a front contact of each of the relays A(3) to J(3), through the No. 4 contact of operated relay A(3), conductor 306, winding of relay AX(3) and to battery whereby relay AX(3) is operated. In a similar manner, had any other one of the relays B(3) to J(3) been operated, the ground on conductor 403 would have been extended through a front contact of the operated one of the relays to the winding of the "X" relay BX(4) to JX(8) individual thereto and individual to the selected cell.

Relay AX(3) locks operated through its No. 5 contact to ground on conductor 501. Relay AX(3), in operating, interrupts, at its No. 6 contact, the previously traced operating path for relay A(3) to prevent subsequent selection of the "A" cell by the player, and interrupts, at its No. 7 contact, the energizing path for relay AO(3) to prevent the machine from subsequently selecting the "A" cell which is already occupied by an "X."

Relay AX(3), in operating, also connects ground through its No. 12 contact, conductor 308, lamp AX(6) to battery. Lamp AX(6), which is the equivalent of lamp 105 in Fig. 2, is thereby lit to place an "X" in the upper left-hand or "A" cell (Fig. 1). It will be noted that had the machine selected this cell whereby relay AO(3) would have been operated as will be described hereinafter, lamp AO(6) would have been lit to project an "O" on the face of the selected cell. Similarly, had any other "X" relay BX(4) to JX(8) been operated, the corresponding lamp BX(6) to JX(6) would have been lit, and when the machine functions to operate any of the other "O" relays BO(4) to JO(8), the corresponding lamps BO(6) to JO(6) will be lit.

Relay AX(3), in operating, also performs certain other operations comprising the controlling of certain networks which determine the operation of the machine as will be seen hereinafter.

Relay P(4) operates at each proper play by the opponent, in the manner above described, and relays Q(4), R(4) and S(4) comprise a counting circuit operative to record the successive moves by counting the operations of relay P(4). Although only the first step of operation of this move recording circuit is presently of interest, the operation of the circuit in response to the successive operations of relay P(4) will be described in detail at this time. At the first operation of relay P(4), as above described, the ground on conductor 501 is extended through the No. 5 contact of relay P(4), conductor 404, No. 2 contacts of unoperated relays R(4) and S(4), conductor 405, winding of relay Q(4) and to battery whereby relay Q(4) is operated. At the first release of relay P(4), hereinafter to be described, the ground

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on conductor 501 is extended through the No. 1 contact of relay S(4), conductor 406, No. 2 contact of released relay P(4), No. 1 contact of operated relay Q(4), winding of relay R(4) and to battery whereby relay R(4) is operated. During the time required for relay P(4) to release and for relay R(4) to operate, relay Q(4) is held operated over a circuit from ground on conductor 501, No. 3 contact of relay Q(4), conductor 404, No. 2 contacts of unoperated relays R(4) and S(4), conductor 405 and to battery through the winding of relay Q(4). When relay R(4) becomes operated, the locking path for relay Q(4) comprises the No. 4 contact of released relay P(4) and the No. 3 contact of relay Q(4). On the second operation of relay P(4), the locking path for relay Q(4) is disrupted and relay Q(4) releases. Relay R(4), however, is held operated over a circuit including the No. 1 contacts of relays S(4) and R(4). The above sequence of operations and the subsequent operations of the counting circuits in response to the successive operations of relay P(4) are shown in the following table in which the figure designation of the several relays has been omitted. The path over which each of the relays is operated or held operated is shown under the heading "Circuit" with a relay designation such as "P" connoting that the circuit includes a front or "make" contact of that relay, and with a relay designation such as "P'" connoting that the circuit includes a back or "break" contact of that relay.

Table 1

Action of Relay P	Result	Circuit
First operation.....	Q operates..... R operates.....	$P+R'+S'$ $S'+P'+Q$
First release.....	Q held operated..... Q releases.....	$\{(1) Q+R'+S'$ $\quad (2) P'+Q$
Second operation.....	R held operated..... S operates.....	$R+S'$ $R'+P'+Q'$
Second release.....	R held operated..... Q operates.....	$Q'+R$ $P+S+R$
Third operation.....	Q held operated..... S held operated..... R releases.....	$\{(1) Q'+R$ $\quad (2) P+R$ $R+S$
Third release.....	Q held operated..... S held operated..... Q releases.....	$\{(1) Q+S+R$ $\quad (2) Q+P'$ $Q+S$
Fourth operation.....	S held operated.....	$\{(1) Q+S$ $\quad (2) P+S$
Fourth release.....	S releases.....	

Relay P(4), in operating, removes ground from conductor 401 to release slow-to-release relay SR1(5). Relay SR1(5), in releasing, connects the winding of "singular play" relay SP(5) through to networks of contacts of the cell relays AX(3)-AO(3) to JX(8)-JO(8), but since there can be no "singular" plays with only one move having been made by the player, the performance of this function by relay SR1(5) is of no utility at this time.

For convenience of circuitry and as predicated on an analysis of the game, the machine operates always to take the center or "E" cell on its first move unless the player has selected that square on his first move, in which event the machine always takes, as an exemplary arrangement, the upper left-hand or "A" cell. Thus, in this case, relay SR1(5), in releasing, connects ground through its No. 3 contact, conductor 503, No. 5 contact of unoperated relay R(4), No. 7 contact of unoperated relay S(4), conductor 407, No. 10 contact of unoperated relay EX(7), No. 5 contact and winding of relay EO(7) and to battery whereby relay EO(7) is operated and lamp EO(6) is lit to place an "O" in the selected square. Relay EO(7) locks operated through its No. 4 contact to ground on conductor 501. It will be noted that had the player selected the middle or "E" cell on his first play, relay EX(7) would have been operated and the above-traced energizing circuit for relay EO(7) would not have existed by virtue of the No. 10 contact of relay EX(7) being

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open. However, in that situation, the ground on conductor 407 would have been extended through the No. 9 contact of operated relay EX(7) to conductor 701, No. 7 contact of relay AX(3) and through the No. 6 contact and winding of relay AO(3) to battery whereby the upper left-hand or "A" cell would have been selected in response to the player's selection of the center or "E" cell.

Relay SR1(5), in releasing, releases relay SR2(5) which releases relay SR3(5). The release of relays SR2(5) and SR3(5) causes the circuits to test successively for "winning" and "defensive" plays, but inasmuch as such plays cannot possibly exist at this time, the functioning of the circuit to perform these tests will be described hereinafter.

After the release of SR3(5), relay SR4(5) releases and removes the ground from conductor 302 to release relay A(3). Relay A(3) in releasing, interrupts, at its No. 2 contact, the energizing circuit for relay P(4) whereby relay P(4) releases. Since this is the first release of relay P(4) relay Q(4) is held operated and relay R(4) is operated as hereinbefore described. Relay P(4), in releasing, also recloses ground through its No. 9 contact to conductor 401 to cause the sequential reoperation of relays SR1(5), SR2(5), SR3(5) and SR4(5). Relay SR4(5), in reoperating, again connects the ground on conductor 501 through its No. 1 contact to conductor 502, No. 8 contact of released relay P(4) to conductor 402 whereby that ground is applied through back contacts of the unoperated ones of the cell relays AX(3)-AO(3) to JX(8)-JO(8) to the respective keys 311A to 311J. The apparatus is now in condition for the next move by the player (the third play of the game). Since relays AX(3) and EO(7) are operated, the keys 311A and 311E are not supplied with ground so relays A(3) and E(3) cannot now be operated, which is proper since the "A" and "E" cells are already occupied.

The player may now make his second play by operating one of the switches 311B, 311C, 311D, 311F, 311G, 311H or 311I. Let it be assumed that he operates key 311J whereby relay J(3) is operated and locked operated. Relay J(3), in operating, connects the ground on conductor 403 through its No. 5 contact to conductor 313, winding of relay JX(8) and to battery. Relay JX(8) operates and locks operated through its No. 5 contact to ground on conductor 501. Relay JX(8), in operating, lights lamp JX(6), operates relay JX1(7) (which is provided to supplement the contacts of relay JX(8)), and performs certain other network-completing operations as will be seen hereinafter.

Relay P(4) is reoperated in the manner hereinbefore described and this reoperation is recorded by the release of relay Q(4), as above discussed. Relay P(4), in operating, releases relay SR1(5). Relay SR1(5), in releasing, connects ground through its No. 3 contact to conductor 503, No. 4 contact of operated relay R(4), No. 5 contact of unoperated relay S(4), conductor 408, winding of relay M4(8) and to battery whereby relay M4(8) is operated for a purpose hereinafter to be described.

At this stage of the machine's operation the condition of the cell-relay contact networks is tested to ascertain whether a "singular" play, a "winning" play or a "defensive" play should be made.

SINGULAR PLAY

Relay SR1(5), in releasing, completes a circuit from ground, No. 3 contact of relay SR2(5) (which is still operated due to its slow-to-release characteristics), lower (high resistance) winding of "singular play" relay SP(5), No. 1 contact of relay SR1(5) and conductor 504 which extends to front contacts of relays EX(7) and EO(7). Since relay EO(7) is operated, this ground will be extended through the No. 8 contact thereof to conductor 702 which extends (in addition to other paths terminating at open relay contacts) to the No. 8 contact of operated

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relay AX(3), conductor 315, No. 2 contact of operated relay JX1(7), conductor 703, No. 2 contact of operated relay M4(8), conductor 801, No. 11 contact of unoperated relay BX(4), and through the No. 4 contact and winding of relay BO(4) to battery.

It will be seen that the machine has tested for a "singular" play, has ascertained that the player has selected cells "A" and "J" since relays AX(3), JX(8) and JX1(7) are operated, and has ascertained that the machine has occupied cell "E" since relay EO(7) is operated. It is apparent that a "singular" play is required. The machine has therefore prepared an operating circuit for relay BO(4) to select the "B" cell for its next move.

Since the above-traced energizing circuit for relay BO(4) includes the high resistance winding of relay SP(5), insufficient current will flow in the circuit to operate relay BO(4), but relay SP(5) is adjusted to operate under these conditions. Relay SP(5) locks operated from battery, upper winding and No. 2 contact of relay SP(5), conductor 502, No. 1 contact of relay SR4(5) and to ground on conductor 501. Relay SP(5), in operating, effectively shunts its lower, high resistance winding by applying ground through its No. 3 contact to conductor 504, whereby relay BO(4) is operated. Relay BO(4) locks operated to the ground on conductor 501 through its No. 5 contact and lights lamp BO(6).

Although the above-described "singular play" test and circuit functioning are representative of what occurs under any other unique one of the permutations of operation of the several "cell" relays, the principles involved may be considered in order to assist in an understanding of the arrangement of the contact "networks," and the reason for the provision of the move recording circuit comprising relays S(4), R(4), Q(4) and P(4) and of the "move" relays M4(8), M6(5) and M8(8).

In ascertaining whether a "singular" play is required, a separate circuit may be provided for each possible condition. Thus, for example, to ascertain the above-described condition wherein relays AX(3), EO(7) and JX(8) are operated (assuming for purposes of convenience that relays JX(8) and JX1(7) are but one relay) and wherein no other ones of the "cell" relays are operated, an individual circuit could be provided to extend through front contacts of those three relays and through back contacts of all of the other cell relays. Additionally, if the apparatus is to take affirmative action in response to the existence of the aforesaid condition, the circuit should also include the winding of the machine's relay individual to the appropriate "cell," e. g., the winding of relay BO(4). This circuit may be represented in symbolic form using a system of notation in which the unmodified relay designation in capital letters connotes a front or "make" contact of that relay, in which a relay designation in capital letters followed by an apostrophe connotes a back or "break" contact of that relay, and in which the unmodified relay designation in lower case letters connotes the winding of that relay:

$$AX+EO+JX+BX'+BO'+CX'+CO'+DX'+DO'+FX'+FO'+GX'+GO'+bo$$

It is evident, however, that such an arrangement for each of the possible "singular plays" would be inordinately extensive and complicated. Analysis demonstrates that the possible combinations may be classified according to the stage of the game in which they occur. Thus, if only three plays have been made and it is ascertained that relays AX(3), EO(7) and JX(8) are operated, it is certain that no other cell relay is operated. The first move by the machine (the second "play") is determined as above described. The following table lists the possible combinations of operated relays prior to the fourth, sixth and eighth "plays" (prior to the second, third and fourth moves, respectively, by the machine) and the relay which the machine should properly operate to select a cell in order to make a proper move.

Table II.—Positions requiring singular plays
FOURTH PLAY

(Three Relays Operated)			Fourth Relay
AO	EX	JX	go
AX	EO	FX	ho
AX	EO	HX	fo
BX	EO	JX	do
BX	EO	GX	fo
CX	EO	HX	do
CX	DX	EO	ho
EO	FX	GX	bo
DX	EO	JX	bo
AX	EO	JX	bo, fo, ho or do
CX	EO	GX	bo, fo, ho or do
BX	EO	HX	ao, co, go or jo
DX	EO	FX	ao, co, go or jo
BX	DX	EO	co or go
BX	EO	FX	ao or jo
EO	FX	HX	go or co
DX	EO	HX	eo or jo

SIXTH PLAY

(Five Relays Operated)					Sixth Relay
AO	BX	EX	HO	JX	do
AO	DX	EX	FO	JX	bo
AX	BO	CX	EO	HX	do or fo
BX	EO	GX	HO	JX	do or fo
AX	DO	EO	FX	GX	bo or ho
CX	DX	EO	FO	JX	bo or ho

EIGHTH PLAY

(Seven Relays Operated)							Eighth Relay
AX	BO	CX	DX	EO	GO	HX	fo or jo
AX	BO	CX	EO	FX	HX	JO	do or go
AO	BX	DX	EO	GX	HO	JX	fo or co
BX	CO	EO	FX	GX	HO	JX	do or ao
AO	BX	CX	DX	EO	FO	JX	ho or go
CX	DX	EO	FO	GO	HX	JX	bo or go
AX	BX	CO	DO	EO	FX	GX	ho or jo
AX	DO	EO	FX	GX	HX	JO	bo or co
AO	BX	EO	FX	GO	HX	JX	co or do
AO	CO	DX	EO	FX	GX	HX	jo or bo
AO	BX	DX	EX	FO	HO	JX	go
AO	BX	CO	EX	GX	HO	JX	do
AO	BX	CX	EX	FX	GO	HO	do
AO	CO	DX	EX	FO	GX	HX	bo
AO	CX	DX	EX	FO	GO	JX	bo

The circuits may be simplified by extending the testing networks only through contacts on those relays which will be operated at a given stage of the game. To do this, three additional relays are provided. Relay M4(8) controls the networks utilized on the fourth play (the second move by the machine); relay M6(5) controls the networks utilized on the sixth play (the third move by the machine); and relay M8(8) controls the networks utilized on the eighth play (the fourth move by the machine). The primary function of the move-recording circuit of Fig. 4 is to operate these "move" relays at the proper time. Thus, at the beginning of the operations incident to the machine making its second move, relay M4(8) is operated through a back contact of relay S(4), through a front contact of relay R(4) and through a back contact of relay SR1(5), as above described. When relay SR1(5) reoperates, as will hereinafter be described, relay M4(8) is released. At the next move by the player, relay P(4) is reoperated and, as is shown in Table I, supra, at this stage all three relays Q(4), R(4) and S(4) are operated. When relay SR1(5) releases, therefore, a circuit is completed from ground through the No. 3 contact of relay SR1(5), conductor 503, No. 4 contacts of operated relays R(4) and S(4), conductor 410, and through the winding of relay M6(5) to battery whereby relay M6(5) is operated. After the machine performs its tests, relay SR1(5) is reoperated whereby relay M6(5) is released. At the next or seventh play (the player's fourth move), relay P(4) is reoperated and only relay S(4) in the move-recording circuit continues to be operated as is shown in Table I. Therefore, upon the release

of relay SR1(5) ground is applied through the No. 3 contact of relay SR1(5), conductor 503, No. 5 contact of relay R(4), No. 6 contact of relay S(4), conductor 411 and through the winding of relay M8(8) to battery whereby relay M8(8) is operated.

The degree of simplification of the circuits resulting from the inclusion in the networks of the contacts of these "move" relays M4(8), M6(5) and M8(8) may be seen, for example, by considering the resulting modification of the circuit above represented in symbolic form for the ascertainment that relays AX(3), EO(7) and JX(8) and no other cell relays are operated. By including a contact on relay M4(8), the circuit need only include front contacts on the three operated relays, a front contact on relay M4(8) and the winding of the appropriate "cell" relay to cause the machine to make the proper move. Thus, utilizing the above described system of notation, the exemplary circuit would be represented:

$$AX+EO+JX+M4+bo$$

A consideration of the circuits of Figs. 3 to 8 will demonstrate that not only have each of the possible network circuits per "stage" of operation been arranged in the above fashion but that certain of the circuits have been partially combined to eliminate any unnecessary duplication. The possibilities of combining the networks may be ascertained by the method of solving simultaneous equations among the symbolic representations of Table II, supra. The following table represents the "singular play" networks used in the preferred embodiment of the invention, employing the presented system of notation:

Table III

35	$EO+HX+AX+M4+FX'+FO'+fo$
	$EO+HX+CX+M4+DX'+DO'+do$
	$EO+HX+CX+AX+BO+M6+DX'+DO'+do$
	$EO+HX+CX+AX+BO+JO+FX+M8+DX'+DO'+do$
	$EO+HX+CX+AX+BO+GO+DX+M8+FX'+FO'+fo$
	$EO+BX+GX+JX+HO+AO+FX+M8+DX'+DO'+do$
	$EO+BX+GX+JX+HO+CO+DX+M8+FX'+FO'+fo$
	$EO+BX+GX+JX+HO+M8+FX'+FO'+fo$
40	$EO+BX+GX+M4+FX'+FO'+fo$
	$EO+BX+JX+M4+DX'+DO'+do$
	$EO+BX+DX+M4+CX'+CO'+co$
	$EO+DX+CX+M4+HX'+HO'+ho$
	$EO+DX+JX+M4+BX'+BO'+bo$
	$EO+DX+JX+CX+FO+M8+BX'+BO'+bo$
	$EO+DX+JX+CX+FO+GO+HX+M8+BX'+BO'+bo$
	$EO+FX+AX+GX+DO+CO+BX+M8+HX'+HO'+ho$
	$EO+FX+AX+GX+DO+JO+HX+M8+BX'+BO'+bo$
	$EO+FX+AX+GX+DO+M8+HX'+HO'+ho$
	$EO+FX+AX+M4+HX'+HO'+ho$
	$EO+FX+HX+M4+GX'+GO'+go$
	$EO+FX+HX+AO+BX+GO+JX+M8+CX'+CO'+co$
	$EO+FX+HX+AO+GX+DX+CO+M8+JX'+JO'+jo$
50	$EO+AX+JX+M4+BX'+BO'+bo$
	$EO+GX+FX+M4+BX'+BO'+bo$
	$EO+GX+CX+M4+BX'+BO'+bo$
	$EO+HX+BX+M4+AX'+AO'+ao$
	$EO+HX+DX+M4+AX'+AO'+ao$
	$EO+FX+BX+M4+AX'+AO'+ao$
	$EO+FX+DX+M4+AX'+AO'+ao$
55	$EX+AO+BX+HO+JX+FO+DX+M8+GX'+GO'+go$
	$EX+AO+BX+HO+JX+M8+DX'+DO'+do$
	$EX+AO+BX+HO+JX+M8+EX+FX+M8+o$
	$EX+AO+BX+HO+JX+CO+GX+M8+DX'+DO'+do$
	$EX+AO+BX+HO+JX+CO+GX+M8+EX+FX+M8+o$
	$EX+AO+BX+HO+CX+FX+GO+M8+EX+FX+M8+o$
	$EX+AO+DX+FO+CO+HX+GX+M8+EX+FX+M8+o$
	$EX+AO+DX+FO+CO+HX+GX+M8+EX+BO'+bo$
60	$EX+AO+DX+FO+JX+CX+GO+M8+BX'+BO'+bo$
	$EX+AO+DX+FO+JX+CX+GO+M8+EX+HX+M8+o$
	$EX+AO+DX+FO+JX+M8+EX+HX+M8+o$
	$EX+AO+DX+FO+JX+M8+EX+BO'+bo$
	$EX+AO+JX+M4+GX'+GO'+go$

By virtue of the assumed sequence of moves, a "singular" play has been found to exist and the machine has properly responded thereto to select cell "B" by operating relay BO(4). Had a "singular" play not existed, neither relay SP(5) nor any of the cell relays would have been operated at this time.

WINNING PLAY

When relay SR1(5) releases as above described, the energizing circuit for relay SR2(5) is interrupted. Relay SR2(5), however, is of the slow-to-release type, and all of the above-described operations incident to

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the "singular play" test occur during the time required for relay SR2(5) to release. Upon the release of relay SR2(5), a "winning play" test is made. Since under the assumed sequence of moves, a "singular" play has been found to exist and has been made, it is obvious that no "winning" play can exist. Since, however, in response to an affirmative response to the "singular play" test, the machine has operated relay BO(4) and since relay EO(7) has previously been operated, it might appear to the machine that a winning play does exist. A false operation is prevented, however, by including a back contact of relay SP(5) in the energizing circuit for the "winning play" relay O(5) whereby relay O(5) cannot be operated since relay SP(5) has previously been operated. Therefore, under the assumed sequence of plays, no "winning play" test will be made.

To demonstrate the functioning of the "winning play" circuit, let there be a temporary departure from the previously assumed sequence of operations, and let it be assumed that the machine has previously operated two of the "cell" relays in a single "row" such as relays CO(5) and FO(8), and let it further be assumed that there was a negative response to the "single play" test and that therefore relay SP(5) remains unoperated. It is obvious that if the machine selects and operates relay JO(8), the machine will win the game. When relay SR2(5) releases, a circuit is completed from ground on conductor 501, No. 1 contact of operated relay SR4(5), conductor 502, No. 1 contact of unoperated relay SP(5), conductor 505, No. 2 contact of operated relay SR3(5), lower (high resistance) winding of relay O(5), No. 1 contact of released relay SR2(5), conductor 506, No. 6 contact of relay CO(5) (which has been assumed for the present to be operated), conductor 507, No. 6 contact of relay FO(8) (which has also been assumed for the present to be operated), conductor 802, No. 7 contact of unoperated relay JX(8) and through the No. 5 contact and winding of relay JO(8) to battery. Since this energizing circuit for relay JO(8) includes the high-resistance winding of relay O(5), insufficient current will flow in the circuit to operate relay JO(8), but relay O(5) is adjusted to operate under this condition. Relay O(5) locks operated from battery, upper winding and No. 2 contact of relay O(5), and to ground on conductor 501. Relay O(5), in operating, effectively shunts its lower, high-resistance winding by completing a path from ground on conductor 501, No. 1 contact of relay SR4(5), conductor 502, No. 1 contact of relay SP(5) (which is unoperated under the present set of assumptions), conductor 505, and through the No. 3 contact of relay O(5) to conductor 506. As a result, relay JO(8) is operated. Relay JO(8), in operating, locks operated to the ground on conductor 501 through its No. 4 contact and lights lamp JO(6).

Relay O(5), in operating, also lights the "win" lamp to indicate that the machine has won the game, and applies ground through its No. 4 contact to prevent the release of slow-to-release relay SR3(5). With relay SR3(5) held operated, the system is immobilized and no further moves may be made.

The interassociation of the contacts of the several cell relays to provide the proper "winning play" networks may be determined symbolically. Under the assumed set of conditions above discussed, relays CO(5) and FO(8) were assumed to be operated and a circuit was completed through front contacts of those operated relays and through back contacts of relays JX(8) and JO(8) to operate relay JO(8). This circuit may be represented in the presented system of notation as:

$$CO+FO+JX'+JO'+jo$$

It will be readily seen that a plurality of other pairs of relays in any row may also be operated and similar test networks should be formed accordingly. In the presented

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system of notation, all such combinations which can possibly occur may be listed as follows:

Table IV

$AO+BO+CX'+CO'+co$
 $AO+CO+BX'+BO'+bo$
 $BO+CO+AX'+AO'+ao$
 $DO+EO+FX'+FO'+fo$
 $DO+FO+EX'+EO'+eo$
 $EO+FO+DX'+DO'+do$
 $GO+HO+JX'+JO'+jo$
 $GO+JO+HX'+HO'+ho$
 $HO+JO+GX'+GO'+go$
 $AX+DX+GX'+GO'+go$
 $AX+GX+DX'+DO'+do$
 $DX+GX+AX'+AO'+ao$
 $BX+EX+HX'+HO'+ho$
 $BX+HX+EX'+EO'+eo$
 $EX+HX+BX'+BO'+bo$
 $CX+FX+JX'+JO'+jo$
 $CX+JX+FX'+FO'+fo$
 $FX+JX+CX'+CO'+co$
 $GX+EX+CS'+CO'+co$
 $GX+CX+EX'+EO'+eo$
 $EX+CX+GX'+GO'+go$
 $AX+EX+JX'+JO'+jo$
 $AX+JX+EX'+EO'+eo$
 $EX+JX+AX'+AO'+ao$

The above circuits provide for all possible winning plays. However, under any particular embodiment of the invention, some of the possibilities do not exist and therefore certain of the networks may be deleted. Thus, for example, in the illustrated embodiment of the invention it has been assumed that if the player places an X in any cell except the center cell "E," then the machine will automatically select that cell on its first move. Therefore, after the second play, the center cell "E" is occupied and there is no possibility of subsequently completing a winning play by selecting that cell. As a result all of those networks in Table III which end in the designation "eo" need not be used. Analysis will further demonstrate that as a result of any particular arrangement of the "singular play" networks, certain others of the above-listed "winning play" possibilities may not, in fact, exist.

DEFENSIVE PLAY

It will be recalled that to test for "singular" plays, conductor 504 was grounded, and that to test for "winning" plays conductor 506 was grounded. As will be seen hereinafter, to test for "defensive plays," conductor 510 is grounded through the No. 3 contact of relay SR3(5), when that relay releases, conductor 505, No. 1 contact of relay SP(5), conductor 502, No. 1 contact of relay SR4(5) and to ground on conductor 501. Under the initially assumed set of conditions, an affirmative response was received on the "singular play" test whereby relay SP(5) was operated. As a result, under those conditions, it is clear that a "defensive" play does not exist. The "defensive play" test is therefore not made by virtue of the fact that the circuit by means of which ground is applied to the "defensive play" lead 510 is interrupted at the No. 1 contact of operated relay SP(5).

Under the second assumed set of conditions, an affirmative response was received on the "winning play" test whereby relay O(5) was operated. As a result, no "defensive" play can exist and therefore no "defensive play" test is made. This is accomplished by preventing the release of relay SR3(5) by connecting ground to the winding thereof through the No. 4 contact of operated relay O(5).

To demonstrate the functioning of the "defensive play" circuit, let it now be assumed that the player or opponent has operated two of the "cell" relays in a single row such as relays BX(6) and EX(7), and let it further be assumed that negative responses have been received to both

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the "singular play" and the "winning play" tests whereby both relay SP(5) and relay O(5) remain unoperated. It is apparent that unless the machine now selects unoccupied cell "H," the player will be in a position to win the game. If neither a "singular" play nor a "winning" play exists, then, under the definition of a "singular play," a "defensive" play must exist. Consequently there is no need for a "defensive play" relay and none is provided.

When relay SR3(5) releases under the last-assumed set of conditions, a circuit is completed from ground at key RL(5), conductor 501, No. 1 contact of relay SR4(5), conductor 502, No. 1 contact of relay SP(5), conductor 505, No. 3 contact of relay SR3(5), "defensive play" conductor 510, No. 4 contact of operated relay EX(7), conductor 708, No. 3 contact of operated relay BX(4), conductor 415, No. 7 contact of unoperated relay HX(7), and through the No. 5 contact and winding of relay HO(7) to battery whereby relay HO(7) is operated. Relay HO(7) locks operated through its No. 4 contact to the ground on conductor 501 and lights lamp HO(6).

Upon the release of relay SR3(5), the energizing path for relay SR4(5) is interrupted, and after a delay sufficient for the above-described defensive play to be made, relay SR4(5) releases. Relay SR4(5), in releasing, releases that one of the relays A(3) to J(3) which is operated and releases relay P(4). Relay P(4), in releasing, again causes the sequential reoperation of relays SR1(5), SR2(5), SR3(5) and SR4(5). When relay SR4(5) reoperates, ground is again applied through a back contact of relay P(4) and through back contacts of the unoperated cell relays to the player's keys 311A to 311J so that the player may proceed with his next selection.

The interassociation of the contacts of the several cell relays to provide the proper "defensive play" networks may be determined symbolically. Under the last-assumed set of conditions, relays EX(7) and BX(4) were assumed to be operated and a circuit was completed through front contacts of those relays and through back contacts of relays HX(7) and HO(7) to operate relay HO(7). This circuit may be represented in the presented system of notation as:

$$EX+BX+HX'+HO'+ho.$$

It will be observed that a plurality of other pairs of relays in any row may also be operated and similar test networks should be formed accordingly. In the presented system of notation, all such combinations which can possibly occur may be listed as follows:

Table V

AX+BX+CX'+CO'+co
 AX+CX+BX'+BO'+bo
 BX+CX+AX'+AO'+ao
 DX+EX+FX'+FO'+fo
 DX+FX+EX'+EO'+eo
 EX+FX+DX'+DO'+do
 GX+HX+JX'+JO'+jo
 GX+JX+HX'+HO'+ho
 HX+JX+GX'+GO'+go
 AX+DX+GX'+GO'+go
 AX+GX+DX'+DO'+do
 DX+GX+AX'+AO'+ao
 BX+EX+HX'+HO'+ho
 BX+HX+EX'+EO'+eo
 EX+HX+BX'+BO'+bo
 CX+FX+JX'+FO'+fo
 CX+JX+FX'+FO'+fo
 FX+JX+CX'+CO'+co
 GX+EX+CX'+CO'+co
 GX+CX+EX'+EO'+eo
 EX+CX+GX'+GO'+go
 AX+EX+JX'+JO'+jo
 AX+JX+EX'+EO'+eo
 EX+JX+AX'+AO'+ao

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If the game proceeds to a point where neither the player nor the machine can win, i. e., a "draw game," the apparatus may be restored to normal in preparation for the starting of a new game by operating key RL(5). If the machine has "won" the game, both keys RL(5) and AL(5) must be operated to restore the apparatus to normal, as was hereinbefore noted.

It is to be understood that the above-described arrangements are but illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In combination, a display board comprising a plurality of cells forming a coordinate array, each of said cells being energizable to a first or a second condition, a switch individual to each of said cells, a first relay connected and individual to each of said cells and connected to and operable under the control of said switch for energizing the cell to said first condition, a second relay connected and individual to each of said cells for energizing the cell to said second condition, apparatus including contacts of said first relays and a control relay operable when any one of a plurality of selected pairs of said first relays is operated, and means controlled by said apparatus for operating the one of said second relays which is individual to the cell in row-alignment with the cells to which the relays of the operated pair of first relays are individual.

2. In combination, a display board comprising a plurality of cells forming a coordinate array, each of said cells being energizable to a first or a second condition, a switch individual to each of said cells, a first relay connected and individual to each of said cells and connected to and operable under the control of said switch for energizing the cell to said first condition, a second relay connected and individual to each of said cells for energizing the cell to said second condition, means including said first relays for operating a pair of said second relays, apparatus including contacts of said second relays and a control relay operable when the operated relays of said pair of second relays correspond to cells in the same row, and means controlled by said apparatus for operating a third one of said second relays which is in row-alignment with the cells corresponding to the operated pair of second relays.

3. In combination, a display board comprising a plurality of cells, each of said cells being energizable to a first or a second condition, a first and a second relay connected and individual to each of said cells, for energizing the cell to said first or said second condition, respectively, a switch individual to each of said first relays, means comprising networks including the contacts of said relays for determining the combinations in which said relays are operated, apparatus controlled by said means for operating a selected one of said second relays, and means operable under the control of said switches for connecting selected ones of said networks to said apparatus in accordance with the number of said first relays which has been operated.

4. In combination, a display board comprising a plurality of cells, each of said cells being energizable to a first or a second condition, a first and a second relay connected and individual to each of said cells, for energizing the cell to said first or second condition, respectively, first means for selectively and automatically operating one of said second relays if any one of a selected group of combinations of said relays is operated, second means for selectively and automatically operating one of said second relays if any one of a different selected group of combinations of said relays is operated, and means operative after each operation of any one of said first relays for successively operating said first and said second means.

5. In combination, a display board comprising a plu-

ality of cells, each of said cells being energizable to a first or a second condition, a first and a second relay connected and individual to each of said cells, for energizing the cell to said first or said second condition, respectively, first means for selectively and automatically operating one of said second relays if any one of a selected group of combinations of said relays is operated, second means for selectively and automatically operating one of said second relays if any one of a different selected group of combinations of said relays is operated, means operative after each operation of any one of said first relays for successively operating said first and said second means, and means operative if one of said second relays is operated by said first means for disabling said second means.

6. In combination, a display board comprising a plurality of cells, each of said cells being energizable to a first or a second condition, a switch individual to each of said cells, a first relay connected and individual to each of said cells and connected to and operable under the control of said switch for energizing the cell to said first condition, a second relay connected and individual to each of said cells for energizing the cell to said second condition, a control relay controlled by said first relays and having an operating winding of high resistance, means effective incident to the operation of at least two of said switches for preparing an operating circuit for a selected one of said second relays which includes the winding of the said one of said second relays, contacts of said first relays and the high resistance winding of said control relay, and means controlled by said control relay, when operated, for excluding the high resistance winding thereof from said operating circuit to thereby cause the operation of the said one of said second relays.

7. In combination, a display board comprising a plurality of cells, each of said cells being energizable to a first or a second condition, a switch individual to each of said cells, a first relay connected and individual to each of said cells and connected to and operable under the control of said switch for energizing the cell to said first condition, a second relay connected and individual to each of said cells for energizing the cell to said second condition, a control relay controlled by said second relays and having an operating winding of high resistance, means effective incident to the operation of any one of a plurality of selected pairs of said second relays for preparing an operating circuit for a third one of said second relays which includes the winding of the said

third one of said second relays, contacts of the operated ones of the selected pairs of said second relays and the high resistance winding of said control relay, and means controlled by said control relay, when operated, for excluding its high resistance winding from said operating circuit to thereby cause the operation of the said third one of said second relays.

8. In combination, a display board comprising a plurality of cells, each of said cells being energizable to a first or a second condition, a switch individual to each of said cells, a first relay connected and individual to each of said cells and connected to and operable under the control of said switch for energizing the cell to said first condition, a second relay connected and individual to each of said cells for energizing the cell to said second condition, control apparatus including a chain of sequentially releasable slow-releasing relays and a pair of control relays, means responsive to the operation of any of said switches for initiating the release of said sequentially releasable relays and for operating a corresponding one of said first relays, means effective incident to the release of the first one of said sequentially releasable relays for operating a predetermined one of said second relays and for connecting the operating winding of one of said control relays to the winding of one of said second relays by way of operated contacts of selected ones of said first and second relays, means effective incident to the release of a second one of said sequentially releasable relays for connecting the operating winding of another of said control relays to the winding of one of said second relays by way of operated contacts of a selected pair of said second relays, means effective incident to the release of a third one of said sequentially releasable relays for operating one of said second relays by way of operated contacts of a selected pair of said first relays, and means controlled by each of said control relays for operating the said one of said second relays whose winding is connected in the said operating circuit of the said control relay.

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