

Jan. 18, 1938.

D. C. WRIGHT

2,105,899

CURRENT FLOW TIMING DEVICE

Filed April 27, 1935

3 Sheets-Sheet 1

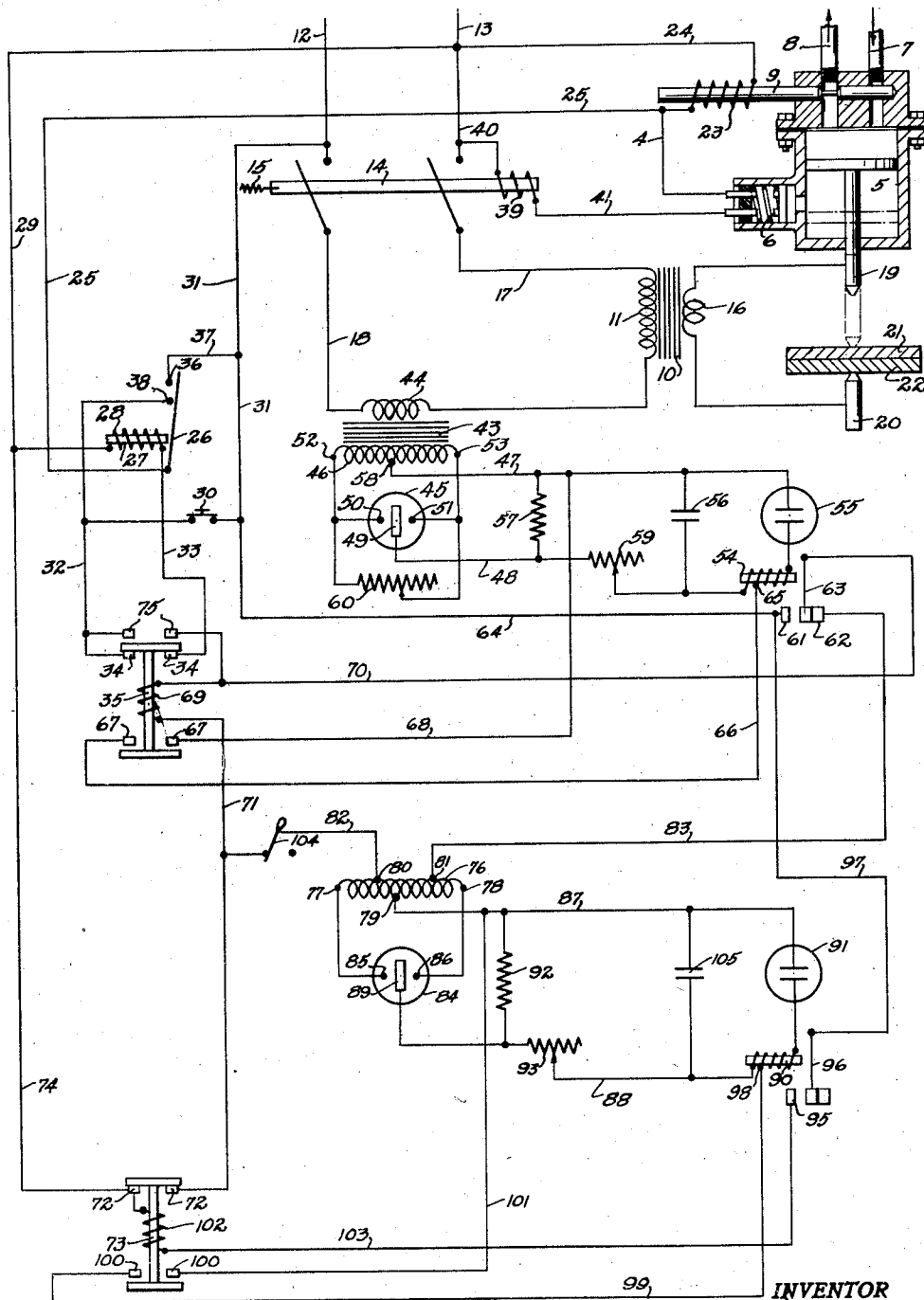


Fig. 1

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3 Sheets-Sheet 2

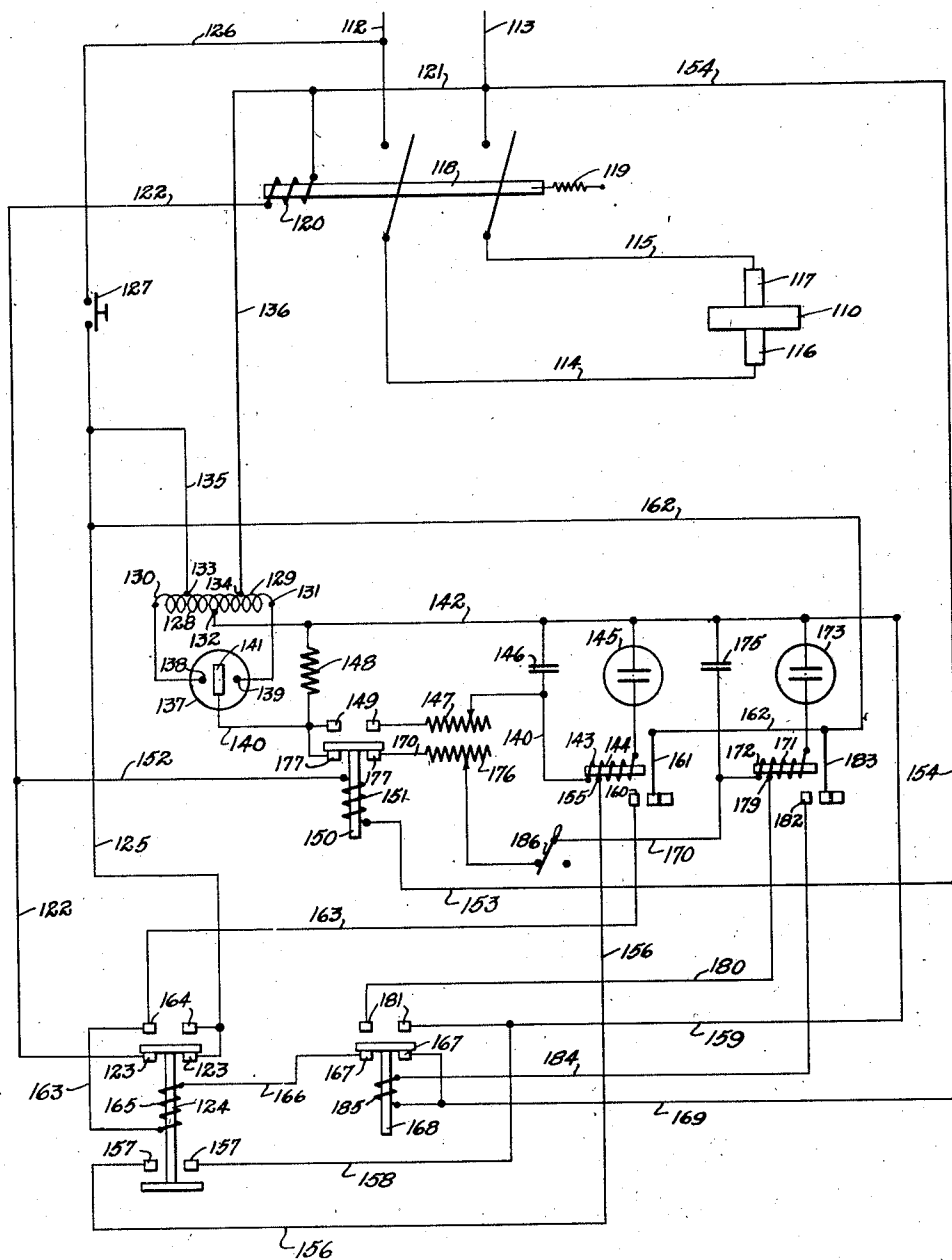


Fig. 2

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3 Sheets-Sheet 3

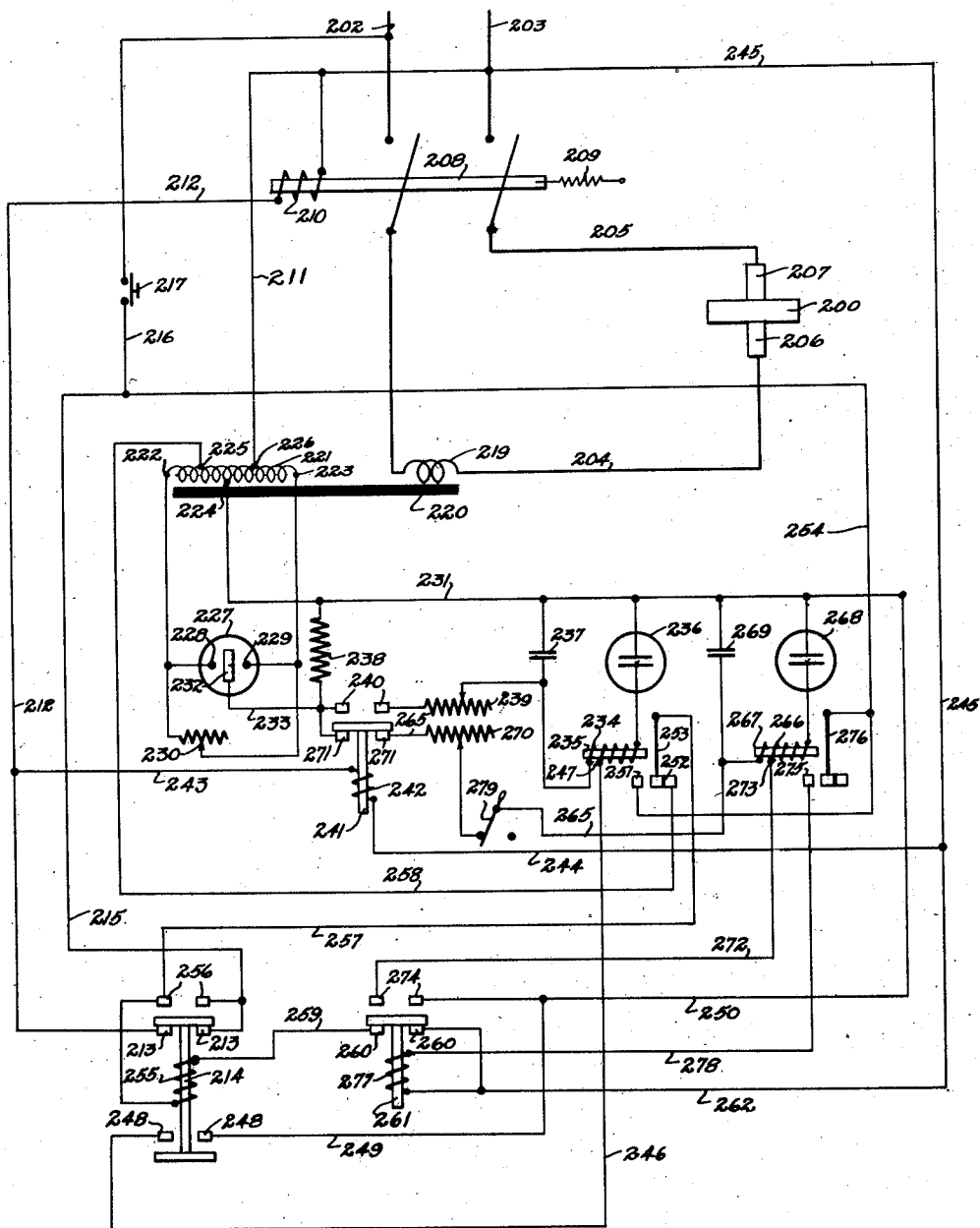


Fig. 3

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2,105,899

CURRENT FLOW TIMING DEVICE

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Application April 27, 1935, Serial No. 18,490

27 Claims. (Cl. 219-4)

This invention relates to apparatus for timing the duration of application of electric current to a work-circuit, and for timing the duration of the period between successive applications of electric current to the work-circuit, and an object of the invention is to provide a new and improved apparatus of this character.

Another object is to provide improved means to automatically time the duration of current flow in a work-circuit for durations of time substantially inversely proportional to the strength of the current in the work-circuit, whereby the duration of current flow in the work-circuit is automatically varied and a substantially predetermined quantity of current is supplied to the work-circuit regardless of the resistance of the work-circuit.

Another object is to provide means to automatically determine the duration of current flow in a work-circuit for durations of time substantially inversely proportional to the magnitude of the voltage applied to the work-circuit, whereby the duration of current flow in the work-circuit is automatically varied dependent upon the magnitude of the voltage applied to the work-circuit.

A further object is to provide means to automatically time the duration of the period between successive applications of electric current to a work-circuit for durations of time substantially inversely proportional to the strength of the voltage applied to said means.

Other objects will appear as my invention is described hereinafter.

This application is a continuation in part of my co-pending applications Serial Nos. 629,642 and 629,643, filed August 20, 1932, since matured into Patent Nos. 2,023,631 and 2,024,019, dated Dec. 10, 1935 and Serial No. 737,419, filed July 28, 1934.

In the drawings accompanying this specification and forming part of this application I have shown, for purposes of illustration, certain embodiments which my invention may assume, and in these drawings:

Figure 1 is a circuit diagram of one embodiment of my invention,

Figure 2 is a circuit diagram of another embodiment of my invention, and

Figure 3 is another circuit diagram of a different embodiment of my invention.

The embodiment of the invention disclosed in Fig. 1 includes a schematic arrangement of parts of a spot-welding machine, not completely shown, comprising a cylinder 5, a pressure switch 6, an inlet fluid conduit 7, and outlet fluid conduit 8, a

control valve 9 which controls the flow of fluid in the conduits 7 and 8, a movable electrode 19 and a stationary electrode 20. The movable electrode 19 is moved by the fluid in the cylinder 5 into engagement with a work-piece 21 and presses the latter against a work-piece 22, here shown in engagement with the stationary electrode 20. The pressure switch 6 is adapted to be closed after the movable electrode 19 is in engagement with the work-piece 21 and after a predetermined pressure has been developed in the cylinder 5.

Included in the work-circuit is a welding transformer 10 provided with a primary winding 11 supplied with alternating current from a pair of supply lines 12 and 13 through conductors 17 and 18 in which is interposed a magnetically-operated welding switch 14 normally held in open position by a spring 15. The secondary winding 16 of the welding transformer 10 is adapted to be connected to the welding electrodes 19 and 20.

The control valve 9 is provided with an operating coil 23 having one terminal connected through a conductor 24 to the supply line 13 and the other terminal connected through a conductor 25 to a movable contact arm 26 of a relay 27.

The relay 27 is provided with a relatively stationary contact 36 connected through conductors 37 and 31 to the supply line 12, and is further provided with an operating coil 28 having one of its terminals connected through a conductor 29 to the supply line 13, and having the other of its terminals connected through a conductor 33, normally closed contacts 34 of a control relay 35, and a conductor 32 to another relatively stationary contact 38 of the control relay 27.

Connecting the conductors 31 and 32 is a push button 30 closure of which energizes the operating coil 28 of the relay 27 to move the contact 26 into engagement with the contacts 38 and 36.

Closure of the contacts 36 and 26 of the relay 27 completes the energizing circuit for the operating coil 23 of the valve 9.

Engagement of the contacts 36, 38 and 26 of the relay 27 completes a holding circuit for maintaining the operating coil 28 of the relay 27 energized in case the push-button 30 is released during a welding period.

The welding switch 14 is provided with an operating coil 39 which has one terminal connected to a conductor 40 and in turn connected to the supply line 13, and has another terminal connected to a conductor 41, pressure switch 6, conductors 4 and 25, contacts 26 and 36 of the relay 27, and the conductors 37 and 31 to the

supply line 12. Closure of the pressure switch 6 effects energization of the operating coil 39 which then closes the switch 14.

The duration of time that the welding switch 14 is maintained closed may be controlled by means hereinafter identified as "on timing" means for the reason that they determine the duration of the "on period", that is, the welding period, and comprise in this instance, a series transformer 43 having its primary winding 44 interposed in circuit with the circuit of the primary winding 11 of the welding transformer 10.

A rectifier 45 is provided for rectifying the alternating current supplied by the secondary winding 46 of the series transformer 43. The secondary winding 46 and the rectifier 45 are respectively connected to output conductors 47 and 48, the conductor 47 being connected to a center tap 58 of the secondary winding 46, and the conductor 48 being connected to one of the electrodes 49 of the rectifier 45. The rectifier 45 also has electrodes 50 and 51 connected respectively to the terminals 52 and 53 of the secondary winding 46. Shunted across the electrodes 50 and 51 of the rectifier 45 is a variable resistance 60, which can be open-circuited if desired.

The output conductors 47 and 48 are adapted to supply unidirectional current to the operating coil of a sensitive relay 54, here shown connected in series with a neon tube 55. A condenser 56 has its terminals connected to the output conductors 47 and 48 in shunt with the sensitive relay 54 and the neon tube 55. Also shunted across the output conductors 47 and 48 is a resistance 57. Interposed in one of the output conductors, here shown as output conductor 48, is an adjustable resistance 59 disposed on the supply side of the condenser 56.

The operating coil of the sensitive relay 54 is here shown as having a conductor 66 tapped thereto at a point 65 intermediate the terminals of the operating coil of the sensitive relay 54. The conductor 66 is connected through the normally-open contacts 67 of the control relay 35 and a conductor 68 to the output conductor 47.

The sensitive relay 54 is provided with relatively stationary contacts 61 and 62, and a movable contact arm 63 which normally engages the stationary contact 62. The stationary contact 61 being connected through a conductor 64 and the conductor 31 to the supply line 12.

The operating coil 69 of the control relay 35 has one of its terminals connected through a conductor 70 to the movable contact arm 63 of the sensitive relay 54, and has the other of its terminals connected to a conductor 71, normally-closed contacts 72 of a control relay 73, a conductor 74, and the conductor 29 to the supply line 13. Connected to the conductors 32 and 70 are normally-open contacts 75 of the control relay 35.

The duration of time that the welding switch 14 is maintained open may be controlled by means hereinafter identified as "off timing" means for the reason that such means determine the duration of the "off period", that is, the period between successive welding periods, and comprise in this instance an auto transformer 76 provided with terminal taps 77 and 78, a center tap 79, and intermediate taps 80 and 81.

A rectifier 84 is provided for rectifying the alternating current supplied by the auto transformer 76, and the rectifier 84 has electrodes 85 and 86 connected respectively to the terminal

taps 77 and 78 of the auto transformer 76. An output conductor 87 is connected to the center tap 79 of the transformer winding, and an output conductor 88 is connected to another one of the electrodes 89 of the rectifier 84.

The output conductors 87 and 88 are adapted to supply unidirectional current to the operating coil of a sensitive relay 90 here shown as connected in series with a neon tube 91. A condenser 105 has its terminals connected to the output conductors 87 and 88 in shunt with the sensitive relay 90 and the neon tube 91. Also shunted across the output conductors 87 and 88 is a resistance 92. Interposed in one of the output conductors, here shown as output conductor 88, is an adjustable resistance 93 disposed on the supply side of the condenser 105.

The operating coil of the sensitive relay 90 is here shown as having a conductor 99 tapped thereto at a point 98 intermediate as between the terminals of the operating coil of the sensitive relay 90. The conductor 99 is connected through the normally-open contacts 100 of the control relay 73 and a conductor 101 to the output conductor 87.

The sensitive relay 90 is provided with a relatively stationary contact 95 and a movable contact arm 96 which is connected through conductors 97, 94, 31 and to the supply line 12.

The operating coil 102 of the control relay 73 has one of its terminals connected to one of the contacts 72 of the control relay 73 and has the other of its terminals connected through a conductor 103 to the stationary contact 95 of the sensitive relay 90.

Interposed in the conductor 82 is a selector switch 104 which is adapted to open or to close the circuit between the conductor 71 and the intermediate terminal 80 of the transformer 76. When the selector switch 104 is in closed position the system is adapted to provide alternate repeat operations of the "on timing" means and of the "off timing" means, and when in open position is adapted to permit only operations of the "on timing" means.

In operation, assume it is desired to have repeat operation, that is alternate operation of the "on time" circuits and of the "off time" circuits, the selector switch 104 is placed in "repeat" position which closes the conductor 82.

The push-button 30 is closed to complete the energizing circuit for the operating coil 28 of the relay 27, from the supply line 12 through conductor 31, push-button 30, conductor 32, normally closed contacts 34 of the control relay 35, conductor 33, operating coil 28, and conductor 29 to the supply line 13. Energization of the operating coil 28 effects closing of the contact arm 26 which completes the energizing circuit for the operating coil 23 of the valve 9, from the supply line 12, through conductors 31 and 37, contacts 36 and 26, conductor 25, operating coil 23 and conductor 24 to the supply line 13. Energization of the operating coil 23 operates the control valve 9 to open the inlet conduit 7 and to close the outlet conduit 8 whereby fluid enters the cylinder 5 and moves the electrode 19 into engagement with the work-piece 21.

Upon engagement of the electrodes 19 and 20 with the work-pieces 21 and 22 and after a predetermined pressure is exerted by the electrodes 19 and 20 on the work-pieces 21 and 22, the pressure switch 6 is automatically closed by the fluid in the cylinder 5. Closure of the pressure switch 6 completes the energizing circuit for the oper-

ating coil 39 of the switch 14, from the supply line 12 through conductors 31 and 37, contacts 36 and 26, conductors 25 and 4, pressure switch 6, conductor 41, operating coil 39, and conductor 40 to the supply line 13. The energized operating coil 39 closes the switch 14 to permit flow of current through the primary windings 44 and 11 to the work-pieces 21 and 22 to start a welding period.

A voltage is induced in the secondary winding 46 from the primary winding 44. The voltage delivered by the secondary winding 46 is rectified by the rectifier 45 which provides unidirectional voltage to the condenser 56. The condenser 56 accumulates a charge until a predetermined voltage is reached, at which voltage the neon tube 55 becomes conducting and permits discharge of the charge accumulated in the condenser 56.

The sensitive relay 54 is energized when the neon tube 55 becomes conducting and is maintained energized for a period, moving the contact arm 63 into engagement with the contact 61. Closure of the contacts 61 and 63 of the sensitive relay 54 completes an energizing circuit for the operating coil 69 of the control relay 35, from the supply line 12, conductors 31 and 64, contacts 61 and 63, conductors 70, operating coil 69, conductor 71, normally closed contacts 72 of the control relay 73, and conductors 74 and 29 to the supply line 13.

Energization of the operating coil 69 of the control relay 35 opens the contacts 34 and closes the contacts 67 and 75 of the control relay 35.

Opening of the contacts 34 of the control relay 35 de-energizes the operating coil 28 of the relay 27, which then de-energizes the operating coil 23 of the control valve 9 and the operating coil 39 of the welding switch 14, interrupting the flow of current to the work-pieces 21 and 22, and terminating the welding period.

The closing of the contacts 67 of the control relay 35 completes a shunt circuit from the output conductor 48, through a portion of the operating coil of the sensitive relay 54, the conductor 66, through the closed contacts 67 and the conductor 68 to the output conductor 47. The condenser 56 discharges through this shunt circuit and maintains the tapped portion of the operating coil of the sensitive relay 54 as included in the shunt circuit, energized for a sufficient length of time to maintain the sensitive relay contacts 61 and 63 closed for a period after the closure of the contacts 75 of the control relay 35.

Closing of the contacts 75 maintains the control relay 35 energized, which would otherwise be de-energized by the opening of the contact 61 of the sensitive relay 54. After closure of the holding circuit contacts 75, the discharge from the condenser 56 is not sufficient to maintain the tapped portion of the sensitive relay 54 sufficiently energized to hold the contact 63 in engagement with contact 61, and accordingly contact 61 opens, and the contacts 63 and 62 close which complete an energizing circuit for the auto-transformer 76, from the supply line 12, through conductor 31, push-button 30, conductor 32, closed contacts 75, conductor 70, contacts 63 and 62, conductor 83, transformer 76, conductor 82, closed selector switch 104, conductor 71, closed contacts 72 of the control relay 73, conductor 74, and conductor 29 to the supply line 13.

The voltage delivered by the auto transformer 76 is rectified by the rectifier 84 which provides unidirectional voltage to the condenser 105. The

condenser 105 accumulates a charge until a predetermined voltage is reached, at which voltage the neon tube 91 becomes conducting and permits discharge of the charge accumulated in the condenser 105.

The sensitive relay 93 is energized when the neon tube 91 becomes conducting and is maintained energized for a period thereby moving the contact arm 96 of the sensitive relay 90 into engagement with the contact 95. Closure of the contacts 95 and 96 of the sensitive relay 90 completes an energizing circuit for the operating coil 102 of the control relay 73 from the supply line 12, through the conductors 31, 64 and 97, contact arm 96, contact 95, conductor 103, operating coil 102 of the control relay 73, and conductors 74 and 29 to the supply line 13. Energization of the operating coil 102 of the control relay 73 opens the contacts 72 and closes the contacts 100.

Opening of the contacts 72 de-energizes the operating coil 69 of the control relay 35 which opens the holding circuit contacts 75, and closes the contacts 34, thus completing the circuit to the operating coil 28 of the relay 27 to thereby begin another welding period. Opening of the contacts 72 also interrupts flow of current to the auto-transformer 76.

At the same time the closing of the contacts 100 of the control relay 73 completes a shunt circuit from the output conductor 88, through a portion of the operating coil of the sensitive relay 90, the conductor 99, through the closed contacts 100 and the conductor 101 to the output conductor 87.

The condenser 105 discharges through the foregoing shunt circuit and maintains the tapped portion of the operating coil of the sensitive relay 90, included in the shunt circuit, energized for a sufficient length of time to hold the sensitive relay contacts 95 and 96 closed for a period after opening of the contacts 72 of the control relay 73. Maintaining the sensitive relay contacts 95 and 96 closed for a period insures sufficient de-energization of the operating coil 69 of the control relay 35 to definitely open the contacts 75 and to definitely close the contacts 34. After definite closure of the contacts 34, the discharge from the condenser 105 is not sufficient to maintain the tapped portion of the sensitive relay 90 sufficiently energized to hold the contacts 95 and 96 closed, and accordingly contacts 95 and 96 open, breaking the circuit to the operating coil 102 of the control relay 73, which then operates to close the contacts 72. Closure of the contacts 72 of the control relay 102, and of the contacts 34 of the control relay 35 places the "on-timing" means again in circuit for another welding period.

Alternate repeat operations of the "on timing" means and of the "off timing" means is obtained as long as the push-button 30 is held closed. If the push-button 30 is opened while a weld is in progress the welding operation will continue until the weld is completed, and the alternate repeat operations of the "on timing" means and of the "off timing" means will then cease, but may be started by again closing the push-button.

For single welds, that is performing welds without employing the "off timing" means, the selector switch 104 is moved to its "single" position, which is its open position, and prevents operation of the auto-transformer 76. On repeated operation of the push-button 30, single repeat welding operations of the "on timing" means will be had without operation of the "off timing" means.

From the foregoing, it will be perceived that the magnitude of the voltage supplied to the secondary winding 46 of the transformer 43 is a function of the magnitude of the current flowing through the work-pieces 21 and 22. Consequently, the time required for the condenser 56 to accumulate a sufficient charge to permit the neon tube circuit to become conducting and energize the sensitive relay 54, is greater for small currents passing through the work-pieces 21 and 22, and is less for large currents passing through the work-pieces 21 and 22.

In other words, the duration of the welding period is not constant but is automatically determined and varied by the magnitude of the current flowing through the work-pieces 21 and 22.

Accordingly, my invention is adapted to weld together work-pieces of different thicknesses, or of different material, since the "on timing" means will automatically interrupt the flow of current to the work-pieces after a predetermined quantity of current has passed through the work-pieces to thereby uniformly weld all of the work-pieces.

The duration of the welding period may be varied by varying the resistance 59, thereby increasing or decreasing the resistance in the supply circuit of the condenser 56 and decreasing or increasing the charging rate of the condenser 56 thus lengthening or shortening the welding period.

The welding period may also be varied by varying the capacity of the condenser 56, and the number of or characteristics of the neon tube 55.

The current range of the transformer 43 is changed by varying the loading resistance 60. Increasing the resistance 60 increases the magnitude of the voltage in the secondary winding 46 and the voltage supplied to the condenser 56, causing the condenser 56 to more rapidly accumulate the voltage required to operate the neon tube 55, and decrease the duration of operation of the "on timing" means and the duration of current flow in the work-circuit.

It will also be perceived that the duration of the "off period", that is the period between successive welding periods, is substantially constant, and is dependent upon the magnitude of the voltage supplied to and furnished by the auto transformer 76. The duration of the "off period" may be altered by varying the resistance 93, by varying the capacity of the condenser 105 and by varying the number of or characteristics of the neon tube 91.

Referring to Fig. 2, the embodiment of the invention therein disclosed comprises a load 110 adapted to be supplied with alternating current from a pair of supply lines 112 and 113, through conductors 114 and 115 connected respectively to electrodes 116 and 117 here shown respectively in an engagement with the load 110.

Interposed in the conductors 114 and 115 is a magnetically operated switch 118 normally held in open position by means of a spring 119. The switch 118 is closed upon energization of its operating coil 120 having one of its terminals connected to a conductor 121 in turn connected to the supply line 113, and having the other of its terminals connected to a conductor 122, normally-closed contacts 123 of a control relay 124, conductors 125 and 126 to the supply line 112. The operating coil 120 of the switch 118 is energized by the closure of a push-button 127 interposed in the conductor 126.

The duration of time that the switch 118 is maintained closed may be controlled by means herein identified as "on timing" means for the reason that they determine the duration of the "on period", that is, the period that current is supplied to the load 110, and comprise in this instance, an auto transformer 128, having its winding 129 provided with terminal taps 130 and 131, a center tap 132 and intermediate taps 133 and 134. Alternating current is supplied to the winding 129 from the supply line 112 through the conductor 126, a conductor 135, winding 129, a conductor 136 and the conductor 121 connected to the supply line 113.

A rectifier 137 is provided for rectifying the alternating current furnished by the auto-transformer 128, and has electrodes 138 and 139 connected to the terminal taps 130 and 131 respectively of the winding 129 of the transformer 128.

An output conductor 140 is connected to another electrode 141 of the rectifier 137, and an output conductor 142 is connected to the center tap 132 of the winding 129 of the transformer 128. The output conductors 140 and 142 are adapted to supply unidirectional current to the operating coil 143 of a sensitive relay 144, here shown connected in series with a neon tube 145.

A condenser 146 has its terminals connected to the output conductors 140 and 142 in shunt with the sensitive relay coil 143 and the neon tube 145. Shunted across the output conductors 140 and 142 is a resistance 148.

Interposed in the output conductor 140 is a variable resistance 147 and normally open contacts 149 of a relay 150. Energization of the operating coil 151 of the relay 150 effects closure of the normally open contacts 149 to complete the circuit to the condenser 146. The operating coil 151 has one of its terminals connected to a conductor 152 in turn connected to conductor 122, and has the other of its terminals connected to a conductor 153 in turn to a conductor 154 which is connected to the supply line 113.

The operating coil 143 of the sensitive relay 144 is here shown as having a conductor 156 tapped thereto at a point 155 intermediate the terminals of the operating coil 143. The conductor 156 is connected through the normally open contacts 157 of the control relay 124, a conductor 158, and a conductor 159 to the output conductor 142.

The sensitive relay 144 is provided with a relatively stationary contact 160 and a movable contact arm 161 which is connected to a conductor 162 in turn connected through the conductor 126 to the supply line 112.

The operating coil 165 of the control relay 124 has one of its terminals connected through one of the normally open contacts 164 of the control relay 124 to a conductor 163 to the stationary contact 160 of the sensitive relay 144, and it has the other terminal connected to a conductor 166, normally closed contacts 167 of a reset relay 168 and a conductor 169 to the conductor 154 in turn connected to the supply line 113.

The duration of time that the switch 118 is maintained open may be controlled by means hereinafter identified as "off timing" means because such means determine the duration of the "off period", that is, the period between successive applications of current to the load 110, and comprise in this instance an output conductor 170 connected to the rectifier 137 through conductor 140. The output conductors 142 and 170 supply unidirectional current to the operating

coil 171 of a sensitive relay 172 here shown connected in series with a neon tube 173.

A condenser 175 has its terminals connected to the output conductors 170 and 142 in shunt with the sensitive relay coil 171 and the neon tube 173. The resistance 148 is also shunted across the output conductors 142 and 170.

Interposed in the output conductor 170 is a variable resistance 176 and the normally closed contacts 177 of the relay 150, which controls the circuit to the condenser 175, the neon tube 173 and the sensitive relay 172.

A selector switch 186 interposed in the output conductor 170 is adapted to open or to close the output conductor 170 and thereby respectively open or close the circuit between the transformer 128 and the condenser 175 and neon tube 173. When the selector switch 186 is in closed position the system is adapted to provide alternate repeat operations of the "on timing" means and of the "off timing" means, and when in open position is adapted to provide only operations of the "on timing" means.

The operating coil 171 of the sensitive relay 172 is here shown as having a conductor 180 tapped thereto at a point 179 intermediate the terminals of the operating coil 171 of the sensitive relay 172. The conductor 180 is connected through the normally open contacts 181 of the reset relay 168 to the conductor 159 in turn connected to the output conductor 142.

The sensitive relay 172 is provided with a relatively stationary contact 182 and a movable contact arm 183 which is connected through the conductor 162 to the conductor 126 to the supply line 112.

The operating coil 185 of the reset relay 168 has one of its terminals connected through a conductor 184 to the stationary contact 182 of the sensitive relay 172, and the other of its terminals is connected to the conductor 169.

In operation, assume it is desired to have repeat operation, that is alternate operation of the "on time" and "off time" circuit means, the selector switch 186 is disposed in its "repeat" position, that is its closed position.

The push-button 127 is closed to complete an energizing circuit for the operating coil 120 of the switch 118, from the supply line 112, through conductor 126, push-button 127, conductor 125, normally-closed contacts 123 of the control relay 124, conductor 122, operating coil 120, and the conductor 121 to the supply line 113. Energization of the operating coil 120 closes the switch 118 permitting current flow to the electrodes 116 and 117 and the application of the current to the load 110.

Closure of the push-button 127 effects energization of the operating coil 151 of the relay 150 to close the contacts 149 and thus close the output conductor 140 and complete the circuits to the condenser 146 and neon tube 145. Closure of the push-button 127 also completes a circuit to the auto transformer 128 whereby the latter is supplied with current from the supply lines 112 and 113.

The voltage furnished by the auto-transformer 128 is rectified by the rectifier 137, providing unidirectional current to the condenser 146. The condenser 146 accumulates a charge until a predetermined voltage is reached, at which voltage the neon tube 145 becomes conducting and permits discharge of the charge accumulated by the condenser 146.

The operating coil 143 of the sensitive relay

144 is energized when the neon tube 145 becomes conducting and is maintained energized for a short time to move the contact arm 161 into engagement with the stationary contact 160. Closure of the contacts 160 and 161 of the sensitive relay 144 completes an energizing circuit for the operating coil 165 of the control relay 124 from the supply line 112, through conductor 126, push-button 127, conductor 162, contacts 161 and 160, conductor 163, operating coil 165 of the control relay 124, conductor 166, contacts 167 of the reset relay 168 and conductors 169 and 154 to the supply line 113. Energization of the operating coil 165 of the control relay 124 opens the contacts 123 and closes the contacts 164 and 157 of the control relay 124.

Opening of the contacts 123 de-energizes the operating coil 120 of the switch 118, permitting the spring 119 to open the switch 118 which interrupts the flow of current to the electrodes 116 and 117 and to the load 110. Opening of the contacts 123 also de-energizes the operating coil 151 of the relay 150, which then opens its contacts 149 to interrupt flow of current to the condenser 146, and closes its contacts 177 to complete the circuit of the output conductor 170 to the condenser 175.

At the same time closure of the contacts 157 of the control relay 124 completes a shunt circuit from the output conductor 140 through a portion of the operating coil 143 of the sensitive relay 144, the conductor 156, contacts 157, and conductors 158 and 159 to the output conductor 142.

The condenser 146 discharges through the foregoing shunt circuit and maintains the tapped portion of the operating coil 143, included in the shunt circuit, energized for a sufficient length of time to hold the sensitive relay contacts 160 and 161 closed for a period after closure of the contacts 164 of the control relay 124. After definite closure of the contacts 164 the discharge from the condenser 146 is not sufficient to maintain the tapped portion of the operating coil 143 sufficiently energized to hold the sensitive relay contacts 160 and 161 closed, and accordingly contacts 160 and 161 open. Closure of the contacts 164 maintains an energizing circuit for the operating coil 165 of the control relay 124, which would otherwise be de-energized upon opening of the sensitive relay contacts 160 and 161. The energizing circuit for the operating coil 165 is from the supply line 112, through conductor 126, push-button 127, conductor 125, contacts 164, operating coil 165, conductor 166, contacts 167, conductor 169, and conductor 154 to the supply line 113.

The "off timing" means are arranged in circuit when the contacts 177 of the relay 150 are closed. The voltage now furnished by the transformer 128 is rectified by the rectifier 137 which provides unidirectional current to the condenser 175. The condenser 175 accumulates a charge until a predetermined voltage is reached, at which voltage the neon tube 173 becomes conducting and permits discharge of the charge accumulated in the condenser 175.

The operating coil 171 of the sensitive relay 172 is energized when the neon tube 173 becomes conducting and is maintained energized for a short time to thereby move the contact arm 183 into engagement with the stationary contact 182. Closure of the contacts 182 and 183 of the sensitive relay 172 completes an energizing circuit for the operating coil 185 of the reset relay 168 from the supply line 112 through conductor 126, push-

button 127, conductor 162, contacts 183 and 182 of the sensitive relay 172, conductor 184, operating coil 185 of the reset relay 168 and conductors 169 and 154 to the supply line 113. Energization of the operating coil 185 of the reset relay 168 opens the contacts 167 and closes the contacts 181 thereof.

Opening of the contacts 167 de-energizes the operating coil 165 of the control relay 124, to open the holding contacts 164 and to close the contacts 123. Closure of the contacts 123 of the control relay 124 effects energization of the operating coil 120 which closes the switch 118 to again permit flow of current to the load 110.

At the same time closing of the contacts 181 of the reset relay 168 completes a shunt circuit from the output conductor 170 through a portion of the operating coil 171 of the sensitive relay 172, conductor 180, contacts 181, and conductor 159 to the output conductor 142.

The condenser 175 discharges through the foregoing shunt circuit and maintains the tapped portion of the operating coil 171, included in the shunt circuit, energized for a sufficient length of time to hold the sensitive relay contacts 182 and 183 closed for a short time after opening of the contacts 167 of the reset relay 168. Maintaining the sensitive relay contacts 182 and 183 closed for this short time insures sufficient de-energization of the operating coil 165 of the control relay 124 to definitely open its contacts 164 and definitely close its contacts 123. After closure of the control relay contacts 123 the discharge from the condenser 175 is too weak to hold the sensitive relay contacts 183 and 182 closed, and accordingly contacts 182 and 183 open to break the circuit to the operating coil 185 of the reset relay 168.

Alternate repeat operations of the "on timing" means and the "off timing" means is obtained as long as the push button 127 is closed.

For single applications of current to the load 110, the selector switch 186 is moved to its "single" position, which is its open position, and prevents operation of the "off timing" means. Under these conditions the condenser 175 and operating coil 171 of the sensitive relay 172 will remain de-energized, and the contacts 182 and 183 of the sensitive relay 172 will remain open. On repeated operation of the push-button 127 single welding operations of the "on timing" means will be had without operation of the "off timing" means.

In this embodiment, as illustrated in Fig. 2; I have provided means to automatically control the duration of the "on period" that is the period during which current is supplied to the load 110, and/or to automatically control the duration of the "off period" that is the period between successive "on periods". The duration of the "on period" and of the "off period" is determined by the magnitude of the voltage supplied to and furnished by the auto-transformer. Accordingly increasing the magnitude of the voltage furnished by the auto-transformer decreases the "on period" and the "off period".

The duration of the "on period" may be altered by varying the resistance 147, by varying the capacity of the condenser 146, and by varying the number of or characteristics of the neon tube 145.

The duration of the "off period" may be altered by varying the resistance 170, by varying the capacity of the condenser 175 and by varying the number of or characteristics of the neon tube 173.

It will be noticed that I employ but one transformer 128 and one rectifier 137 to effect the foregoing operations.

Referring to Fig. 3 the embodiment of the invention therein disclosed comprises a load 200 adapted to be supplied with alternating current from supply lines 202 and 203, through conductors 204 and 205 connected respectively to electrodes 206 and 207, here shown in engagement with the load 200.

Interposed in the conductor 204 is the primary winding 219 of a transformer 220. Interposed in the conductors 204 and 205 is a control switch 208 held normally open by means of a spring 209. The switch 208 is provided with an operating coil 210 having one of its terminals connected to a conductor 211 in turn connected to the supply line 203, and having the other of its terminals connected to a conductor 212, normally closed contacts 213 of a control relay 214, conductors 215 and 216 to the supply line 202. Interposed in the conductor 216 is a push-button 217, and closure of it effects energization of the operating coil 210, which then closes the switch 208.

The duration of time that the switch 208 remains closed may be controlled by means herein identified as "on timing" means, because they determine the duration of the "on period," that is, the period that the current is supplied to the load 200, and comprise in this instance the transformer 220 having its secondary winding 221 provided with terminal taps 222 and 223, a center tap 224 and intermediate taps 225 and 226, the latter tap being connected through the conductor 211 to the supply line 203.

A rectifier 227 rectifies the alternating current furnished by the transformer 220 and has electrodes 228 and 229 connected respectively to the terminal taps 222 and 223 of the transformer 220. Shunted across the electrodes 228 and 229 of the rectifier 227 is a variable resistance 230 which can be open-circuited if desired.

Connected to the center-tap 224 of the transformer 220 is an output conductor 231; and connected to another electrode 232 of the rectifier 227 is an output conductor 233. The output conductors 231 and 233 are adapted to supply unidirectional current to the operating coil 234 of a sensitive relay 235, here shown connected in series with a neon tube 236.

A condenser 237 has its terminals connected to the output conductors 231 and 233 in shunt with the sensitive relay coil 234 and the neon tube 236. Also shunted across the output conductors 231 and 233 is a resistance 238.

Interposed in the output conductor 233 is an adjustable resistance 239 and normally open contacts 240 of a relay 241. Energization of the operating coil 242 of the relay 241 effects closure of the normally open contacts 240 to complete the circuit to the condenser 237 and the sensitive relay 235. The operating coil 242 of the relay 241 has one of its terminals connected to a conductor 243 in turn connected to the conductor 212, and has the other of its terminals connected to a conductor 244 in turn connected to a conductor 245 which is connected to the supply line 203.

The operating coil 234 of the sensitive relay 235 is here shown as having a conductor 246 tapped thereto at a point 247 intermediate the terminals of the operating coil 234. The conductor 246 is connected through the normally open contacts 248 of the control relay 214, a conductor 249, and a conductor 250 to the output conductor 231.

The sensitive relay 235 is provided with rela-

tively stationary contacts 251 and 252, and a movable contact arm 253 normally in engagement with the contact 252. The stationary contact 251 is connected to a conductor 254 in turn connected to the conductor 216.

The operating coil 255 of the control relay 214 has one of its terminals connected through one of the normally open contacts 256 of the control relay 214 to a conductor 257, normally closed contacts 253 and 252 of the sensitive relay 235, a conductor 258 in turn connected to the intermediate tap 225 of the transformer 220; and has the other of its terminals connected through a conductor 259, normally closed contacts 260 of a reset relay 261 and a conductor 262 to the conductor 245.

The duration of time that the switch 208 is maintained open may be controlled by means herein identified as "off timing" means for the reason that they determine the duration of the "off period," that is, the period between successive application of current to the load 200, and comprise an output conductor 265 connected to the output conductor 233 and thus to the rectifier 227. The output conductors 265 and 231 supply unidirectional current to the operating coil 266 of a sensitive relay 267 connected in series with a neon tube 268.

A condenser 269 is connected to the output conductors 231 and 265 in shunt with the sensitive relay coil 266 and the neon tube 268. The resistance 238 is also shunted across the output conductors 231 and 265.

Interposed in the output conductor 265 is a variable resistance 270 and the normally closed contacts 271 of the relay 241, which is adapted to control the circuit to the condenser 269, the sensitive relay 267 and the neon tube 268.

The operating coil 266 of the sensitive relay 267 is here shown as having a conductor 272 tapped thereto at a point 273 intermediate the terminals of the operating coil 266. The conductor 272 is connected through the normally open contacts 274 of the reset relay 261 to the conductor 250 in turn connected to the output conductor 231.

The sensitive relay 267 is provided with a relatively stationary contact 275 and a movable contact arm 276 which is connected to the conductor 254.

The operating coil 277 of the reset relay 261 has one of its terminals connected through a conductor 278 to the stationary contact 275 of the sensitive relay 267, and has the other of its terminals connected to the conductor 262.

Interposed in the output conductor 265 is a selector switch 279 which performs the same functions as described in connection with the selector switch 186 in Fig. 2.

In operation, assume it is desired to have repeat operation, that is alternate operation of the "on timing" means and of the "off timing" means, the selector switch 279 is placed in its "repeat" position.

The push-button 217 is closed to complete an energizing circuit for the operating coil 210 of the switch 208, from the supply line 202, through conductor 216, push-button 217, conductor 215, normally closed contacts 213 of the control relay 214, conductor 212, operating coil 210, and the conductor 211 to the supply line 203. Energization of the operating coil 210 closes the switch 208 to permit current flow through the primary winding 219 of the transformer 220, to the electrodes 206 and 207 to begin the application of current to the load 200.

Closure of the push-button 217 also energizes the operating coil 242 of the relay 241 to close the contacts 240 and complete the circuits to the condenser 237 and the neon tube 236.

The transformer 220 operates as a series transformer and a voltage is induced in the secondary winding 221 from the primary winding 219. The voltage delivered by the secondary winding 221 is rectified by the rectifier 227 providing unidirectional current to the condenser 237. The condenser 237 accumulates a charge until a predetermined voltage is reached, at which voltage the neon tube 236 becomes conducting and permits discharge of the charge accumulated in the condenser 237.

The operating coil 234 of the sensitive relay 235 is energized when the neon tube 236 becomes conducting, and is maintained energized for only a short time to move the contact arm 253 into engagement with the stationary contact 251. Closure of the contacts 251 and 253 of the sensitive relay 235 completes an energizing circuit for the operating coil 255 of the control relay 214 from the supply line 202, through conductor 216, push-button 217, conductor 254 contacts 251 and 253 of the sensitive relay 235, conductor 257, operating coil 255 of the control relay 214, conductor 259, normally closed contacts 260 of the reset relay 261 and conductors 262 and 245 to the supply line 203. Energization of the operating coil 255 of the control relay 214 opens the contacts 213 and closes the contacts 256 and 248 of the control relay 214.

Opening of the contacts 213 de-energizes the operating coil 210 of the switch 208, permitting the spring 209 to open the switch 208 which interrupts flow of current in the work-circuit through the primary winding 219 and to the load 200, to thereby terminate the application of current to the load 200. Opening of the contacts 213 also de-energizes the operating coil 242 of the relay 241, which then opens its contacts 240 to interrupt flow of current to the condenser 237, and closes its contacts 271 to complete the circuit of the output conductor 265 to the condenser 269 and sensitive relay 267.

At the same time closure of the contacts 248 of the control relay 214 completes a shunt circuit from the output conductor 233 through a portion of the operating coil 234 of the sensitive relay 235, the conductor 246, contacts 248, and the conductors 249 and 250 to the output conductor 231.

The condenser 237 discharges through the foregoing shunt circuit and maintains the tapped portion of the operating coil 234, included in the shunt circuit, energized for a sufficient length of time to hold the sensitive relay contacts 251 and 253 closed only for a short time after closure of the control relay contacts 256. After definite closure of the control relay contacts 256, the sensitive relay contacts 253 and 252 are closed, since the charge in the condenser is too weak to attract the contact 253 into engagement with the contact 251.

The "off timing" means are arranged in circuit when the contacts 252 and 253 of the sensitive relay 235 are closed and when the contacts 256 of the control relay 214 are closed to complete a circuit to the transformer 220 to supply the latter with current from the supply line 202, through conductors 216 and 215, contacts 256 of the control relay 214, conductor 257, contacts 253 and 252 of the sensitive relay 235, conductor 259, the winding 221 of the transformer 220, and conductor 211 to the supply line 203.

The transformer 220 now operates as an auto transformer and furnishes alternating current to the rectifier 227 which provides unidirectional current to the condenser 269 through the output conductor 265 and the closed contacts 271 of the relay 261. The condenser 269 accumulates a charge until a predetermined voltage is reached, at which voltage the neon tube 268 becomes conducting and permits discharge of the charge accumulated in the condenser 269.

The operating coil 265 of the sensitive relay 267 is energized when the neon tube 268 becomes conducting and is maintained energized for a short time to move the contact arm 276 into engagement with the stationary contact 275. Closure of the contacts 276 and 275 of the sensitive relay 267 completes an energizing circuit for the operating coil 277 of the reset relay 261 from the supply line 282 through conductor 216, push-button 217, conductor 254, contacts 276 and 275 of the sensitive relay 267, conductor 278, operating coil 277 of the reset relay 261, and conductors 262 and 263 to the supply line 203. Energization of the operating coil 277 of the reset relay 261 opens the contacts 268 and closes the contacts 274 of the reset relay 261.

Opening of the contacts 268 de-energizes the operating coil 255 of the control relay 214, to open the contacts 256 and to close the contacts 213 of the control relay 214. Closure of the contacts 213 effects energization of the operating coil 218 which closes the switch 208 to supply current to the primary winding 219 of the transformer 220 which now operates as a series transformer, to again supply current to the electrodes 258 and 267 and to the load 200.

At the same time closing of the contacts 274 of the reset relay 261 completes a shunt circuit from the output conductor 265 through a portion of the operating coil 266 of the sensitive relay 267, conductor 272, contacts 274, and conductor 250 to the output conductor 231.

The condenser 269 discharges through the foregoing shunt circuit and maintains the tapped portion of the operating coil 266, included in the shunt circuit, energized for a sufficient length of time to hold the sensitive relay contacts 275 and 276 closed for a short time after reset relay contacts 268 have opened. Maintaining the sensitive relay contacts 275 and 276 closed for this short time, and reset relay contacts 268 open, insures sufficient de-energization of the control relay coil 255 to definitely open the contacts 256 and to close the contacts 213. After closure of the control relay contacts 213 the discharge from the condenser 269 is too weak to hold the sensitive relay contacts 275 and 276 closed, and accordingly contacts 275 and 276 open to break the circuit to the operating coil 277 of the reset relay 261.

Alternate repeat operations of the "on timing" means and of the "off timing" means is had as long as the push-button 217 is closed. For single applications of current to the load 200, the selector switch 279 is moved to its "single" position, which is its open position, to prevent operation of the "off timing" means, and upon each closing of the push-button 217, the "on timing" means operate to supply current to the load 200.

In this embodiment I have provided means for automatically varying the duration of the period during which current flows to the load 200. The duration of the current flow period being greater for small currents passing through the load 200, and less for large currents passing through the load 200, that is, the duration of current flow

period is automatically determined and varied by the magnitude of the current flowing through the load 200.

The duration of the current flow period may be varied by varying the resistance 239, by varying the capacity of the condenser 237, and by varying the number of or characteristics of the neon tube 236.

The current range of the transformer 220, when acting as a series transformer, may be altered by varying the resistance 230. Increasing the resistance 230 increases the magnitude of the voltage in the secondary winding 221 and thus the voltage furnished to the condenser 237, and causes the condenser 237 to more rapidly accumulate the voltage required to operate the neon tube 236, and decrease the duration of operation of the "on timing" means and the duration of current flow in the work-circuit.

The duration of the "off period" is dependent upon the magnitude of the voltage supplied to and furnished by the transformer 220, when it acts as an auto-transformer. The duration of the "off period" may be altered by varying the resistance 270, by varying the capacity of the condenser 269, and by varying the number of or characteristics of the neon tube 268.

It will be noted that in this embodiment I employ but one transformer which acts as a series transformer during the flow of current to the load 200 and as an auto transformer during the "off period" between successive applications of current to the load 200; and that I employ but one rectifying tube.

In Figures 2 and 3 I have omitted the pressure switch 6 and the control valve 9, and other parts of a spot welding machine as shown in Figure 1, but it will be understood that these omitted elements may be employed in Figures 2 and 3.

The timing means need not be supplied with current from the same source of supply as the work-circuit. For example, the output conductors 87 and 88 in Fig. 1 can be connected to a separate source of either alternating current or direct current, and when connected to a source of direct current supply the transformer 76 and the rectifying tube 84 can be eliminated. The output conductors 142 and 170 of Fig. 2 and the output conductors 231 and 265 of Fig. 3 can be connected to separate sources of either alternating current or direct current supply.

In Fig. 1, I described my invention as applied to a spot welding machine, but it is obvious, as shown in Figures 2 and 3, that my invention is also applicable wherever the quantity of electricity to be supplied by a circuit is to be maintained approximately constant, and the duration of time of current application is to be substantially correspondingly inversely varied with the quantity of electricity supplied by the circuit, and/or where timed intermittent operation of the circuit is desired.

From the foregoing, it will be obvious to those skilled in the art that I have accomplished at least the principal objects of my invention, and at the same time it will be obvious that the embodiments of my invention herein disclosed and described embody advantages other than those particularly pointed out or suggested herein, and that the embodiments may be obviously changed and modified without departing from the spirit of my invention or sacrificing the advantages thereof. It will be understood by those skilled in the art that the disclosures herein are illus-

trative only and that my invention is not limited thereto.

Having thus described my invention, I claim:

1. Apparatus for timing the periods during which a work-circuit is closed and open, comprising: on-timing means for controlling the duration of the closed period; and off-timing means for controlling the duration of the open period between successive closed periods; the duration of one of said periods being dependent upon the magnitude of the voltage applied to one of said timing means, said one period being greater for small voltages applied to said one timing means and less for large voltages; said one timing means including means for causing termination of said one period and for effecting initial operation of the other of said timing means.
2. Apparatus for timing the periods during which a work-circuit is closed and open, comprising: on-timing means for controlling the duration of the closed period dependent upon the magnitude of the voltage applied to said on-timing means, said closed period being greater for small voltages applied to said on-timing means and less for higher voltages; and off-timing means for controlling the duration of the open period between successive closed periods dependent upon the voltage applied to said off-timing means, said open period being greater for small voltages applied to said off-timing means and less for higher voltages; said on-timing means including means for causing termination of said closed period and for effecting initial operation of said off-timing means; and said off-timing means including means for causing termination of said open period and for effecting initial operation of said on-timing means.
3. Apparatus for timing the periods during which a work-circuit is closed and open, comprising: on-timing means for controlling the duration of the closed period dependent upon the value of the current flowing in said work-circuit, said closed period being greater for small currents through said work-circuit and less for larger currents; and off-timing means for controlling the duration of the open period between successive closed periods; said on-timing means including means for causing termination of said closed period and effecting initial operation of said off-timing means.
4. Apparatus for timing the periods during which a work-circuit is closed and open, comprising: on-timing means for controlling the duration of the closed period dependent upon the value of the current flowing in said work-circuit, said closed period being greater for small currents through said work-circuit and less for large currents; and off-timing means for controlling the duration of the open period between successive closed periods dependent upon the voltage applied to said off-timing means, said open period being greater for small voltages applied to said off-timing means and less for high voltages; said on-timing means including means for causing termination of said closed period and effecting initial operation of said off-timing means; and said off-timing means including means for causing termination of said open period and effecting initial operation of said on-timing means.
5. Apparatus for timing the periods during which a work-circuit is closed and open, comprising: on-timing means for controlling the duration of the closed period; off-timing means for controlling the duration of the open period between successive closed periods; induction means

for furnishing current to said on-timing means and to said off-timing means; and means operable to alternately connect said on-timing means and said off-timing means to said induction means to effect alternate operations of said on-timing means and of said off-timing means.

6. Apparatus for timing the periods during which a work-circuit is closed and open, comprising: on-timing means for controlling the duration of the closed period; off-timing means for controlling the duration of the open period between successive closed periods; power supply means; switching means operable to alternately connect said on-timing means and said off-timing means to said power supply means to effect alternate operation of said on-timing means and of said off-timing means, said switching means being rendered operative by each of the timing means upon termination of its period to initiate operation of the other timing means.

7. Apparatus for timing the periods during which a work-circuit is closed and open, comprising: on-timing means for controlling the duration of the closed period; off-timing means for controlling the duration of the open period between successive closed periods; induction means; means whereby said induction means act as a series transformer during operation of said on-timing means to furnish current to said on-timing means, and acts as an auto-transformer during operation of said off-timing means to furnish current to said off-timing means; and means operable to alternately connect said on-timing means to said induction means when acting as a series transformer and said off-timing means to said induction means when acting as an auto-transformer, and to effect alternate operations of said on-timing means and of said off-timing means.

8. Apparatus for timing the periods during which a work-circuit is closed and open, comprising: on-timing means for controlling the duration of the closed period; off-timing means for controlling the duration of the open period between successive closed periods; one of said timing means including means responsive to a predetermined electro-motive-force for causing termination of its respective period, and including means for altering the value of the electro-motive-force applied to said one timing means to said predetermined electro-motive-force, as required to effect operation of said responsive means; and means operable to alternately connect said on-timing means and said off-timing means to a source of electric current to effect alternate operation of said on-timing means and of said off-timing means.

9. Apparatus for controlling flow of current to a work-circuit, comprising: control relay means operable to disconnect said work-circuit from a source of power supply; relay means having an operating coil and contacts for effecting operation of said control relay means upon energization of said operating coil; condenser means; means including a portion of said operating coil for forming a discharge path for said condenser means to maintain said operating coil energized and thus said contacts closed until said control relay means have effected disconnection of said work-circuit from said source of power supply.

10. Apparatus for controlling flow of current in a circuit, comprising: relay means having an operating coil; condenser means; means forming one discharge path for said condenser means to energize said operating coil; and means including a portion of said operating coil for forming an-

other discharge path for said condenser means to energize said operating coil.

11. Apparatus for controlling flow of current in a circuit, comprising: relay means having an operating coil; normally non-conducting means rendered conducting at a predetermined voltage to complete an energizing circuit for said operating coil; condenser means for rendering conducting said normally non-conducting means; means, including said normally non-conducting means, for forming one discharge path for said condenser means to energize said operating coil; and means, including a portion of said operating coil, forming another discharge path for said condenser means and to energize said operating coil.

12. Apparatus for controlling flow of current in a circuit, comprising: control relay means operable to control the current flow to said circuit; relay means having an operating coil and contacts for effecting operation of said control relay means upon energization of said operating coil; condenser means; means forming one discharge path for said condenser means to energize said operating coil and operate said contacts to operate said control relay means; and means including a portion of said operating coil for forming another discharge path for said condenser means to maintain said coil portion energized and said contacts in said operative position until said control relay means have definitely completed their control operation.

13. Apparatus for controlling flow of current in a work-circuit, comprising: timing means for controlling the duration of current flow to said work-circuit; a circuit for said timing means; transformer means for furnishing voltage to said timing means circuit; and resistance means shunted across at least a portion of said transformer means for altering the voltage furnished by said transformer means to said timing means circuit, whereby increasing said resistance means increases the voltage in said timing means circuit to decrease the duration of current flow in said work-circuit.

14. Apparatus for controlling flow of current in a work-circuit, comprising: timing means for controlling the duration of current flow to said work-circuit; a circuit for said timing means; transformer means having a primary winding in said work-circuit and a secondary winding for furnishing voltage of magnitudes to said timing means circuit depending upon the value of the current in said primary winding; and resistance means shunted across at least a portion of said secondary winding for altering the voltage furnished by said secondary winding to said timing means circuit, whereby increasing said resistance means increases the voltage in said timing means circuit to decrease the duration of current flow in said work-circuit.

15. Spot welding apparatus comprising, in combination, a pair of relatively movable welding electrodes for engaging work, means for moving said electrodes into engagement with the work under pressure, means for applying welding current to said electrodes for a predetermined time interval after a predetermined pressure is applied to the work, and means for preventing the reapplication of pressure to the work for a predetermined time interval.

16. Spot welding apparatus comprising, in combination, a pair of relatively movable welding electrodes for engaging work, means for moving said electrodes into engagement with the

work under pressure, means for applying welding current to said electrodes for a predetermined time interval, and means for preventing the reapplication of pressure to the work for a predetermined time interval.

17. Spot welding apparatus comprising, in combination, a pair of relatively movable welding electrodes for engaging work, means for moving said electrodes into engagement with the work under pressure, manually-operable means for initiating the functioning of said means, means for applying welding current to the work for a predetermined time interval, and means for preventing the reapplication of pressure to the work for a predetermined time interval after the expiration of said first-mentioned time interval with said manual means in the operated position.

18. Spot welding apparatus comprising, in combination, a pair of relatively movable welding electrodes for engaging work, means for moving said electrodes into engagement with the work under pressure, manually-operable means for initiating the functioning of said means, means for applying welding current to said welding electrodes and work for a predetermined time interval after a predetermined pressure is applied to the work, and means for preventing the reapplication of pressure to the work for a predetermined time interval after the expiration of said first-mentioned time interval with said manual means in the operated position.

19. Spot welding apparatus comprising, in combination, fixed and movable welding electrodes disposed to engage opposite sides of work to be welded, means for causing the movable electrode to engage the work under pressure, means for applying welding current to said electrodes and through the work for a predetermined time interval, means for relieving the pressure applied to said electrodes after the expiration of said time interval, and means for preventing the reapplication of pressure to said electrodes for a predetermined time interval.

20. Spot welding apparatus comprising, in combination, fixed and movable welding electrodes disposed to engage opposite sides of work to be welded, means for causing the movable electrode to engage the work under pressure, means for applying welding current to said electrodes and through the work for a predetermined time interval after a predetermined pressure is applied to the work, means for relieving the pressure applied to said electrodes after the expiration of said time interval, and means for preventing the reapplication of pressure to said electrodes for a predetermined time interval.

21. Spot welding apparatus comprising, in combination, a pair of relatively movable welding electrodes disposed to oppositely engage work to be welded, fluid pressure means operable to cause the electrodes to engage the work, circuit means for applying welding current to said welding electrodes and through the work for a predetermined time interval, pressure responsive means for initiating the functioning of said circuit means on application of a predetermined pressure to the work, means for relieving the pressure applied by said pressure means to the work after the expiration of said time interval, and means for preventing the reapplication of pressure to the work for a predetermined time interval.

22. Spot welding apparatus comprising, in combination, fixed and movable welding elec-

trodes disposed to oppositely engage work to be welded, fluid pressure means operatively connected to the movable electrode for causing the electrodes to engage the work, manually-operable means for initiating the functioning of said pressure means, a current source, circuit means for connecting the welding electrodes to the current source for a predetermined time interval, pressure responsive means for initiating the functioning of said circuit means on application of a predetermined pressure to the work, means for relieving the pressure applied by said pressure means to the work after the expiration of said time interval, and means for preventing the reapplication of pressure to the work for a predetermined time interval with said manual means in the operated position.

23. Apparatus for timing the periods during which a work circuit is closed and open, comprising a means for on-timing to control the duration of the closed period, and another means for off-timing to control the duration of the open period between successive closed periods, each of said timing means including means for effecting initial operation of the other of said timing means upon termination of its own timing period, and means to vary the duration of one of said periods inversely with variations of the voltage applied to the timing means which controls said one of said periods.

24. Apparatus for timing the periods during which a work circuit is closed and open, comprising a means for on-timing to control the duration of the closed period, and another means for off-timing to control the duration of the open period between successive closed periods, each of said timing means including means for effecting initial operation of the other of said timing means upon termination of its own timing period, one of said timing means including means responsive to a predetermined electromotive force for causing termination of its timing period independently of the duration of the timing period of the other timing means.

25. Apparatus for timing the period during which a work circuit is closed and open and comprising on-timing means for controlling the duration of the closed period, said closed period being a function of the voltage applied to said on-timing means, and off-timing means for con-

trolling the duration of the open period between successive closed periods, said open period being a function of said voltage applied to said off-timing means, said on-timing means including means for causing termination of said closed period and for effecting initial operation of said off-timing means, and said off-timing means including means for causing termination of said open period and for effecting initial operation of said on-timing means.

26. Apparatus for timing the period during which a work circuit is closed and open and comprising an on-timing means for controlling the duration of a closed period which is dependent upon the value of the current flowing in said work circuit, said closed period being greater for small currents through said work circuit and less for large currents, and an off-timing means for controlling the duration of the open period between successive closed periods, said open period being a function of voltage applied to said off-timing means, said on-timing means including means for causing termination of said closed period and effecting initial operation of said off-timing means, and said off-timing means including means for causing termination of said open period and effecting initial operation of said on-timing means.

27. In a spot welding device including electrodes movable, prior to the initiation of welding current, into contact with work pieces to be welded, and to be separated from the work pieces after the cessation of the welding current, apparatus for timing the intervals during which the spot welding device is welding and not welding, comprising a means for on-timing to control the duration of the welding interval, and another means for off-timing to control the duration of the period during which the electrodes are separated from the work pieces, and the part of the non-welding interval coextensive therewith, said off-timing means including means for initiating operation of the on-timing means after termination of its own timing interval, said off-timing means including means responsive to a predetermined electromotive force for causing termination of its said timing interval.

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