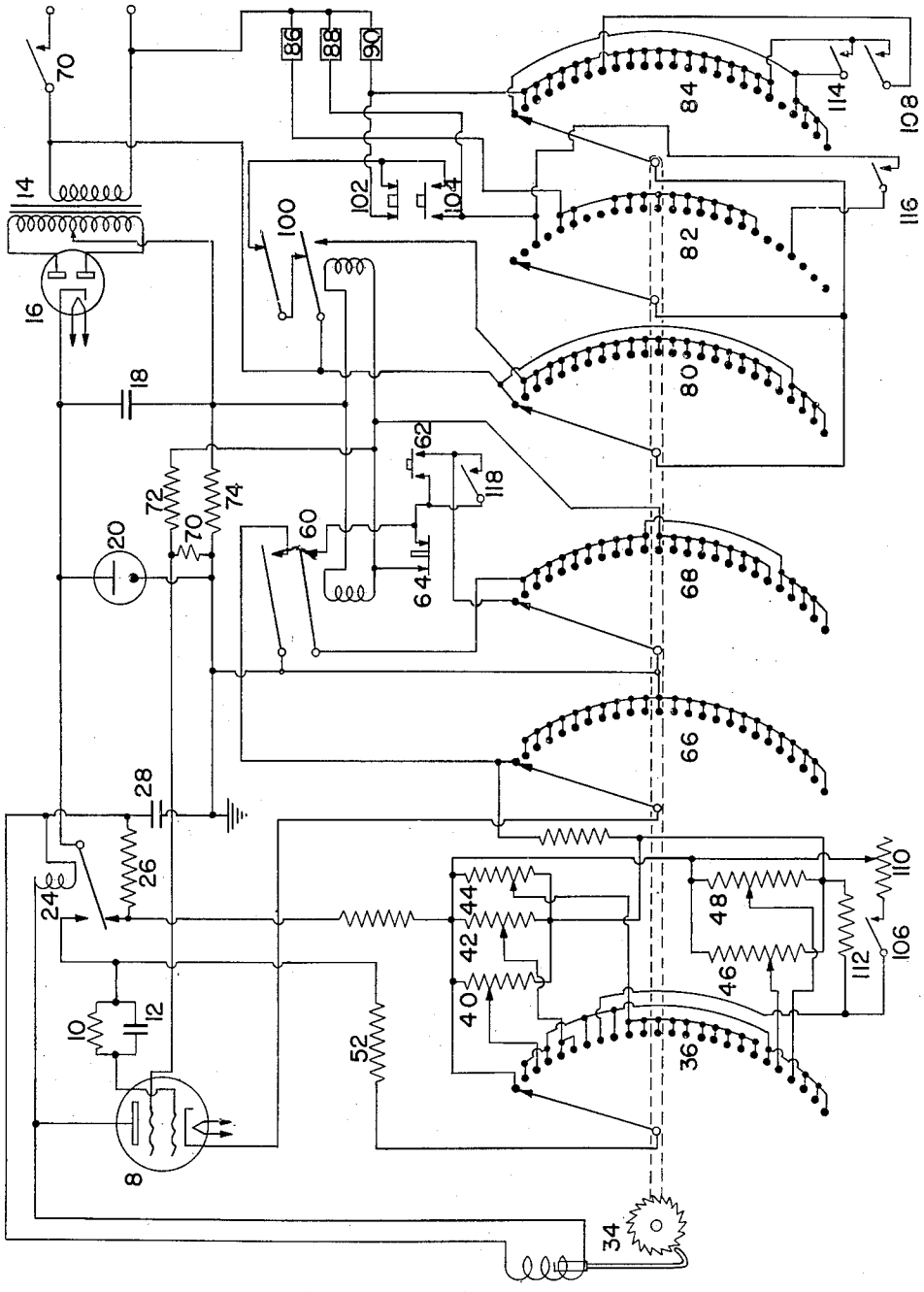
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TIMING DEVICE

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TIMING DEVICE

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The present invention relates to timing devices, and more particularly to devices for timing a series of operations according to a predetermined time sequence.

In many manufacturing operations and processes, a sequence of steps is carried out on a time basis, with definite time periods allotted for at least some of the steps. Thus, in the case of plastic molding operations, which will hereinafter be used as a typical example of a sequential operation which the timing device is well adapted to control, the sequence of operations may include charging the die with the material, a preliminary closing and pressing, a slight reopening for gassing, reclosing under full pressure, a curing period, and opening and ejection of the molded piece.

While such a sequence may be carried out under the direct control of the press operator, it has been found that substantially improved results may be obtained by providing automatic timing means for carrying out the sequence according to an accurately controlled time basis. Not only does this relieve the operator of the control problem, but it insures that intervals such as the curing period will be given the full predetermined time.

Accordingly, one of the objects of the invention is to provide a simple and effective control device for automatically carrying out a repetitive operation involving a predetermined sequence of steps, at least some of which involve intervals of appreciable duration.

It is likewise an object of the invention to provide a timing control not dependent on clockwork or similar mechanism for the basic timing element, and wherein the time intervals of the several timing periods may be readily adjusted or modified to suit the particular requirements of the operation.

Still another object of the invention is to provide apparatus for control of a sequence of operations which permits certain of said operations to be controlled on a time basis, while other steps may be automatically controlled on some other basis such as position or displacement.

In accordance with these and other objects, a feature of the invention involves the use as the basic timing unit, of a simple resistance-capacity network in association with an electron discharge device controlled thereby, the timed intervals being provided by the selective application of appropriate potentials to the resistance-capacity network. In order to permit the use of readily available values of capacity and resistance in this

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timing circuit, progressively actuated switching means are provided so that time intervals substantially longer than would normally be available in terms of the time constant of the circuit may be obtained with high accuracy.

The drawing shows a schematic wiring diagram of a time sequence control embodying the invention. For purpose of illustration, the timer is shown as arranged to provide a typical operating sequence for a plastic molding operation, a showing of the press itself being omitted as unnecessary to a full disclosure of the invention.

The timing apparatus comprises, in general, a basic timing unit (shown in the upper portion of the drawing), and switching circuits shown in the lower portion of the diagram and under the control of the timing unit.

The timing unit involves an electron discharge tube 8 with associated power supply, and a resistance-capacity (RC) network composed of resistor 10 and condenser 12 connected to the control grid. The tube 8 is preferably of the gas discharge type, although conventional high-vacuum types of tubes may be employed with minor circuit modifications. In either case, it is advantageous to employ a tetrode having a screen or second grid in addition to the control grid. Appropriate operating potentials are provided by the usual power supply composed of transformer 14, rectifier 16, filter condenser 18 and voltage regulator tube 20.

Included in the anode circuit of the tube is a relay 24 having contacts which normally connect the power supply to the anode. A series isolating resistor 26 and a shunt anode capacitor 28 of relatively high capacity are likewise included in the anode circuit.

In accordance with the usual operating characteristics of a grid-controlled gaseous discharge tube or thyratron, so long as the control grid of the tube is maintained at an appreciable negative potential relative to the cathode, the tube will be substantially non-conductive, and the anode-circuit relay 24 will remain de-energized. If, however, the grid is caused to become positive relative to the cathode, the tube "fires" or becomes conductive, and the anode current rises to a high value by reason of the discharge of condenser 28. This pulse of anode current actuates relay 24, causing its contacts to transfer and thereby disconnect the anode circuit from the power supply. As soon as the charge on condenser 28 has been dissipated, the relay returns to normal position. By this time, however, the anode potential will have dropped below the extinction voltage of the

tube, hence the tube is no longer conductive. Furthermore, the triggering potential has been removed from the control grid as will hereinafter appear, so that the tube remains non-conductive upon restoration of the full anode potential, until such time as a suitable triggering potential is again applied to the grid.

The pulse of anode current provided by the discharge of condenser 28 when the tube fires is utilized to operate a stepping relay by which the switching of the timing circuits and of the controlling circuits for the machine or process is accomplished. The stepping relay, shown in the lower portion of the diagram, is of conventional construction, having an actuating solenoid and ratchet drive indicated at 34 by which the switching arms of the several banks of contacts are advanced simultaneously. As is well known in the art, the contacts and arms are so arranged in the actual construction that there is no break in the progression of the switch arms from the last set of contacts of each bank to the first set, so as to permit continuous repetition of a cycle as the solenoid is successively energized.

The times at which the tube is fired in order that a desired operating sequence may be provided by the stepping relay are under the control of potentiometers 40, 42, 44, 46 and 48 associated with the first contact bank 36 of the stepping relay. The particular arrangement shown in the drawing and hereinafter more fully described is to be understood as merely typical, since numerous other combinations of contacts and control potentiometers are possible to provide a wide variety of control sequences. These interval-controlling potentiometers in effect provide a multiple voltage divider connected across the anode supply during normal, de-energized position of the relay 24. The various voltages which are successively derived as the stepping relay advances are applied through an isolating resistor 52 to the RC network of the control grid circuit. Before considering the switching sequence over a typical complete timing cycle, however, the method of providing a single timed interval will first be described.

Assuming for the present that the operating sequence of the timer has been initiated and that the tube has just fired, the time interval until the tube next fires is provided in the following manner. As has already been indicated, when the tube becomes conductive, the relay 24 is briefly actuated. This disconnects the anode circuit from the anode supply, and transfers the latter to the RC circuit of the control grid. Since the tube remains conductive until the charge on condenser 28 drops below the extinction voltage for the tube, the condenser 12 becomes charged with a potential equal to the anode supply voltage less the relatively small potential drop across the diode composed of control grid and cathode. By way of illustration, for an anode supply potential of 150 volts, the charge on condenser 12, or difference in potential between the two sides of the condenser, might be of the order of 140 volts, allowing a 10 volt drop between grid and cathode for conductive conditions.

Upon the substantial completion of discharge of the anode condenser 28 and the consequent extinction of the tube, the RC circuit is disconnected by the relay from the anode supply line and is connected through the voltage divider circuit to a point of relatively lower potential. The magnitude of this reference potential is adjustable, depending on the particular potentiometer setting. Because of the charge on condenser 12, the control grid is now negative by the amount the charge exceeds the reference potential. Thus the tube, which has been extinguished, does not become conductive when anode potential is reapplied.

The charge on condenser 12 is gradually dissipated by the shunt resistor 10, the difference in potential decreasing exponentially. After a time dependent on the reference potential supplied by the voltage divider setting, the control grid potential reaches a value, relative to cathode, at which the tube fires, causing the stepping relay to advance one contact and initiating the next timing interval.

By way of illustration of the time intervals which may be provided with this type of basic timing unit, it has been found possible to provide periods from approximately 1.5 seconds to 60 seconds, using values of the order of 20 megohms and 2 microfarads for the resistor 10 and condenser 12 of the RC circuit. The fact that only a single RC circuit is employed as the critical timing unit is of advantage, since it enables the components to be sealed in a single envelope to minimize the effects of changes in atmospheric conditions.

In order to provide accurately timed intervals substantially longer than could be provided in a single timing interval with an RC timing circuit having a time constant of readily realizable magnitude, the present invention provides for multiplying the time intervals through use of the stepping switch. Thus, a plurality of contacts of the voltage divider bank may be connected together to provide a cumulative interval equal to the sum of the intervals. By joining ten contacts, for example, a period of approximately ten minutes may be accurately timed, the relay advancing one contact for each interval as determined by the common potentiometer setting.

To provide control over the starting and stopping of the timing sequence, and to permit either automatic or nonautomatic repetition thereof, a relay 60 may be employed in conjunction with push-button type start and stop switches 62 and 64, making use of banks 66 and 68 of the stepping relay. With the relays 24 and 60 in the position shown, but with the power supply switch 70 closed, the following conditions prevail in the circuit. The anode, control grid and cathode are all at the full anode potential (positive) since the cathode and the interval-determining voltage divider circuits are interconnected but ungrounded, the upper contacts of relay 60 being open. The screen grid is at a negative potential, however, since resistors 70 and 72 form a voltage divider across resistor 74. Thus the timer will remain in standby condition indefinitely.

Upon pressing the start button 62, the relay 60 is energized, connecting the cathode and the screen grid of the tube to ground and causing the tube immediately to fire, since the control grid is already at positive potential. The stepping relay thereupon advances to the second contact position to complete a holding circuit for relay 60 through the lower set of relay contacts and switch bank 68, and to connect the cathode and voltage divider group to ground through switch bank 66. The timer will then proceed with the operating sequence in accordance with the particular settings and arrangement of the interval controlling switch and potentiometers.

If the stop button 64 be pushed during the

carrying out of a timing sequence, as for an emergency stop, the relay 60 is de-energized. This opens the interval-controlling voltage divider circuit to ground, but leaves the cathode grounded through switch bank 66 except when the latter's arm is at "home" position. Since the control grid remains at high positive potential, the tube fires in rapid succession, at a frequency determined by the voltage across resistor 70. Only sufficient time is necessary to allow the condenser 28 to build up its charge before the tube again fires. If the connection 74 be omitted and all contacts of switch bank 68 except the first, be connected together, whenever the stop button is depressed the stepping relay will rapidly advance automatically to "home" position and come to rest in that position. In the arrangement shown, where a separate connection is provided from the twelfth through the twentieth contact, inclusive, of bank 68 around the stop switch, the stop switch is rendered ineffective during the time the stepping relay is on said contacts. This prevents an operator, during that portion of the timing sequence, from improperly shortening the time interval for which the timer may be set, as for example the cure period in a plastic molding operation.

To apply the timing sequence of the timer to the control of a machine or process, connections are made to the stepping relay, as many switch banks being utilized as are necessary to handle the circuits to be controlled. In the illustrative embodiment of a timer suitable for controlling a molding press, three switch banks 80, 82 and 84 are shown connected to relay devices 86, 88 and 90 which may be taken to represent solenoid-actuated valves in control of the high pressure, low pressure, and return lines of the press. In addition, a relay 100 and supplementary push button switches 102 and 104 are included for flexibility of control in this typical application. These switches permit, at certain stages in the operating sequence, such as before initiation of a timing cycle and consequent energization of relay 100, manual control of press opening and closing, through actuation of the low pressure and release valve controls 88 and 90, respectively.

A complete operating sequence will now be described by way of illustration only, since the actual control sequence is merely typical. Upon initiating the timing cycle by means of push button 62, the tube immediately fires, as has already been indicated, thus advancing the stepping relay to the second contact. The cathode is now connected to ground for the duration of the cycle by switch bank 66, and the relay 60 is held closed by bank 66. The switches 102 and 104 have been by-passed by relay 100 to insure automatic control of the press, and the return valve 90 is held open by switch bank 84.

The stepping relay quickly advances to the third contact, due to the high positive reference potential provided at the second contact of bank 36. The time interval at the third contact is determined by the setting of potentiometer 40. This provides for rapid press closing by the low pressure supply, via the third contact of bank 82. Next the low pressure is cut off (fourth contact), and the high pressure briefly applied (fifth and sixth contacts of bank 82), for a preliminary pressing determined by potentiometer 42.

To provide a gassing cycle, the high pressure supply is cut off at the seventh contact, and at the eighth contact a supplementary control circuit becomes operative to provide a predetermined separation of the mold. For this purpose, switches 106 and 108 are mounted on the press to be closed by the press movement when the mold has opened the desired distance for gassing. When the eighth contact of bank 84 is reached, the valve 90 is de-energized to operate the pull back and open the press. As soon as limit switch 108 is closed, however, the valve 90 is re-energized to stop further opening.

The length of time the press stays in this partly open position for gassing is controlled by variable resistor 110. Since, before the closing of switch 106, the reference voltage applied through resistor 112 to the RC is relatively low, a substantial time interval is provided, permitting control by some external control means, illustrated here by this limit switch. Alternatively, a negative reference voltage may be provided by connection to an appropriate point in the circuit to provide indefinite suspension of the timing cycle, until resumed through operation of the external device or control.

Upon termination of the gassing cycle as timed by resistor 110, the high pressure is applied to close the mold and begin the cure period. It will be observed that the tenth through nineteenth contacts of bank 36 are connected together to provide a multiplied or cumulative time interval during which the tube fires at intervals determined by the setting of potentiometer 44. Throughout this period, which may be a matter of several minutes, the high pressure valve is energized by switch bank 82. As has previously been indicated, during this cure period the stop switch 64 is by-passed by the connection 74 to the corresponding contacts of switch bank 68 to prevent interrupting or shortening the curing time.

Following the cure period, the high pressure is cut off by bank 82, twentieth contact, and the release valve 90 deenergized by bank 84, twenty-first contact, to render the pullback operative. The distance the press opens is determined by the time interval provided by potentiometer 46, if switch 114 has been closed. If switch 114 is left open, the press will fully open at the end of the cure period. Switch 116 provides, when desired, for automatic partial reclosing of the press following removal of the molded piece and preparatory to a new molding cycle, the extent of reclosing being controlled on a time basis by the duration of the interval provided by potentiometer 48. The final contacts, the twenty-third, fourth and fifth, are passed over rapidly by reach of the high reference voltage, bringing the switch arms of the stepping relay to the initial or home position, where the timer goes into standby condition by reason of the opening of the holding circuit for relay 60.

By providing a switch 118 in parallel with the push button start switch 62, the sequence may be made to repeat automatically, where such mode of operation is desired. When it is desired to stop the repetition, it is merely necessary to open switch 118, and the timer will complete the sequence and then come to rest in its standby position.

For applications where it is advantageous to permit adjustment of the relative times of two or more intervals while maintaining the total time unchanged, the potentiometers in control of said intervals may be interconnected in the manner of the conventional T-pad so that the reference potential provided by one potentiometer is decreased when the other is increased, and vice versa.

I have described as my invention an electrical

timing control or relative simplicity, yet adapted for accurate and reliable control of numerous types of machines and processes requiring a wide range of timed intervals according to a definite sequence. My invention may thus be considered as involving an electrical timing control wherein the timing intervals are determined by a single RC timing circuit whose reference potential is modified by appropriate switching and control means to provide a succession of timed intervals of predetermined duration. While a particular embodiment of the invention has been described, this is by way of illustration only, as it will be understood that numerous modifications and adaptations of the control principles to specific applications may be made, within the scope of the appended claims.

I claim:

1. A timing control comprising an electron discharge device having an anode, a cathode and a control grid, a condenser connected to the grid, multiple, voltage divider means for supplying a plurality of reference potentials, relay switching means in the anode circuit responsive to flow of anode current for briefly connecting the condenser to a source of charging potential and for thereafter applying a selected reference potential to the condenser to cause the control grid to assume a potential differing from the reference potential by the charge on the condenser, a resistor for dissipating the condenser charge to cause the grid, after a time dependent on the magnitude of the reference potential, to render the electron discharge device operative, said relay switching means including stepwise actuated switching means for successively applying selected reference potentials to the condenser to provide a predetermined sequence of timed intervals between successive operations of the electron discharge device.

2. A timing control comprising an electron discharge device having an anode, a cathode and a control grid, a condenser connected to the control grid, voltage divider means for developing a reference potential, relay means in the anode circuit responsive to flow of anode current for applying a charging potential to the grid condenser when the relay means is actuated and for connecting the grid condenser to the source of reference potential when the relay means is de-energized, whereby a potential is applied to the control grid differing from the reference potential by the charge on the condenser, a resistor connected across the grid condenser for dissipating the charge thereon and for causing the control grid after a time dependent on the reference potential to assume a potential at which the electron discharge device becomes operative, and switching means actuated stepwise by successive operations of the electron discharge device for repetitively applying the reference potential upon said successive operations to provide a timed interval equal to the sum of the intervals.

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