

Oct. 9, 1951

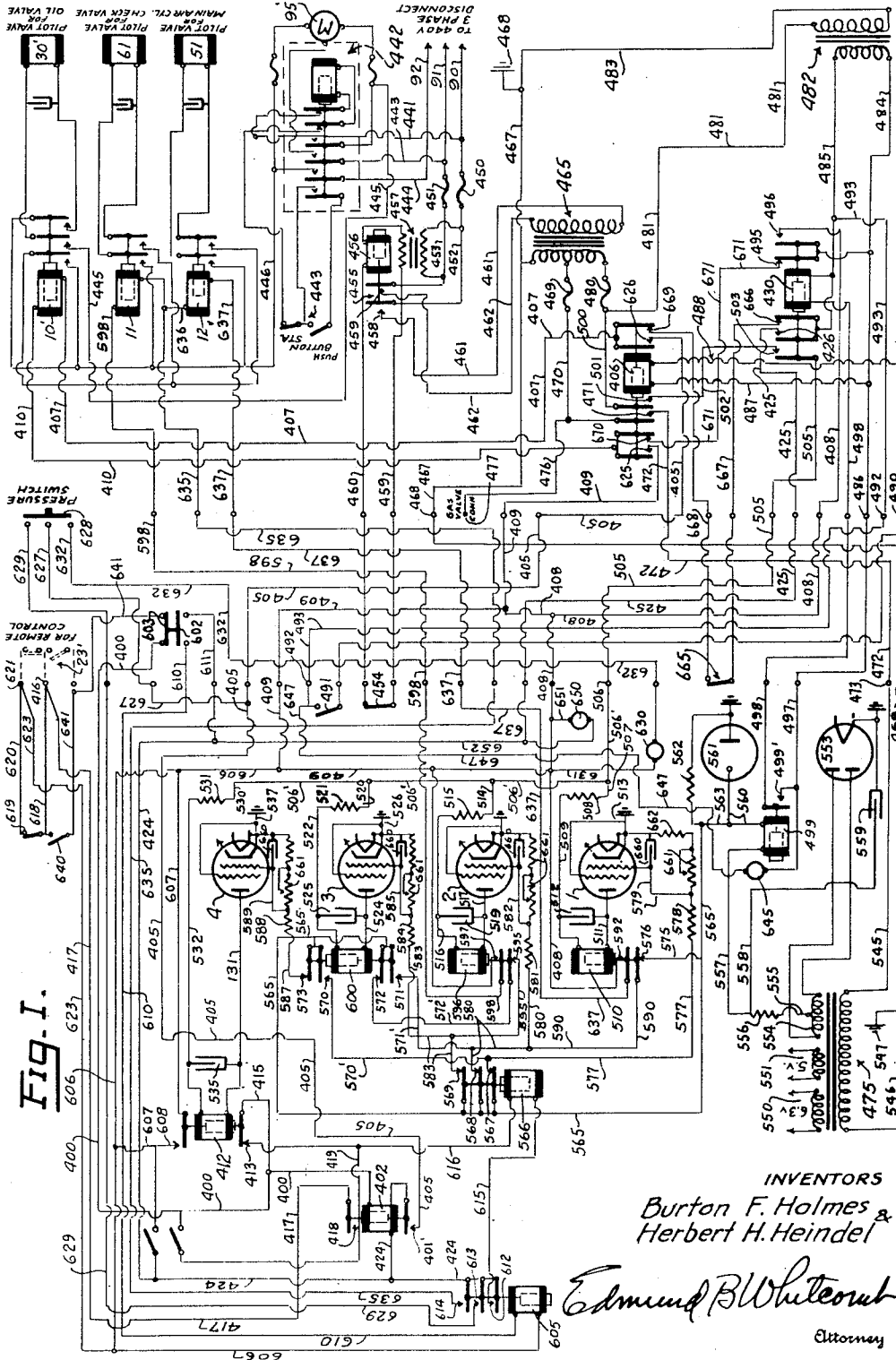
B. F. HOLMES ET AL

2,570,448

ELECTRONIC SEQUENCE SPACE DISCHARGE TUBE NETWORK

Original Filed Dec. 10, 1947

6 Sheets-Sheet 1



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ELECTRONIC SEQUENCE SPACE DISCHARGE TUBE NETWORK

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6 Sheets-Sheet 2

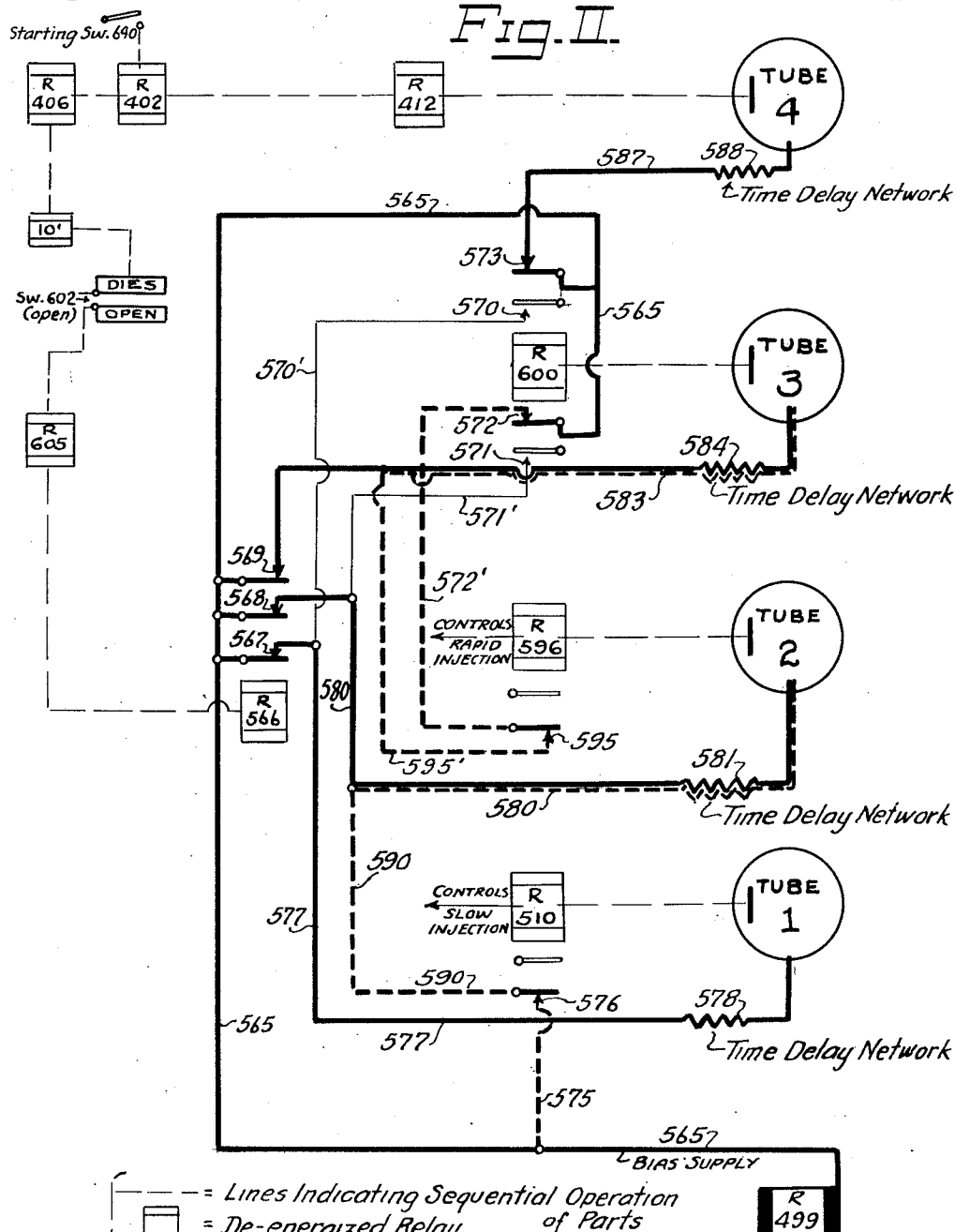


Fig. II^a

- = Lines Indicating Sequential Operation of Parts
- = De-energized Relay
- = Energized Relay
- = Inactive Circuits
- = Main Bias Supply Circuits
- = Auxiliary Parallel Bias Supply Circuits
- = Additional Bias Circuits

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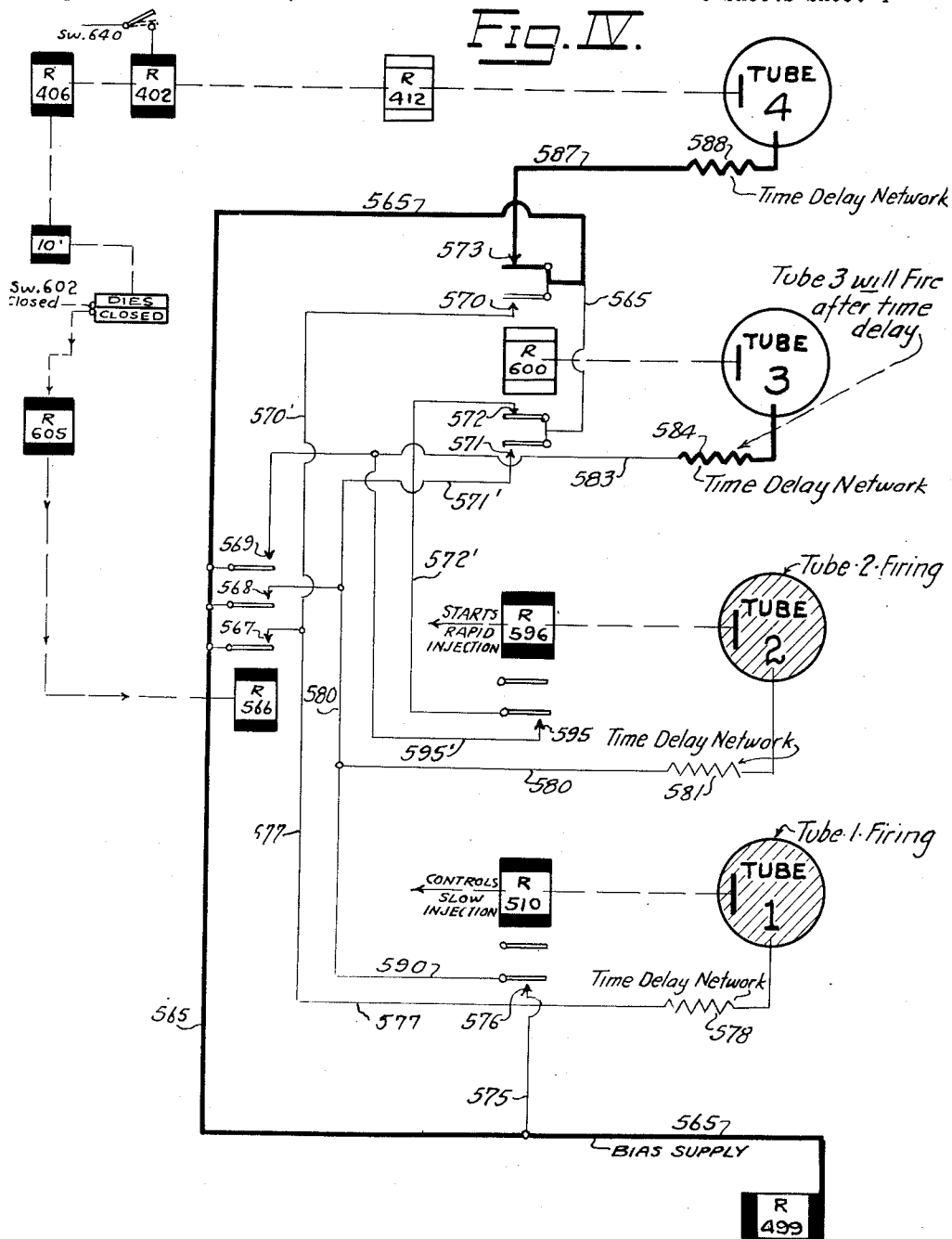
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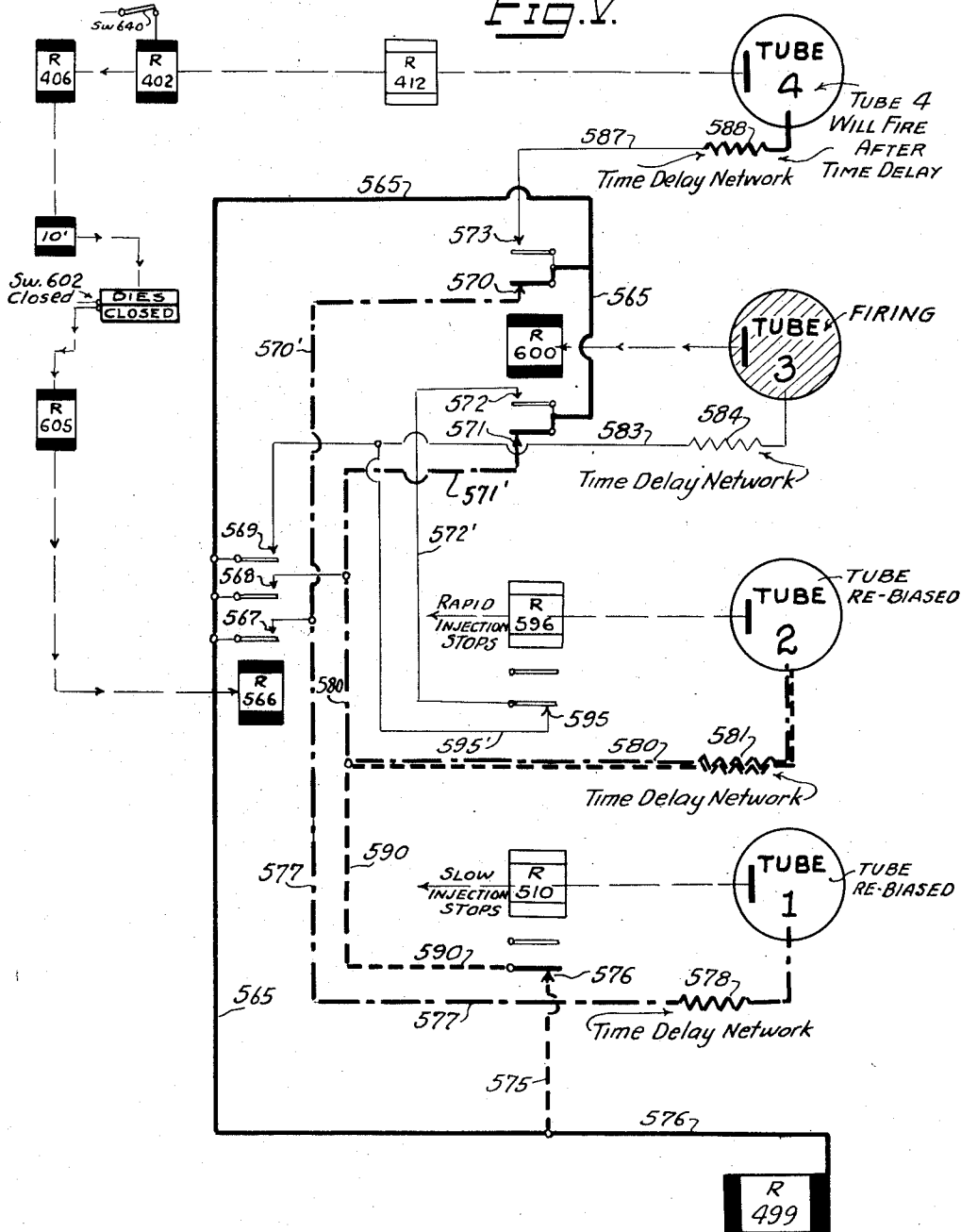
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6 Sheets-Sheet 5

Fig. V.



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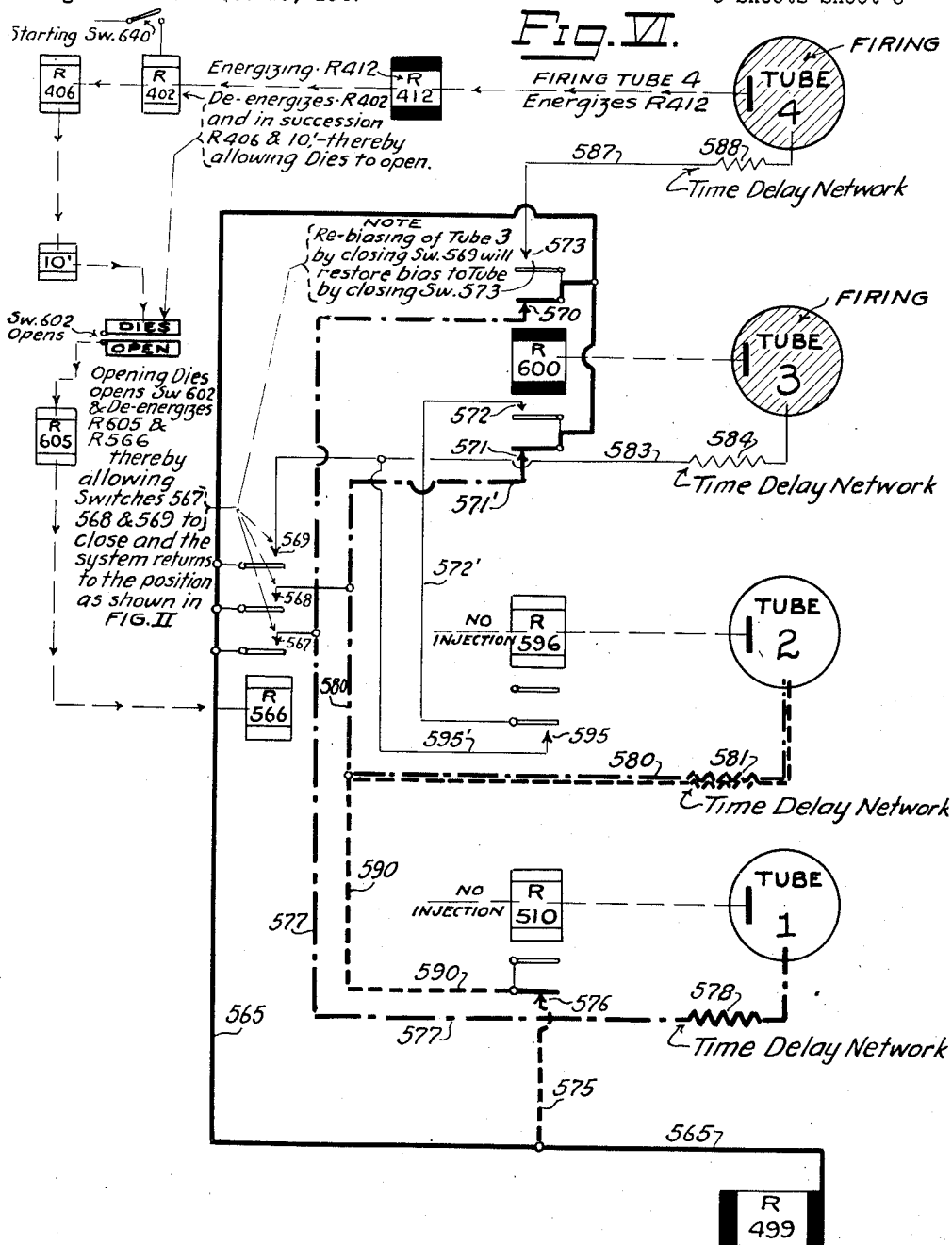
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ELECTRONIC SEQUENCE SPACE DISCHARGE TUBE NETWORK

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6 Sheets-Sheet 6



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2,570,448

ELECTRONIC SEQUENCE SPACE DISCHARGE
TUBE NETWORK

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Original application December 10, 1947, Serial No.
790,838. Divided and this application October
28, 1949, Serial No. 124,153

6 Claims. (Cl. 175-320)

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This invention relates to an electronic sequence operating network involving space discharge tubes for controlling circuits and is a division of our copending application, Serial No. 790,838, filed December 10, 1947, now Patent No. 2,532,256, issued November 28, 1950.

The object of the present invention is to provide a novel network arrangement in the sequence operation of discharge tubes which has been found very efficient in operation and particularly useful in connection with the operation of solenoids for controlling die casting machine operations as set forth in our copending application.

An object of the present invention is to provide a network of the character described in which the sequence discharge of the tubes is controlled by a special arrangement and interconnection of circuits for the maintenance and removal of grid bias supply including the resetting of the cycle of operations after one complete cycle has been accomplished.

More specifically, an object of the invention is to provide an especially satisfactory operating bias control and removal thereof for the space discharge tubes of the series in an arrangement we have found substantially fool-proof in action, our bias supply circuits involving in the main three bias circuits for certain of the tubes, namely, a main bias supply circuit for normally supplying a negative bias to all of the tubes of the series to prevent firing of any of the tubes in normal inoperative position; an auxiliary bias supply circuit for certain of said tubes adapted to temporarily supply bias to such tubes during a portion of the cycle of operation and a third additional bias supply circuit for certain of said tubes during another period of the cycle of operation, it being an object of our invention to provide a single source of bias supply for each of said alternative circuits.

Further objects and advantages are within the scope of this invention, such as relate to the arrangement, operation and function of the related elements and circuits of the system, to various details of construction and to combinations of parts, elements per se, and to economies of manufacture and numerous other features, as will be apparent from a consideration of the specification and drawings of a form of the invention, which may be preferred, in which:

Figure I is an electrical diagram illustrating the circuits embodying our invention;

Figure II is a schematic diagram of the bias supply circuits and controls to tubes 1, 2, 3 and

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4 and also the output controlled relays in connection with these tubes, the circuits being in the same condition as shown in Figure I and the machine being ready for operation;

Figure IIa is a legend showing the types of line and symbols used in Figure II as well as succeeding figures;

Figure III is a schematic diagram similar to Figure II but with the circuits and controls in the condition they assume at the time of the firing of tube 1;

Figure IV is a schematic diagram similar to Figure II but with the circuits and controls in the condition they assume at the time of the firing of tube 2;

Figure V is a schematic diagram similar to Figure II but with the circuits and controls in the condition they assume at the time of the firing of tube 3;

Figure VI is a schematic diagram similar to Figure II but with the circuits and controls in the condition they assume at the time of the firing of tube 4, and immediately thereafter.

In the embodiment of our invention illustrated in the accompanying drawings, we have shown an electrical system particularly adapted for use in operating a die casting machine illustrated in our copending application and including a source of electrical current supply and the electronic sequence timing network adapted to be operated from said current supply which includes a plurality of space discharge tubes 1, 2, 3 and 4, the biasing, discharge and rebiasing of which are properly controlled in a desired manner to operate and reset relays, solenoids, and interconnected electrical circuits and apparatus for controlling the action of certain machine moving elements, the electrical network interconnected with and dependent in part upon a movement of a part of the machine itself.

Referring to Figure I of the drawings, it will be understood that the hand operated switch 640 is connected to the power line through a temporarily "locking in" switch mechanism through lead 400 to coil 402 which energizes coil 402 and consequently closes contacts so that the die casting machine closes. Following this operation, our network is particularly adapted upon the firing of the thyratron tubes 1, 2, 3 and 4 to operate the metal injection in two stages, reset the bias on certain of the tubes and open the dies and complete the resetting of the cycle to initial position.

In connection with the electrical circuits dis-

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closed, we have a 220 volt input circuit supplied through leads 90, 91 and 92 and a main transformer 465. From this main transformer 465 we provide a 110 volt circuit to the primary winding of a second transformer 475, the secondaries of which supply current to the filaments of tubes 1, 2, 3 and 4 at 6.3 volts and another circuit for a heat control including a 6 volt circuit for a rectifier tube and a high voltage for the plate of the same to supply a negative direct current for the grid bias circuits for the thyatron space discharge tubes 1, 2, 3 and 4. Another transformer 482 has a primary winding which is also energized from transformer 465 and has a 24 volt secondary winding adapted to supply current to a 24 volt circuit arrangement of leads and relays for effecting supply of current for electrical means for actuating the apparatus with which this invention is concerned.

The plate circuits for the tubes include the terminal 468 as a common grounded cathode circuit from transformer 465. On the other side from said transformer, the plate circuit includes the fuse 480, lead 500, to normally open point 501 on relay 406 when point is closed in the automatic position of the apparatus. From point 501 we provide lead 502 to normally open point 503 on relay 430 also closed in the automatic position after time delay for the tube warm up has taken place (hereinafter described). Lead 505 from point 503 connects with terminal 506, all tube plate circuits connect from terminal wire 506'. Thus, for tube 1, we have a lead 507 connected to lead 506', resistor 508 to limit the current flow, lead 509, to coil 510, lead 511 to the plate of tube 1. The cathode circuit of tube 1 is grounded as indicated by a circuit 513. We also have a condenser 512 connected across coil 510 to supply current to coil on the negative one-half cycle and prevent chattering.

The other tubes 2, 3 and 4 are similarly connected.

Thus for tube 2 lead 514 is connected to the lead 506' common to all of tubes 1, 2, 3 and 4 as indicated supra. Lead 514 connects through resistor 515, lead 516, to coil 596, hence by lead 517 to the plate of tube 2. A condenser 519 is connected across leads 515 and 517, as shown.

For connecting tube 3, we provide a lead 520 passing through the resistor 521 to lead 522, which connects with coil 600 having lead 524 connected to the plate of tube 3. A condenser 525 is connected across leads 522 and 524. The cathode circuit of tube 3 is grounded as indicated by circuit 526.

For tube 4 we also provide a lead 530 connected with a common connecting lead 506', limiting resistor 531, lead 532, coil 412, lead 131, to the plate of tube 4. We also provide a condenser 535 across leads 532 and 131 as in the case of the other three tubes. The cathode of tube 4 is also grounded by circuit 537 as indicated.

Bias circuits

The bias supply for each of tubes 1, 2, 3 and 4 which is from a common source to each tube, will now be described.

A 110 volt circuit from the main transformer 465, through relay 406 connects by lead 472 to point or terminal 473, which is connected by lead 545 to the primary of the "tube" transformer 475 and returns by 546 to ground as shown at 547.

The transformer 475 has three secondaries, one 550 for the 6.3 volts for the filaments of the

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thyatron tubes 1, 2, 3 and 4. Another secondary output circuit of 5 volts is indicated 551 for the rectifier tube 553.

The third center tapped winding 554 of the transformer 475 is for supplying voltage to two circuits, one the plates of a rectifier tube 553 and the other for the main thyatron tube bias circuit. We have grounded the filament (cathode) of rectifier tube 553 as shown. At the center tap of the secondary 554 we have a lead 555 to resistor 556, lead 557 combined choke and relay coil 499. From lead 557 we also have a lead 558 to condenser 559, the other side of which is grounded as shown.

From coil 499 we have lead 560 to the cathode of voltage regulator tube 561, the plate of which is grounded as indicated. Across tube 561 is a resistor 562 connected by lead 563 to lead 560 to said tube 561, the other side of resistor 562 being grounded.

Our connections for these tubes also forms a time delay for the warming up of tubes 1, 2, 3 and 4, since relay 499, when energized, closes points 499', there being a time delay on the make of said points 499' with a well-known type of switch which has a quick break.

Moreover, this relay 499 provides a safety arrangement since failure of any part of the bias supply will cause 499' to open, dropping out relay 430 which disconnects the plate circuits of the tubes 1, 2, 3 and 4. This also drops out the 24 volt control circuit to the automatic operation.

Connections for the bias supply voltage for tubes 1, 2, 3 and 4

The above circuits and the tubes 553 and 561 provide means to produce the bias voltage for the main thyatron tubes 1, 2, 3 and 4. We will now describe its connections to these tubes. Thus we have a lead 565 joined to lead 563 as shown. Lead 565 is the main bias supply line for all four tubes. This main lead 565 connects with three points (normally closed) on relay 566; namely, points 567, 568 and 569, lead 565 also being connected with points 570, 571, 572 and 573 of relay 600 controlled by tube 3.

For tube 1, bias is normally supplied from lead 565 to point 567, lead 577, resistor 578 and lead 579 to the grid of tube 1.

For tube 2, the main bias is from point 568, lead 580, resistor 581, lead 582, to the grid of tube 2. This main bias lead 565 also has a connection for an auxiliary circuit for tube 2 by lead 575 to a contact 576 of relay 510 controlled by tube 1.

For tube 3, the main bias includes lead 583 from point 569, to resistor 584, lead 585, to the grid of tube 3. Tube 3 also has an auxiliary bias circuit, since we provide, as more clearly shown in Figure II, a lead from a bias line 565 to point 572 of the relay 600 as shown. We also provide a lead 572' from point 572 to point 595 of relay 596 of tube 2. Then we also provide a lead 595' connecting with lead 583 to the grid of tube 3. Hence, the auxiliary bias for tube 3 is so connected as to have in series therewith a switch controlled by the relay for tube 2.

For tube 4, the bias includes a lead 587 from point 573 to resistor 588, lead 589, to the grid of tube 4. As the necessary part of the operation, as will hereinafter appear more fully, we also provide additional temporary bias circuits for tubes 1 and 2. This additional bias for tubes 1 and 2 includes a circuit from switch point 570 of relay 600 by way of lead 570' which connects

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to lead 577 to the bias of tube 1. For tube 2, this additional temporary circuit is connected with relay point 571 by lead 571' which connects with lead 580 to the grid of tube 2.

Sequential firing of tubes

We have provided means for causing tubes 1, 2, 3 and 4 to "fire" in a desired sequence for proper machine operation one after the other, and moreover, any subsequent tube in the series cannot "fire" until the preceding tube has fired. The circuits and means for accomplishing this will now be described. Thus, when relay coil 566 is energized this opens points 567, 568 and 569, removing the main bias from tubes 1, 2 and 3. However bias for tube 2 is now being supplied through the temporary auxiliary circuit constituting a second supply circuit for tube 2 just described and including point 576, lead 590, lead 580, resistor 581, lead 582 to grid of tube 2. When tube 1 fires (at the end of its time delay, to be described) relay 510, through lead 511, is then energized and normally closed point 576 now opens, removing this auxiliary bias from tube 2.

Also the firing of tube 1 and energizing of coil 510 closes the normally open point 592 thereby applying 24 volts to the power relay 12 by leads 637 to apply a delayed shot of metal into the mold of the die casting machine.

Firing of tube 2

At the expiration of the time delay for tube 2 (to be described) tube 2 fires (the auxiliary bias being removed by firing of tube 1, as stated supra). The bias now on tube 3 is by reason of the auxiliary bias circuit described above. Firing of tube 2 opens normally closed point 595 of relay 596 which removes this auxiliary bias from tube 3.

The energizing of coil 596 also closes normally open point 597 which, through lead 598, energizes relay 11 for operating the check valve mechanism 61 to give the full shot of metal used in the die casting machine.

Firing of tube 3

Removing bias from tube 3 allows tube 3 to fire at the end of its time delay energizing the coil of relay 600, closing normally open points 570 and 571, thereby reapplying the third or temporary additional bias to tubes 1 and 2, thus resetting these tubes and their associated plate circuit relays.

Moreover, normally closed points 572 and 573 are opened and since 572 is opened, this prevents reapplying bias to tube 3 by tube 2 at this point of the cycle.

Firing of tube 4

The opening of 573 removes bias from tube 4. When tube 4 fires at the end of its time delay, the relay 412 is energized, opening normally closed point 413 which breaks the holding circuit for the die operating mechanism.

Interconnected circuits from tube controls to machine part operated microswitch to tube 3

The bias control of the tube 3 is interlocked with a microswitch 602 which switch in turn is actuated by the rack on the machine, which rack is operated by a hydraulic system. Closing of point 602 closes relay 605 by leads from contact 496 of relay 430 and leads 408, 499 and 606. Another lead 607 connects from lead 606 to a point 608 (normally open) of relay 412.

On the other side of coil 605, a lead 610 con-

nects with normally open side of microswitch 602, referred to supra and lead 611; leads 424 and 425, normally open point 426 on relay 430.

When coil 605 is energized, coil of relay 566 is also energized. Relay 605 has three normally open points 612, points 613 and 614. The connection from relay 605 to relay 566 includes point 612, lead 615, relay coil 566. From the other side of relay 566, lead 616 connects to lead 419, point 418 of relay 402, the other side of the switch 418 has a lead 417 extending to terminal 416; hence by lead 618 to safety point 619 of push button switch 640 which also connects to lead 620 and connection 621, lead 623, which connects to lead 606 completing the circuit for energizing coil 605 and hence coil 566. Thus, when point 602 opens, due to the action of the machine part with the dies starting to open, from the foregoing circuits it will be seen that coil 605 and hence coil 566 are de-energized, all three points 567, 568 and 569 of relay 566 are closed, thus reapplying the main original bias to tube 3 as well as to tubes 1 and 2.

After relay 566 has been de-energized and the main bias restored to tubes 1 and 2 the additional bias for tubes 1 and 2 above described has been broken by the biasing of tube 3. This occurs since the main bias is restored immediately to tubes 1 and 2 whereas the additional bias circuit is not broken until tube 3 becomes biased and relay 600 subsequently operates to break points 570 and 571 of said additional bias circuit.

Time delay circuits for tubes 1, 2, 3 and 4

For each of tubes 1, 2, 3 and 4 we have a time delay network for the bias circuits thereof which includes lead 577 (bias supply lead for tube resistor 578) lead 579, for example, to grid of tube 1. Before normally closed point 567 opens, there is a circuit through resistor 578, lead 579, which also charges condenser 660 which until the bias is removed, supplies a voltage to grid 1. However, when switch point 567 is opened, condenser 660 is discharged through adjustable potentiometer 661 (which may be variably set by the operator) and current limiting resistor 662 to ground 513 as shown. The other side of the bias circuit is grounded as shown in the drawing and described supra. Thus, the setting of the adjustment on potentiometer 661 determines the time for discharge of condenser 660 which when it reaches critical grid voltage of tube 1 allows the tube to fire. Resistor 662 limits the current for a very low setting of the potentiometer 661. Resistor 578 has two purposes, one to prevent the main bias supply from being shorted in case condenser 660 fails. Also it provides a buffer action to prevent burning of point 567, due to sudden inrush of current to condenser 660. A similar time delay network consisting of a similar condenser 660 and potentiometer 661 for the discharge of the bias is provided for each of the other tubes 2, 3 and 4 as shown in the drawing.

Operation—One complete cycle

The system is started in operation by the operator closing the quick return close button 640 through relay 402, relay 406 and correlated circuits and controls from the relay 430 connected with the 24 volt transformer 482 to supply current thereto, through the various circuits shown in Figure I of the drawings and cause the coil 10' to close the power circuit through the operating coil 30' and close the dies. The tube circuits

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and conditions at this point are shown in diagram Figure II.

The microswitch at point 602 is operated by a machine part to thereby move the microswitch to final closed position and effect an energization of relay 605. This closes switch point 612 and relay 566 is energized, opening point 567 which is in the main bias circuit for tube 1—this being the main bias circuit for tube 1 as well as for the other tubes as described above. Opening the tube 1 bias, permits tube 1 to fire through its plate circuit at the end of its time delay, thereby energizing relay 510, closing switch point 592 as stated supra. The circuits at this point are illustrated in Figure III. This, through the various circuits shown, energizes relay 12 which in turn supplies power to the pilot valve for the main air cylinder 51, permitting a delayed shot of metal to be injected into the die as the first part of the two-stage metal injection.

Temporary auxiliary circuit for biasing tubes 2 and 3

It will be noted that while the main bias supply circuit to the tubes controlled by relay 566 and points 567, 568 and 569 has been broken, tubes 2 and 3 are temporarily biased by the auxiliary circuits described above. These auxiliary circuits for tubes 2 and 3 have been temporarily energized simultaneously with the main bias described above and the auxiliary bias circuits for these two tubes are illustrated in the diagram of Figure II.

Firing of tube 2

By the firing of tube 1, just described, the auxiliary bias for tube 2 is opened because switch point 576 which is in the bias circuit for tube 2, has now been opened by relay 510. Removing this auxiliary tube 2 bias causes the discharge of its circuit at the end of its time delay since the main bias supply was previously removed, energizes relay 596. The circuits as now operating are illustrated in Figure IV. Thus, when point 597 is closed, current is supplied from the transformer 432 to relay 11 circuits and switches for rapid metal injection. However, since the time delay in the firing of tube 2 after both bias circuits have been removed depends on setting of the variable potentiometer 661 for tube 2, by adjustment thereof to its low position, tube 2 may fire substantially immediately after tube 1 fires so that in the overall operation of the network sequential firing system disclosed, tubes 1 and 2 in such case fire without any appreciable difference in time but act as one tube.

Firing of tube 3

The firing of tube 2 energizes coil 596 which breaks the auxiliary bias supply for the grid circuit of tube 3. Since the main bias supply was previously removed this now removes all bias from tube 3 and causes it to fire after its time delay—illustrated in Figure V.

Firing of tube 3 acts to reset bias of tubes 1 and 2

Next in the cycle of operations, we provide means through the firing of tube 3 to reset the bias by the additional or a third temporary circuit for tubes 1 and 2, described supra. However, firing of tube 3 energizes relay 600 which is in the plate circuit of tube 3 as shown, so that energization thereof closes switch point 570 and 571 which are in the additional bias circuits for tubes 1 and 2, as described above and shown

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in Figures I and V. By closing these switch points 570 and 571, tubes 1 and 2 are rebiasing. It is understood that when the proper bias is applied to tubes 1 and 2, discharge thereof through the plate circuit ceases.

Prevention of rebiasing of tube 3

To prevent improper rebiasing of tube 3, we have also provided another switch point 572 for relay 600 so that when relay 600 is energized, as just stated, this switch point 572 opens with the result that re-establishing bias of tubes 1 and 2 will not also re-establish bias of tube 3.

From the foregoing it will be understood that when bias is re-established to tubes 1 and 2 these tubes cease firing and coils 11 and 12 are de-energized, permitting solenoid operated pilot valves 51 and 61 to be returned to normal position.

Firing of tube 4 and resetting circuits to initial position

Firing of tube 4 is for the purpose of accomplishing the last step in the machine operation in our system; namely, re-opening the dies which in turn, by the machine controlled switch 602, causes return of circuits to initial position with the main bias on tubes 1, 2, 3 and 4. This is illustrated in Figure VI. Referring back to tube 3 it will be noted that when it fires, it has opened switch point 573 on relay 600 which in turn removes the bias from tube 4 after its time delay through its potentiometer circuit 611—4. When the bias on tube 4 is removed, then the tube discharges, energizing coil 412, opening point 413 on relay 412, thereby breaking the holding circuit for relay 402 which drops out relay 402. This effects an opening of the dies and consequently opens microswitch 602 which deenergizes relay coil 605 and consequently coil 566. This allows points 567, 568 and 569 in the main bias circuit for the tubes 1, 2 and 3 to be re-established, thereby resetting these in initial position. Rebiasing tube 3 in this manner thereupon permits its relay coil 600 to operate, breaking points 571 and 570 thereby disconnecting the additional bias circuits which were temporarily established for tubes 1 and 2. It will be also noted that this operation of relay coil 600 also closes point 573 which establishes the main bias supply to tube 4. The entire electrical apparatus is now in initial position. The system will not recycle until the operator restarts the action by pressing the manual close button 640 as heretofore described.

In referring to the bias supply circuits for the several tubes, we have referred in Figure IIa and in the description thereof to the main bias, an auxiliary bias and an additional bias. However, it is to be understood that the various circuits—some leads of which are common to the different circuits—for supplying bias at the proper time to the different tubes, according to the drawings and description may be properly termed "additional" or "supplemental" with respect one to other of the bias circuits.

It is apparent that, within the scope of the invention, modifications and different arrangements may be made other than is herein disclosed, and the present disclosure is illustrative merely, the invention comprehending all variations thereof.

What we claim is:

1. In an electrical system for causing mechanical operations, said system adapted to be connected to a source of electric current, an electronic sequence timing network adapted to be energized

from said source of current; said network including a plurality of space discharge tubes connected in said network; each of said tubes having cathode, plate and control grid elements; a plate-cathode circuit for each of said tubes; and a variable time constant network for controlling the sequential discharge of said tubes, said network including a capacitance and resistance connected to the grid element of each of said tubes; a source of bias supply; a main normally closed bias circuit; switching means therefor for connecting said main bias supply to the control grid elements of each of said tubes to prevent firing thereof; auxiliary bias circuits for the control grid elements of certain of said tubes upon opening of the main bias circuit to said tubes; means operable to open the switch of the main bias supply circuit to a plurality of said tubes, said means causing dissipation of the capacitance from the grid circuit of one of said tubes through its resistance causing delayed discharge of said one tube only through its plate-cathode circuit; switching means connecting said auxiliary bias to certain of the other of said tubes when said main bias switch is opened; means operated by the discharge of said first-mentioned tube to open said auxiliary bias supply circuit to the control grid of a second tube to permit delayed discharge thereof; means controlled by the discharge of said second tube for opening the auxiliary bias circuit for a third tube to cause discharge thereof; additional bias circuits for the first two mentioned tubes; switching means controlled by said third tube discharge circuit for connecting said additional bias circuits for the first two tubes to the bias supply to rebias said tubes; switching means for breaking the bias supply to a fourth tube; and means under the control of said last-mentioned tube to close the first-mentioned main bias supply circuit to each of said plurality of tubes in said system.

2. In an electrical system for causing mechanical operations, said system adapted to be connected to a source of electric current, an electronic sequence timing network adapted to be energized from said source of current; said network including a plurality of space discharge tubes connected in said network; each of said tubes having cathode, plate and control grid elements; a plate-cathode circuit for each of said tubes; and a variable time constant network for controlling the sequential discharge of said tubes, said network including a capacitance and resistance connected to the grid element of each of said tubes; a source of bias supply; a main normally closed bias circuit; switching means therefor for connecting said main bias supply to the control grid elements of each of said tubes to prevent firing thereof; auxiliary bias circuits for the control grid elements of certain of said tubes upon opening of the main bias circuit to said tubes; means operable to open the switch of the main bias supply circuit to a plurality of said tubes, said means causing dissipation of the capacitance from the grid circuit of one of said tubes through its resistance causing delayed discharge of said one tube only through its plate-cathode circuit; switching means connecting said auxiliary bias to certain other of said tubes when said main bias switch is opened; means operated by the discharge of said first-mentioned tube to open said auxiliary bias supply circuit to the control grid of a tube to permit delayed discharge thereof; additional bias connections for certain of said tubes; switching means controlled by a

previously mentioned tube discharge circuit for connecting said additional bias circuits to the bias supply to rebias certain of said tubes; switching means for breaking the bias supply to another tube; and means under the control of said last-mentioned tube to close the first-mentioned main bias supply circuit to each of said plurality of tubes in said system.

3. In an electrical system for causing mechanical operations, said system adapted to be connected to a source of electric current, an electronic sequence timing network adapted to be energized from said source of current; said network including a plurality of space discharge tubes; each of said tubes having cathode, plate and control grid elements; a plate-cathode circuit for each of said tubes; and a variable time constant network for controlling the sequential discharge of said tubes, said network including a capacitance and resistance connected to the grid element of each of said tubes; a source of bias supply; a main normally closed bias circuit; switching means therefor for connecting said main bias supply to the control grid elements of each of said tubes to prevent firing thereof; auxiliary bias connections for the control grid of certain of said tubes upon opening of the main bias circuit to said tubes; means operable to open the switch of the main bias supply circuit to a plurality of said tubes, said means causing dissipation of the capacitance from the grid circuit of one of said tubes through its resistance causing delayed discharge of said one tube only through its plate-cathode circuit; switching means connecting said auxiliary bias to certain of the other of said tubes when said main bias switch is opened; means operated by the discharge of said first-mentioned tube to open said auxiliary bias supply circuit to the control grid of a second tube to permit delayed discharge thereof; means controlled by the discharge of said second tube for opening the auxiliary bias circuit for a third tube to cause delayed discharge thereof; the auxiliary bias circuit for said third tube being in series with the switch points of the switch means operated by the discharge of each of said second and said third tubes to prevent reapplication of bias to said third tube through said auxiliary circuit; additional bias circuits for the first two mentioned tubes; switching means controlled by said third tube discharge circuit for connecting said additional bias circuits for the first two tubes to the bias supply to rebias said tubes; switching means for breaking the bias supply to a fourth tube; and means under the control of said last-mentioned tube to close the first-mentioned main bias supply circuit to each of said plurality of tubes in said system.

4. In an electrical system for causing mechanical operations, said system adapted to be connected to a source of electric current, an electronic sequence timing network adapted to be energized from said source of current; a tying-in relay; circuits and switches from said source of current supply to said relay; circuits controlled by said relay to connect said source of supply to said network; said network including a plurality of space discharge tubes connected in said network; each of said tubes having cathode, plate and control grid elements; a plate-cathode circuit for each of said tubes; and a variable time constant network for controlling the sequential discharge of said tubes, said network including a capacitance and resistance connected to the grid element of each of said tubes; a source of

bias supply; a main normally closed bias circuit; switching means therefor for connecting said main bias supply to the control grid elements of each of said tubes to prevent firing thereof; auxiliary bias circuits for the control grid elements of certain of said tubes upon opening of the main bias circuit to said tubes; means operable to open the switch of the main bias supply circuit to a plurality of said tubes, said means causing dissipation of the capacitance from the grid circuit of one of said tubes through its resistance causing delayed discharge of said one tube only through its plate-cathode circuit; switching means connecting said auxiliary bias to certain other of said tubes when said main bias switch is opened; means operated by the discharge of said first-mentioned tube to open said auxiliary bias supply circuit to the control grid of a tube to permit delayed discharge thereof; means controlled by the discharge of said tube for opening the auxiliary bias circuit for another tube to cause delayed discharge thereof; additional bias connections for certain of said tubes; switching means controlled by a previously mentioned tube discharge circuit for connecting said additional bias circuits to the bias supply to rebias certain of said tubes; switching means for breaking the bias supply to another tube; and means under the control of said last-mentioned tube to close the first-mentioned main bias supply circuit to each of said plurality of tubes in said system.

5. In an electrical system for causing mechanical operations, said system adapted to be connected to a source of electric current, an electronic sequence timing network adapted to be energized from said source of current; a tying-in relay; circuits and switches from said source of current supply to said relay; circuits controlled by said relay to connect said source of supply to said network; said network including a plurality of space discharge tubes connected in said network; each of said tubes having cathode, plate and control grid elements; a plate-cathode circuit for each of said tubes; and a variable time constant network for controlling the sequential discharge of said tubes, said network including a capacitance and resistance connected to the grid element of each of said tubes; a source of bias supply; a main normally closed bias circuit; switching means therefor for connecting said main bias supply to the control grid elements of each of said tubes to prevent firing thereof; auxiliary bias circuits for the control grid elements of certain of said tubes upon opening of the main bias circuit to said tubes; means operable to open the switch of the main bias supply circuit to a plurality of said tubes, said means causing dissipation of the capacitance from the grid circuit of one of said tubes through its resistance causing delayed discharge of said one tube only through its plate-cathode circuit; switching means connecting said auxiliary bias to certain of the other of said tubes when said main bias switch is opened; means operated by the discharge of said first-mentioned tube to open said auxiliary bias supply circuit to the control grid of a second tube to permit delayed discharge thereof; means controlled by the discharge of

said second tube for opening the auxiliary bias circuit for a third tube to cause delayed discharge thereof; additional bias circuits for the first two mentioned tubes; switching means controlled by said third tube discharge circuit for connecting said additional bias circuits for the first two tubes to the bias supply to rebias said tubes; switching means for breaking the bias supply to a fourth tube; and means under the control of said last-mentioned tube for simultaneously directly connecting the main bias supply to the first three tubes; means controlled by said last-mentioned biasing of the third tube for thereafter simultaneously disconnecting said additional bias supply to the first and second tubes.

6. In an electrical system for causing mechanical operations, said system adapted to be connected to a source of electric current, an electronic sequence timing network adapted to be energized from said source of current; said network including a plurality of space discharge tubes connected for sequential operation in said network; each of said tubes having cathode, plate and control grid elements; a plate-cathode circuit for each of said tubes; and a variable time constant network for controlling the sequential discharge of said tubes, said network including a capacitance and resistance connected to the grid element of each of said tubes; a source of bias supply; a main normally closed bias circuit; switching means for connecting said main bias supply to the control grid elements of each of said tubes to prevent firing thereof; means operable to open the switch of the main bias supply circuit to a plurality of said tubes, said means causing dissipation of the capacitance from the grid circuit thereof through its resistance causing delayed discharge through the plate cathode circuit of one tube only; additional bias circuit means adapted to be connected to a sequential tube; switching means controlled by said first-mentioned discharge circuit for opening said last-mentioned additional bias circuit to permit delayed discharge thereof; switching means controlled by said sequential tube discharge circuit for rebiasing said first-mentioned tube and for breaking the bias supply of another tube; and means under the control of said last-mentioned tube to close the first-mentioned main bias supply circuit to each of said plurality of tubes in said system.

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