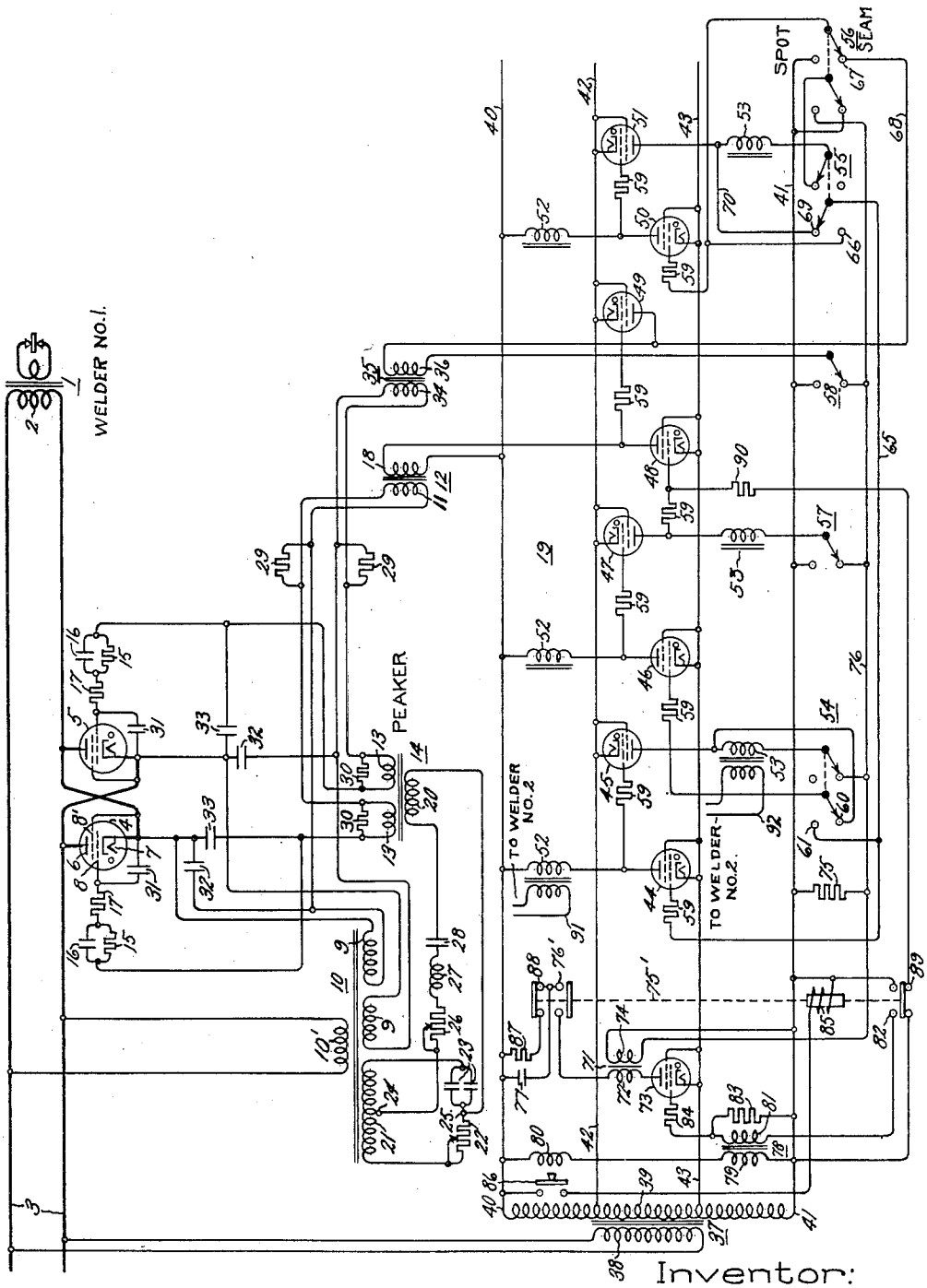
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ELECTRONIC CONTROL CIRCUITS

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Inventor:
Maurice E. Bivens,
by Harry E. Dunham
His Attorney.

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ELECTRONIC CONTROL CIRCUITS

Maurice E. Bivens, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

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24 Claims. (Cl. 250—27)

1

My invention relates to electric control circuits and more particularly to improved timing or cycle counting circuits. While not limited thereto, my invention is particularly well adapted for use in connection with the control of intermittently energized load circuits, such as the welding transformer of resistance, spot or seam welding systems.

As the commercial application of resistance welding has increased, there has been an increased need for improved timing circuits which are unaffected by voltage fluctuations, and preferably for circuits operating on a cycle counting principle rather than merely timing intervals by capacitor charging or discharging. Many electrical and mechanical timing systems have been employed but most of these have lacked flexibility in the adjustment of the different time intervals to be measured, or in the accuracy of the timing operations, particularly with variable supply line voltage.

In accordance with the teachings of my invention, I provide an improved timing circuit which may be readily adjusted for different timing intervals and in which a high degree of accuracy is maintained under varying operating conditions.

It is an object of my invention to provide a new and improved electric control circuit.

It is another object of my invention to provide a new and improved electronic timing circuit.

It is still another object of my invention to provide a new and improved electronic cycle counting system.

It is a still further object of my invention to provide a new and improved timing circuit which offers flexibility of adjustment and consistent timing despite supply line voltage fluctuations.

In accordance with the illustrated embodiment of my invention, the energization of a load circuit of an alternating current supply is controlled by a pair of reversely connected electric valve means. The cycles of the supply line voltage during which the electric valve means are conductive correspond to the cycles during which an alternating current turn-on voltage is supplied to the control members of the electric valve means by an improved timing or cycle counting circuit including a plurality of pairs of reversely connected electric valves which are arranged to conduct in leading and trailing relationship. The alternating current turn-on voltage is supplied by the conduction of one of these pairs of reversely connected electric valves. When operating to time a spot weld, the number of cycles during which

2

current is supplied for one energization of the load circuit is determined by the number of successive cycles during which this pair of reversely connected electric valves is conducting. When operating to time a seam weld, the number of pairs of electric valves in the timing circuit is equal to the maximum number of cycles of conduction and nonconduction of the repetitive pattern to be supplied to the load circuit. The number of cycles of conduction for the pattern is determined by the number of the valves initially rendered conductive. After conduction is initiated, it progresses from valve to valve in sequence at the rate of one valve per half cycle of supply circuit voltage. The timing is effected, therefore, entirely by the cycle counting operation of the leading and trailing electric valves and is independent of variations in the supply line voltage.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawing, in which the single figure is a schematic representation of one embodiment of my invention, and its scope will be pointed out in the appended claims.

Referring now to the drawing, I have shown my invention embodied in a system for controlling the energization of a load circuit, such as a resistance welding transformer 1 having the primary winding 2 thereof energized from an alternating current supply line 3 through a pair of electric valves 4 and 5 which are reversely connected in parallel between the supply circuit and the primary winding of the welding transformer. The electric valves 4 and 5 may be any of the types well known in the art such as those employing a mercury pool type cathode or mercury vapor, and, as illustrated, each comprises an anode 6, a cathode 7, a control member or grid 8 and a screen grid 8' which is preferably connected directly to the cathode. The control member of each of the electric valves 4 and 5 is energized with the resultant of four components of voltage to determine the cycles and the instants in the cycles of the supply line voltage that conduction is initiated. These components include an alternating current hold-off voltage, a self-biasing hold-off voltage, a periodic or alternating turn-on voltage supplied by the timer control to determine the cycles during which the load circuit is energized and a peak voltage of adjustable phase which determines the instant in the cycle at which conduction is initiated.

Referring now to the circuit of the control

member of the electric valve 4, it may be traced from the cathode through the secondary winding 9 of a transformer 10, the secondary winding 11 of a transformer 12, a secondary winding 13 of a peaking transformer 14, a self-biasing circuit including parallel connected resistor 15 and capacitor 16, and a current limiting resistor 17. The transformer 10 has the primary winding 10' thereof energized from the alternating current supply 3 and provides by winding 9 a voltage 180° out of phase with respect to the anode voltage of electric valve 4. The winding 11 of transformer 12 provides the periodic or alternating current turn-on voltage during periods that the primary winding 18 thereof is energized by the timing circuit designated generally by the numeral 19. The primary winding 20 of the peaking transformer 14 is energized by a voltage of adjustable phase with respect to the voltage of supply circuit 3 by means of a phase shifting circuit including a secondary winding 21 of transformer 10 having a midtap 24, resistor 22 and capacitor 23. Resistor 22 and capacitor 23 are connected in series and across the end terminals of transformer winding 21 to provide a voltage between the midtap 24 of transformer winding 21 and the common terminal 25 of resistor 22 and capacitor 23 which is readily adjusted by adjusting the magnitude of resistor 22. The primary winding 20 of the transformer 14 is energized from the terminals 24 and 25 through a series circuit including a resistor 26 and a filter including inductance 27 and a capacitor 28. This circuit for producing peaked voltages of adjustable phase is fully described and claimed in Levoy Patent 2,246,177, dated June 17, 1941, and assigned to the assignee of the present invention. The resistors 29 and 30 are connected, respectively, across the secondary windings 11 and 13 to maintain a reasonably low impedance in the circuit of control member 8 during periods that the transformer 12 is deenergized and during periods that transformer 14 is unsaturated. In order to insure consistent operation of electric valves 4 and 5 in accordance with the control voltages impressed on the control members thereof, suitable filter capacitors 31, 32 and 33 are provided. Capacitor 31 is connected directly between the control member 8 and cathode 7; capacitor 32 is connected across the terminals of the winding 9 which impresses the hold-off voltage on control member 8, and capacitor 33 is connected to the cathode of electric valve 4 and to a point in the control circuit between the self-biasing circuit including resistor 15 and capacitor 16 and the secondary winding 13 of the peaking transformer. In the above description only the circuit of the control member of electric valve 4 is described. The control circuit for the control member of electric valve 5 is in general the same and corresponding parts have been given the same reference numerals. Instead of the transformer 12, the control member of electric valve 5 is energized by the secondary winding 34 of a transformer 35 also having the primary winding 36 thereof energized for predetermined half cycles under the control of the timer circuit 19.

From the preceding description it is apparent that the load circuit 1 will be energized during the cycles of supply line voltage that transformers 12 and 35 are energized which is, in turn, controlled by the operation of the circuit 19 which will now be described. A transformer 37 having a primary winding 38 energized from the alternating current supply circuit 3 is provided with a secondary winding 39 having end terminals 40 and 41 and intermediate terminals 42 and 43 connected with conductors bearing the same reference numerals to provide four different levels of alternating voltage. These voltages are employed for energizing electric valves 44 to 51, inclusive, which are arranged in pairs in each of which the electric valves are connected in inverse relation. The valves 44 to 51 are preferably of the type employing an ionizable medium such as a gas or a vapor. Electric valves 44, 46, 48 and 50 have the cathodes thereof connected with the alternating current supply conductor 43 and the anodes connected with the alternating current supply conductor 40. Each of the anode leads is connected to the conductor 40 through an inductance which, in the case of valves 44, 46 and 50, is designated by the numeral 52, and in the case of electric valve 48 is provided by the primary winding 18 of the transformer 12. The cathodes of electric valves 45, 47, 49 and 51 are connected with the alternating current supply conductor 42, and the anodes of these valves are connected for energization from the supply conductor 41. The anode circuits of valves 45, 47 and 51 each include a reactor 53 while the inductive reactance in the anode circuit of valve 49 is provided by the primary winding of transformer 35. The inductive reactance in the anode-cathode circuits of valves 44 to 51, inclusive, extends the period of conduction with respect to the applied voltage to improve the leading and trailing operation of the valves which will be described at a later point in the specification.

In order to facilitate setting the system for different spot lengths and different weld patterns for seam welding, double pole double throw switches 54, 55 and 56 and single pole, single throw switches 57 and 58 are provided. These switches determine the number of valves which are employed, the number of valves in which conduction is initiated originally and whether the valves conduct in sequence only once as for spot welding or whether they trail one another in a closed loop as for seam welding. The manner in which the different circuit relations are established by operation of the switches 54 to 58, inclusive, will become more apparent as the description proceeds.

The control members of valves 45, 47, 49 and 51 are connected directly with the anodes of valves 44, 46, 48 and 50, respectively, through current limiting resistors 59. The control member of valve 48 is connected with the anode of valve 47 while the control member of valve 46 is connected with the anode of valve 45 through a contact 60 of switch 54, or to the anode of valve 49 through a contact 61 of switch 54, a conductor 65, contact 66 of switch 55, contact 67 of switch 56 and a conductor 68 or to the anode of valve 51 through a circuit extending from conductor 65 through contact 69 of switch 55 and conductor 70, dependent upon the positions of switches 54, 55 and 56. In a similar manner, the control member of valve 44 is connected with the anode of valve 49 or 51 dependent upon the positions of switches 55 and 56, and the control member of valve 50 may be connected with the anode of valve 49 through conductor 68 and contact 67 of switch 56. Current limiting resistors 59 are also provided in circuit with the control members of valves 45, 47, 49 and 51.

From the preceding description of the energizing circuits for the electric valves 44–51, in-

clusive, it will be apparent that the control members of electric valves 44, 46, 48 and 50 are energized through circuits each of which includes the voltage of winding 39 appearing between conductors 41 and 43. This voltage is 180 degrees out of phase with the voltage impressed on the anodes of the valves and maintains these valves normally nonconductive. In a similar manner, the valves 45, 47, 49 and 51 are maintained normally nonconductive by the voltage of winding 39 appearing between conductors 40 and 42. From the preceding description, it is also apparent that the connection of the control members of the successive valves with the anodes of the preceding valves provides a system in which conduction once initiated will advance from valve to valve at the rate of one valve per half cycle of the supply circuit voltage. In order to determine the spot length or weld pattern for seam welding, I provide means for initially rendering selected ones of the valves conducting. In the illustrated embodiment, this means is provided by a transformer 71 having the primary winding 72 thereof energized under the control of an electric valve 73 and the secondary winding 74 connected to impress a voltage across a resistor 75 which is connected between the conductor 41 and a conductor 76 which may be considered an initiating bus. From an inspection of the drawings, it will be seen that the control members of selected ones of the electric valves 44—50 may be connected with the initiating bus 76 by means of the switches 54, 58, inclusive. For example, with switch 57 in the lower position, as shown, the control member of electric valve 48 is energized by a voltage across resistor 75 in addition to the holdoff component of alternating voltage between conductors 41 and 43. The electric valve 73 which controls the energization of the transformer 71 is preferably of the type employing an ionizable medium and is connected for energization from the voltage of transformer winding 39. As indicated on the drawings, the cathode is connected with conductor 43 and the anode is connected to conductor 40 through the primary winding 72 of transformer 71, a normally open contact 76' of an initiating relay 75' and a capacitor 77. The capacitor is provided so that a single steep wave front pulse of current is supplied to the primary winding 72 for each operation of the initiating relay 75'. The conduction of valve 73 is initiated at a predetermined point in the alternating voltage wave supplied by transformer winding 39 by a peaking transformer 78 having a primary winding 79 connected in series with a reactor 80 and across the terminals 40 and 41 of winding 39. A secondary winding 81 of the peaking transformer is connected between the control member of electric valve 73 and the conductor 41 by a circuit including a normally open contact 82 of the initiating relay 75'. A resistor 83 is provided across the secondary winding of the peaking transformer and a current limiting resistor 84 is connected in series with the control member of the electric valve 73. Energization of the operating coil 85 of the initiating relay from the alternating voltage supplied by conductors 43 and 41 is controlled by a manual initiating switch 86. A discharge circuit for the capacitor 77 is provided by a shunt circuit including a resistor 87 and a normally closed contact 88 on the initiating relay. With the initiating circuit described, it will be apparent that closure of switch 86 provides a voltage impulse between conductor 41 and initiating bus 76, and that only one voltage impulse is provided for each closure of the initiating switch regardless of the length of time that the switch is maintained closed. The initiating relay 75' is also provided with a normally closed contact 89 in a circuit connecting the control member of electric valve 48 with the conductor 41 to prevent further conduction by valves 48 and 49 after deenergization of the initiating relay. A suitable current limiting resistor 90 is included in this circuit. Since valves 48 and 49 conduct, respectively, for half cycles corresponding to the half cycles of conduction of the power valves 4 and 5, the contact 89 provides means for terminating conduction by valves 4 and 5 upon release of the initiating switch 86.

The system described above including four pairs of reversely connected electric valves may be set to time spot welds of 1 to 3 cycles in length and to establish weld patterns for seam welding in which the sum of the cycles of conduction and nonconduction of the repetitive patterns is 4 cycles or less. The range of operation of the system may be increased by increasing the number of pairs of valves employed. A better understanding of the features and advantages of my invention may be had by a consideration of the operation of the illustrated embodiment of the invention for both spot and seam welding operations. First, the operation of the system for seam welding with a weld pattern of 3 cycles on and 1 cycle off will be considered. For this operation, switches 54 to 58, inclusive, are in the position illustrated on the drawing, that is, with switch 55 in the "up" position and the remaining switches in the "down" position as illustrated on the drawing. With the alternating current supply circuit 3 energized and the cathodes of all the electric valves at operating temperature, all of the valves will remain nonconducting due to the holdoff voltages impressed on the control members thereof. The main power valves 4 and 5 are maintained nonconductive by the holdoff voltage supplied by transformer 10. Valves 44–51, inclusive, are maintained nonconductive by the alternating holdoff voltages provided by the portions of the transformer winding 39 appearing between conductors 40 and 42 and 41 and 43, and valve 73 is also maintained nonconductive by the voltage between conductors 41 and 43. The instant in the half cycles of voltage of the supply circuit that electric valves 4 and 5 are to be rendered conducting is predetermined by the phase relation of the peaked voltage produced by transformer 14 which is controlled by adjustment of the resistor 22 of the static phase shifting circuit. To initiate operation of the welder, initiating switch 86 is closed to energize the operating coil 85 of the initiating relay 75'. Operation of relay 75' closes contact 76' to complete the anode-cathode circuit of electric valve 73 and opens contact 89 to release the control member of valve 48. Operation of relay 75' also closes contact 82 to connect to secondary winding 81 of peaking transformer across the resistor 83 in the control member circuit of valve 73. This impresses a peaked voltage on the control member at an instant determined by the reactor 80 and the design of the peaking transformer 78. Because of capacitor 77 in the anode circuit of valve 73, only a single impulse of voltage appears across resistor 75 for each closure of the initiating switch 86. This voltage appears in the control member circuits of electric valves 46, 48 and 50 to initiate conduction of these valves. For example, the cathode to control member circuit of valve 46 may be traced from conductor 43 through

the lower section of transformer winding 39 to conductor 41, through resistor 75, the right-hand contact of switch 54, reactor 53, the left-hand contact of switch 54 and the current limiting resistor 59. When valves 46, 48 and 50 conduct, the control members of valves 47, 49 and 51 are brought substantially to the voltage of the conductor 43 since these control members are connected respectively with the anodes of valves 46, 48 and 50. This places valves 47, 49 and 51 in condition to conduct as soon as the anode-cathode voltage impressed on these valves reverses. In this manner, valves 47, 49 and 51 trail valves 46, 48 and 50 and the conduction initiated in the three valves spaced alternately in the sequence continues to advance around the loop including valves 44 to 51 at the rate of 1 valve per half cycle of voltage of the supply circuit. During the third half cycle after initiation, electric valve 48 will again be rendered conductive and during the fourth half cycle electric valve 49 will be rendered conductive. The first period of energization of the seam weld will be only two cycles in duration but from then on valves 48 and 49 each conduct for three successive half cycles by the trailing action of the electric valves 44—51. Since conduction by electric valve 48 energizes transformer 12 to produce a turn-on voltage across resistor 29 in the control member circuit of electric valve 4 and conduction by valve 49 energizes transformer 35 to produce a turn-on voltage across resistor 29 in the control member circuit of electric valve 5, it is apparent that the half cycles of conduction by valves 4 and 5 correspond exactly to the half cycles of conduction by electric valves 48 and 49. The pattern of conduction of valves 48 and 49 is, therefore, the weld pattern. It will be understood that the time in the cycle of the alternating voltage that conduction of valves 4 and 5 is initiated is adjusted independently of valves 48 and 49 by adjustment of the phase shifting circuit including resistor 22. Thus, it is seen that the circuit 19 operates on a cycle counting principle and that the duration of the periods of energization and deenergization of the welding transformer 1 are accurately measured in half cycles independently of supply line voltage fluctuations. In the table below are shown the positions of switches 54 to 58, inclusive, for different seam welding patterns which may be preestablished with the illustrated embodiment of the invention.

SEAM WELDING

Table I

Weld Pattern	Switch Position					Valves Trailing in a Closed Loop	Conduction Originally Initiated in Valves
	54	57	58	55	56		
1 on 1 off	Down	Up	Down	Up	Seam	All	46 and 50.
1 on 2 off	do	do	Up	Down	do	All but 50 and 51	48.
1 on 3 off	do	do	do	Up	do	All	46.
2 on 1 off	do	Down	do	Down	do	All but 50 and 51	46 and 48.
2 on 2 off	do	do	do	Up	do	All	46 and 48.
3 on 1 off	do	do	Down	do	do	do	46, 48 and 50.

For a pattern of one cycle on and one cycle off, switches 54 and 58 are in the down position, switches 55 and 57 in the up position, and switch 56 in the down or seam position. With this arrangement, electric valves 46 and 50 are initially rendered conductive. After one cycle of the supply circuit voltage the conduction initiated in valve 46 has caused conduction of valve 48 to effect energization of the welding transformer 1 by conduction of valve 4. During the next half cycle valve 49 conducts and the opposite half cycle is supplied to the welding transformer. During the first cycle after initiation while conduction advances from valve 46 to valve 48, conduction originally initiated in valve 50 advances to valve 44. During the cycle of energization of the load which corresponds to the cycle during which valves 48 and 49 conduct, conduction advances from valve 44 to valve 46. During the succeeding cycle valves 48 and 49 are nonconducting, establishing a cycle of deenergization of the load circuit. During this cycle conduction progresses from valve 46, through valve 47, to valve 48 at the beginning of the next succeeding cycle to initiate another period of energization of the load circuit. In a similar manner, the other patterns indicated in the table may be established by placing the switches in the positions indicated. The second pattern, namely one cycle on and two cycles off, is a pattern having a total of three cycles which is not a factor of the total number of valves shown in the drawing. It is therefore necessary to effectively remove one pair of the valves from the valves which conduct successively in a loop to establish this pattern. This is accomplished by placing switch 55 in the down or out position which effectively removes valves 50 and 51 by interrupting the anode-cathode voltage supply of valve 51. For this pattern, electric valve 46 only is initiated. For a pattern of one cycle on and three cycles off, all of the electric valves are employed and only valve 48 is initiated. The operation of the system for the other patterns is believed to be apparent from a consideration of the information included in the table. From the above description and a consideration of Table I it is apparent that the total number of pairs of valves connected to conduct in sequence in a closed loop is equal to the length in cycles of the respective patterns to be established or is an integral multiple thereof. It is also apparent that this is determined by the number or numbers and location in the sequence of the valves initially rendered conductive.

In the above description of the operation of the system for seam welding, it is pointed out that the electric valves trail each other in a closed loop as long as the initiating switch 86 remains closed. When switch 86 is released, initiating relay 75' drops out to close its contact 89, thus connecting the control member of electric valve 48 directly with the alternating current supply conductor 41 to prevent further conduction by this electric valve and in this way terminate the supply of current to the load circuit.

From the foregoing description of the operation of the timing circuit 19 for timing a seam weld, it is apparent that each pair of valves has the same pattern of conduction as the power valves 4 and 5 which supply the welding load circuit and that the patterns of the different

pairs are displaced with respect to one another by integral cycles of voltage of the supply circuit. This feature of the timing circuit 19 makes it possible to operate a plurality of seam welders operating on the same weld pattern in such a manner that the current demand on the supply circuit is evenly distributed. For example, if one welder or a group of welders is controlled from the electric valves 48 and 49, as previously described, and these welders are, for example, operating on a pattern of two cycles on—two cycles off, another group of welders controlled by valves 44 and 45 would operate with a weld pattern of two cycles on—two cycles off but with the pattern displaced two cycles with respect to the welders controlled by valves 48 and 49. In this manner the maximum demand on the load circuit 3 at any time is the demand of one of the groups of welders. To accomplish this control it is only necessary to employ initiating transformers similar to transformers 12 and 35 in place of the reactors 52 and 53 in circuit with valves 44 and 45, respectively. The secondary windings of these transformers have been designated by the numerals 91 and 92, respectively. These windings also carry a legend designating that they are associated with Welder No. 2. It will be appreciated that these secondary windings are connected in the control circuit of a welder which is a duplicate of the one illustrated in full and designated Welder No. 1 in the same manner as control transformer windings 11 and 34. Similarly, if a number of seam welders were to be operated with a pattern of one cycle on—two cycles off, they would be divided into three groups with each group being controlled in accordance with a different pair of electric valves which are arranged to conduct in succession. That is, one group would be controlled by valves 44 and 45, a second group by valves 46 and 47, and a third group by valves 48 and 49.

When the system is operated to time a spot weld, switch 56 is placed in the up position and switches 54, 55, 57 and 58 are placed in the up or down position, in accordance with the following table, to time spot welds of different spot lengths.

SPOT WELDING

Table II

Spot Length	Switch Position					Valves in Sequence	Conduction Originally Initiated in Valves
	54	57	58	55	56		
1 Cycle	Up	Down	Up	Down	Spot	All but 44, 45, 50 and 51	48.
2 Cycle	Down	do	do	do	do	All but 50 and 51	46 and 48.
3 Cycle	do	do	do	Up	do	All	44, 46 and 48.

For a spot weld of a single cycle duration, switches 54 and 58 are up and switches 55 and 57 are down. This effectively removes valves 44, 45 and 50, 51 from the system and provides for the initiation of conduction in electric valve 48. After one cycle of the supply circuit voltage conduction in electric valve 49 is complete, energization of the load circuit is interrupted since no further trailing action in the system of electric valves takes place. This results from the position of switch 56 which interrupts connection from the anode of electric valve 49 which is otherwise completed to the control member of valve 50, valve 44, or valve 46, dependent upon the number of pairs of valves effectively connected in the system. In the operation of the system to time a spot weld there are two notable differences as compared with the operation for seam welding. First, the electric valves trail each other starting with a leading valve only once. That is, the valves trail one another in a single sequence rather than in a closed loop. Second, the number of pairs of valves connected in sequence is one greater than the spot length, measured in cycles.

From an inspection of Tables I and II, it will be noted that switch 54 is in the down position in all cases except for spot welding with a one cycle spot length. Since for this operation it is only necessary that electric valve 46 not be initiated, it would be adequate if switch 54 were a single pole, single throw switch the same as switches 57 and 58. However, the switch 54 connected as illustrated is necessary if six pairs of valves are employed to make it possible to establish seam weld patterns of six cycles duration. The extension of the system to time six cycles can be made by simply adding two pairs of electric valves between valve 47 and valve 48 with single pole, single throw switches connected in the same manner as switches 57 and 58.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, an alternating current supply circuit, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from said supply circuit so that half of said electric valves are energized with voltage of one polarity and the other half of said electric valves are energized with voltage of the opposite polarity, means energizing the control members of each of said electric valves in response to conduction by a different one of said electric valves for rendering said electric valves conducting in sequence by trailing one another, and means for establishing a repetitive pattern of conduction and nonconduction of one of said electric valves by simultaneously applying to the control elements of more than one of said electric valves a voltage which renders said more than one electric valves initially conductive, said repetitive pattern of conduction and nonconduction of said one of said electric valves being measured in half cycles determined by number and location in the sequence of said more than one electric valves initially rendered conductive.

2. In combination, an alternating current supply circuit, a plurality of electric valves each including an anode, a cathode and a control mem-

ber, means connecting the anode-cathode circuits of said electric valves for energization from said supply circuit so that half of said electric valves are energized with voltage of one polarity and the other half of said electric valves are energized with voltage of the opposite polarity, means energizing the control members of each of said electric valves in response to conduction by a different one of said electric valves for rendering said electric valves conducting in sequence by trailing one another in a closed loop at the rate of one electric valve per half cycle of the voltage of the supply circuit, and means for establishing a repetitive pattern of conduction and nonconduction of one of said electric valves by simultaneously applying to the control elements of more than one of said electric valves a voltage which renders said more than one electric valves initially conductive, said repetitive pattern of conduction and nonconduction of said one of said electric valves being measured in half cycles determined by number and location in the sequence of said more than one electric valves initially rendered conductive.

3. In combination, an alternating current supply circuit, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from said supply circuit so that half of said electric valves are energized with voltage of one polarity and the other half of said electric valves are energized with voltage of the opposite polarity, means for energizing the control member of each of said electric valves in response to conduction by a different one of said electric valves so that said electric valves conduct in sequence by trailing one another in a closed loop at the rate of one electric valve per half cycle of the voltage of the supply circuit, means for simultaneously applying a voltage to the control elements of a predetermined number of said electric valves for rendering said predetermined number of electric valves conducting and thereby establishing a repetitive pattern of conduction and nonconduction by one of said electric valves measured in half cycles determined by the number and location in the sequence of said electric valves initially rendered conductive, and switching means for connecting in said loop a number of pairs of said electric valves equal to the number of cycles or an integral multiple thereof of the pattern to be established.

4. In combination, an alternating current supply circuit, a plurality of electric valves each including an anode, a cathode and a control member and the number of said electric valves being equal to the number of half cycles in a repetitive pattern of conduction to be established by said electric valves, means connecting the anode-cathode circuits of said electric valves for energization from said supply circuit so that half of said electric valves are energized with voltage of one polarity and the other half of said electric valves are energized with voltage of the opposite polarity, means for energizing the control members of each of said electric valves in response to conduction by a different one of said electric valves so that said electric valves conduct in sequence by trailing one another in a closed loop, means for pre-establishing the number and location in the sequence of selected ones of said electric valves whose initial conduction establishes the pattern of conduction of all of said electric valves, and means for simultaneously applying to the control members of said selected electric valves a voltage which renders said selected electric valves initially conducting.

5. In combination, circuit controlling means for transmitting alternating current to a load circuit from an alternating current supply circuit, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from a supply of alternating voltage so that the valves are arranged in two groups with one group connected to conduct during half cycles of voltage of one polarity and the other group connected to conduct during half cycles of voltage of the opposite polarity, means conductively connecting the control members of the valves of each group respectively with the anode-cathode circuits of different electric valves of the other group for transferring conduction initiated in one of said valves from valve to valve at the rate of one valve per half cycle of the alternating voltage, means for determining the total number of said electric valves employed and for applying simultaneously to the control members of selected ones of said total number of electric valves a control voltage which renders said selected ones of said electric valves conducting initially and establishes a pattern of conduction by one of said electric valves which is dependent on the number and location of said electric valves initially rendered conductive, and means responsive to the pattern of conduction by said one of said valves for controlling the operation of said circuit controlling means.

6. In combination, an alternating current supply circuit, a plurality of electric valves each having an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from said alternating current supply circuit so that they are arranged in two groups with one group connected to conduct during half cycles of voltage of one polarity and the other group connected to conduct during half cycles of voltage of the opposite polarity, means for energizing the control members of each of said electric valves of one group for conduction in response to conduction by a different electric valve of the other group and with conduction by one of said electric valves causing successive conduction by said electric valves with the conduction advancing from electric valve to electric valve at the rate of one electric valve per half cycle of the voltage of said supply circuit, and means for establishing the number of successive half cycles of voltage of one polarity that one of the said electric valves conducts by simultaneously applying to the control members of more than one of said electric valves a voltage which simultaneously initiates conduction of said more than one of said electric valves.

7. A plurality of electric valves each including an anode, a cathode and a control member, means for supplying an alternating voltage to the anode-cathode circuits of said electric valves so that the anodes of half of said valves are positive during half cycles of voltage of one polarity and the anodes of the remaining valves are positive during half cycles of opposite polarity, means energizing the control member of each of said electric valves in response to conduction by a different one of said valves for rendering said valves conducting in succession upon initiation of conduction of any one of said valves, means for determining different time patterns of half cycle

conduction of one of said electric valves in accordance with the selection of a number of said electric valves in which conduction is simultaneously initiated, and means responsive to an initiating operation for applying to the control members of said selected number of electric valves a voltage which simultaneously initiates conduction in said selected number of electric valves.

8. In combination, circuit controlling means for controlling the energization of a load circuit from an alternating current supply circuit comprising a plurality of electric valves each including an anode, a cathode and a control means, means for supplying alternating voltage to the anode-cathode circuits of said electric valves, means energizing the control means of each of said valves in response to conduction by a different one of said valves for transferring conduction initiated in one of said valves from valve to valve at intervals dependent upon the periodicity of the alternating voltage impressed on said anode-cathode circuits, means for applying simultaneously to the control means of selected ones of said electric valves a control voltage which renders said selected ones of said electric valves conducting initially and establishes a pattern of half cycle conduction by one of said electric valves which is dependent on the number of said electric valves initially rendered conductive, and means responsive to conduction by said one of said electric valves for controlling said circuit controlling means to transmit current to said load circuit in accordance with the pattern of conduction established by said one of said electric valves.

9. In combination, circuit controlling means for controlling the energization of a load circuit from an alternating current supply circuit comprising a plurality of electric valves each including an anode, a cathode and a control means, means for supplying alternating voltage to the anode-cathode circuits of said electric valves, means for energizing the control means of each of said valves in response to conduction by a different one of said valves so that conduction initiated in one of said valves progresses from valve to valve at intervals determined by the periodicity of the alternating voltage impressed on said anode-cathode circuits, means for impressing a voltage on the control means of selected ones of said valves to render the selected valves conducting initially, and means responsive to conduction by one of said valves for controlling said circuit controlling means to transmit current to said load circuit for a number of half cycles dependent on the number of electric valves selected.

10. In combination, a source of alternating current voltage, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from said source so that half of said valves are energized with voltage of one polarity and the other half with voltages of opposite polarity, means for energizing the control member of each of said valves in response to conduction by a different one of said valves so that said valves trail one another in a closed loop, means for initiating conduction simultaneously of a plurality of said valves, and means responsive to the conductivity of one of said valves for effecting a circuit controlling operation during half cycles determined by the total number of valves employed and the number and location in the loop of the electric valves initially rendered conductive.

11. An alternating current supply circuit, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from said alternating current supply circuit so that said electric valves are arranged in pairs connected in inverse parallel relationship, means connecting the control members of said electric valves so that the valves of each pair are energized in leading and trailing relationship and so that each pair of valves is in leading and trailing relationship with respect to other pairs of the system, means for initially rendering predetermined ones of said valves conductive so that each valve is rendered conductive for a number of half cycles determined by the number of valves initially rendered conductive and the half cycles of conduction are spaced in accordance with the location in the sequence of leading and trailing valves of the valves initially rendered conductive.

12. In combination, a pair of reversely connected electric valve means for transmitting alternating current to a load circuit from an alternating current supply circuit in a repetitive pattern measured in half cycles of the supply circuit voltage, said pattern including a predetermined number of half cycles of conduction by said valve means and a predetermined number of half cycles of nonconduction by said valve means, a plurality of electric valves arranged in two groups, means for energizing said valves from a supply of alternating voltage so that the valves of one group may conduct during half cycles of voltage of one polarity and the valves of the other group may conduct during half cycles of opposite polarity, means for controlling the conductivity of each of the valves of each of said groups in response to conduction by a different one of the valves of the other of said groups so that conduction initiated in any one of said valves advances from valve to valve at the rate of one valve per half cycle of the alternating voltage, the number of said valves being equal to the maximum number of half cycles in a repetitive pattern to be established, means for initiating conduction simultaneously of predetermined ones of said valves, and means for controlling conduction of each one of said electric valve means respectively in response to conduction by one of said valves in each group of said groups to transmit a repetitive pattern of current to said load circuit determined by the number and location in the sequence of the valves initially rendered conductive.

13. In combination, a pair of electric valves means each having an anode, a cathode and a control member and having their anode-cathode circuits reversely connected in parallel for transmitting alternating current to a load circuit from an alternating current supply circuit, means for controlling the conductivity of said electric valve means to transmit current to said load circuit in a repetitive pattern measured in half cycles of the supply circuit voltage, said pattern including a predetermined number of half cycles of conduction by said valve means and a predetermined number of half cycles of nonconduction by said valve means, said means comprising a plurality of electric valves arranged in two groups, each of said valves having an anode, a cathode and a control member, means for energizing the anode-cathode circuits of said valves

from a supply of alternating voltage so that the valves of one group may conduct during half cycles of voltage of one polarity and the valves of the other group may conduct during half cycles of opposite polarity, means for energizing the control member of each of the valves of each of said groups in response to conduction by a different one of the valves of the other of said groups so that conduction initiated in any one of said valves advances from valve to valve at the rate of one valve per half cycle of the alternating voltage, the number of said valves being equal to the maximum number of half cycles in a repetitive pattern to be established, means for simultaneously energizing the control members and thereby initiating conduction of more than one of said valves simultaneously, means for preestablishing the number and location in the sequence of the electric valves initially rendered conductive by operation of said last mentioned means to establish the pattern of conduction by said valves and means responsive to conduction by one of said valves in each of said groups for controlling respectively the energization of the control member and thereby the conduction of each of said pair of reversely connected electric valve means.

14. In combination, circuit controlling means for transmitting alternating current to a load circuit from an alternating current supply circuit, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from a supply of alternating voltage so that the valves are arranged in two groups with one group connected to conduct during half cycles of voltage of one polarity and the other group connected to conduct during half cycles of voltage of the opposite polarity, said connections being arranged so that the voltage of the cathodes of the valves of each group is intermediate the voltage impressed on the anode-cathode circuits of the other group, an initiating bus, means for impressing an initiating voltage between the alternating current supply connection for the anodes of one group of said valves and said initiating bus, means for energizing the control members of each of the valves of said one group in response to conduction of a different one of the valves of the second of said groups so that conduction of a valve in said second group initiates conduction of a valve in said one group during the next half cycle of the anode-cathode voltage of said valves, switching means for selectively connecting the control members of each of said electric valves of said second group to said initiating bus and to said alternating current supply connection for the anodes of said one group of said valves to render one of said valves conducting in accordance with a pattern established by said switching means and means responsive to conduction by said one of said valves for controlling the operation of said circuit controlling means.

15. In combination, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from a supply of alternating voltage so that the valves are arranged in two groups with one group connected to conduct during half cycles of voltage of one polarity and the other group connected to conduct during half cycles of voltage of the opposite polarity, means for energizing the control members of the valves of each group respectively in response to conduction by a different one of the valves of the other group so that conduction initiated in one of said valves progresses from valve to valve and means for selecting more than one of said electric valves of one of said groups and simultaneously impressing a voltage on the control members of said selected valves to initiate conduction thereof and establish a pattern of conducting and nonconducting valves which advances through the valves of each of said groups in sequence from valve to valve in response to said last mentioned means.

16. In combination, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from a supply of alternating voltage so that the valves are arranged in two groups with one group connected to conduct during half cycles of voltage of one polarity and the other group connected to conduct during half cycles of voltage of the opposite polarity, said connections being arranged so that the voltage of the cathodes of the valves of each group is intermediate the voltage impressed on the anode-cathode circuits of the other group, means conductively connecting the control members of the valves of each group respectively with the anode cathode circuit of a different one of the valves of the other group so that conduction initiated in one of said valves progresses from valve to valve, an initiating bus, switching means for connecting the anode circuits of said last mentioned group directly with said supply connection or with said initiating bus to determine the electric valves to be rendered conducting initially, and means for supplying a single pulse of voltage to said initiating bus in response to an initiating operation.

17. In combination, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from a supply of alternating voltage so that the valves are arranged in two groups with one group connected to conduct during half cycles of voltage of one polarity and the other group connected to conduct during half cycles of voltage of the opposite polarity, said connections being arranged so that the voltage of the cathodes of the valves of each group is intermediate the voltage impressed on the anode-cathode circuits of the other group, means for energizing the control members of the valves of each group respectively in response to conduction by a different one of the valves of the other group so that conduction initiated in one of said valves progresses from valve to valve, an initiating bus, means for initiating an initating voltage between the alternating current supply connection for the anodes of one group and said initiating bus, and switching means for connecting the anode circuits of said last mentioned group directly with said supply connection or with said initiating bus to determine the electric valves to be rendered conducting initially.

18. A control system for controlling the energization of a plurality of load circuits from an alternating current supply circuit through a plurality of circuit controlling means so that each load circuit is alternately energized and deenergized in accordance with the same repetitive current-time pattern with the pattern of each of said load circuits displaced with respect to the others of said load circuits to distribute the demand

on the supply circuit evenly with respect to time, said system comprising a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from said supply circuit so that half of said electric valves are energized with voltage of one polarity and the other half of said electric valves are energized with voltage of the opposite polarity, means for energizing the control member of each of said electric valves in response to conduction by a different one of said electric valves so that said electric valves conduct in sequence by trailing one another in a closed loop at the rate of one electric valve per half cycle of the voltage of the supply circuit, means for simultaneously applying a voltage to the control elements of a predetermined number of said electric valves to render said predetermined number of electric valves initially conducting and thereby establish a repetitive pattern of conduction and nonconduction by different ones of said electric valves which are electrically displaced with respect to one another by an amount equal to the desired time displacement of energization of said different load circuits, means for deriving control voltages from each of the circuits of said different ones of said electric valves, and means for controlling said circuit controlling means associated with each of said loads in response to one of said control voltages.

19. A control system for controlling the energization of a plurality of load circuits from an alternating current supply circuit through a plurality of circuits controlling means so that each load circuit is alternately energized and deenergized in accordance with the same repetitive time pattern with the pattern of each of said load circuits displaced with respect to the other of said load circuits to distribute the demand on the supply circuit evenly with respect to time, said system comprising a plurality of electric valves each including an anode, a cathode and a control means, means for supplying alternating voltage to the anode-cathode circuits of said electric valves, means for energizing the control means of each of said electric valves in response to conduction by a different one of said electric valves so that conduction initiated in one of said electric valves progresses from valve to valve at intervals determined by the periodicity of the alternating voltage impressed on said anode-cathode circuits, means for impressing a voltage on the control means of selected ones of said electric valves to render the selected valves conducting initially, and means for controlling said circuit controlling means associated with each of said loads in response to a control voltage derived from the circuit of different ones of said electric valves so that the patterns of control voltage and the patterns of load current of said different load circuits are displaced in time with respect to one another in accordance with the location in the sequence of said different ones of said electric valves controlling said different circuit controlling means.

20. In combination, a plurality of electric valves each including a pair of principal electrodes and a control member, means for connecting the principal electrodes of each of said valves for energization from an alternating current supply circuit, the control member of each of said electric valves being connected to the anode circuit of another of said values so that conduction initiated in one of said valves progresses from valve to valve in a closed loop in synchronism with the voltage of the supply circuit, and means for selecting and simultaneously applying to the control members of more than one of said electric valves a control voltage which renders said selected valves initially conducting and thereby establishes a pattern of conduction by one of said valves determined by the number and location in the sequence of the valves initially rendered conductive.

21. In combination, a supply of alternating voltage, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from said supply of alternating voltage so that the valves are arranged in two groups with one group connected to conduct during half cycles of voltage of one polarity and the other group connected to conduct during half cycles of voltage of opposite polarity, said connections being arranged so that the voltage of the cathodes of the valves of each group is intermediate the voltage impressed on the anode-cathode circuits of the other group, means providing inductive reactance connected in the anode circuit of each of said valves, and means connecting the control member of each one of the valves of one of said groups with the anode circuit of a different one of the valves of the other of said groups so that conduction initiated in one of said valves progresses from valve to valve in synchronism with the voltage of said supply circuit.

22. In combination, a supply circuit providing four different limits of alternating voltage, a plurality of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of said electric valves for energization from said supply of alternating voltage so that the valves are arranged in two groups with one group connected to conduct during half cycles of voltage of one polarity and the other group connected to conduct during half cycles of voltage of opposite polarity, said connections being arranged so that the voltages of the cathodes of the valves of each group are at different limits and at a value intermediate the voltage impressed on the anode-cathode circuits of the other group, and means for controlling the energization of the control member of each one of the valves of one of said groups in response to conduction by a different one of the valves of the other of said groups so that conduction initiated in one of said valves progresses from valve to valve in synchronism with the voltage of said supply circuit.

23. In combination, a supply circuit providing four different limits of alternating voltage, a pair of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of each of said electric valves for energization from said supply circuit so that one of said electric valves is connected to conduct during half cycles of voltage of one polarity and the other of said electric valves is connected to conduct during half cycles of voltage of opposite polarity, said connections being arranged so that the voltages of the cathodes of each of said electric valves are at different limits and at values intermediate the voltage impressed on the anode-cathode circuit of the other of said electric valves, means for applying a control voltage to the control member of one of said electric valves in circuit with the alternating voltage of said supply circuit between the

cathode of said one of said electric valves and the anode of the other of said electric valves to render said one of said electric valves conducting, an inductive circuit between the anode of said one of said electric valves and its connection through said inductive circuit with said alternating current supply circuit, and means for connecting the control member of said other of said electric valves with the anode connection of said one of said electric valves with said inductive circuit.

24. In combination, an alternating current supply circuit, a pair of electric valves each including an anode, a cathode and a control member, means connecting the anode-cathode circuits of each of said electric valves for energization from said supply circuit so that one of said electric valves is connected to conduct during half cycles of voltage of one polarity and the other of said electric valves is connected to conduct during half cycles of voltage of opposite polarity, the connection of one of said electric valves being so arranged that the voltage of its cathode is intermediate the voltage impressed on the anode-cathode circuit of the other of said electric

valves, an inductive circuit between the anode of said other electric valve and its connection with said alternating current supply circuit, means for connecting the control member of said one of said electric valves to the anode connection of said other of said electric valves with said inductive circuit so that conduction of said other electric valve progresses to said one electric valve in synchronism with the voltage of the supply circuit, and means for applying a voltage to the control member of said other of said electric valves to render said other of said electric valves conducting.

MAURICE E. BIVENS.

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