Oct. 7, 1941. L. G. LEVOY 2,258,253

TIMING APPARATUS

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Fig. 1.

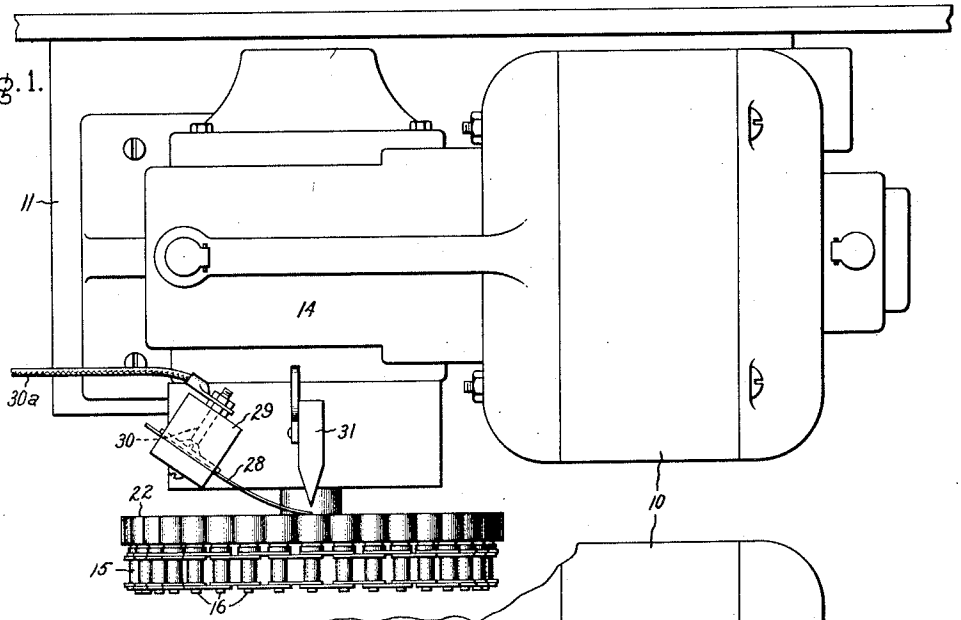
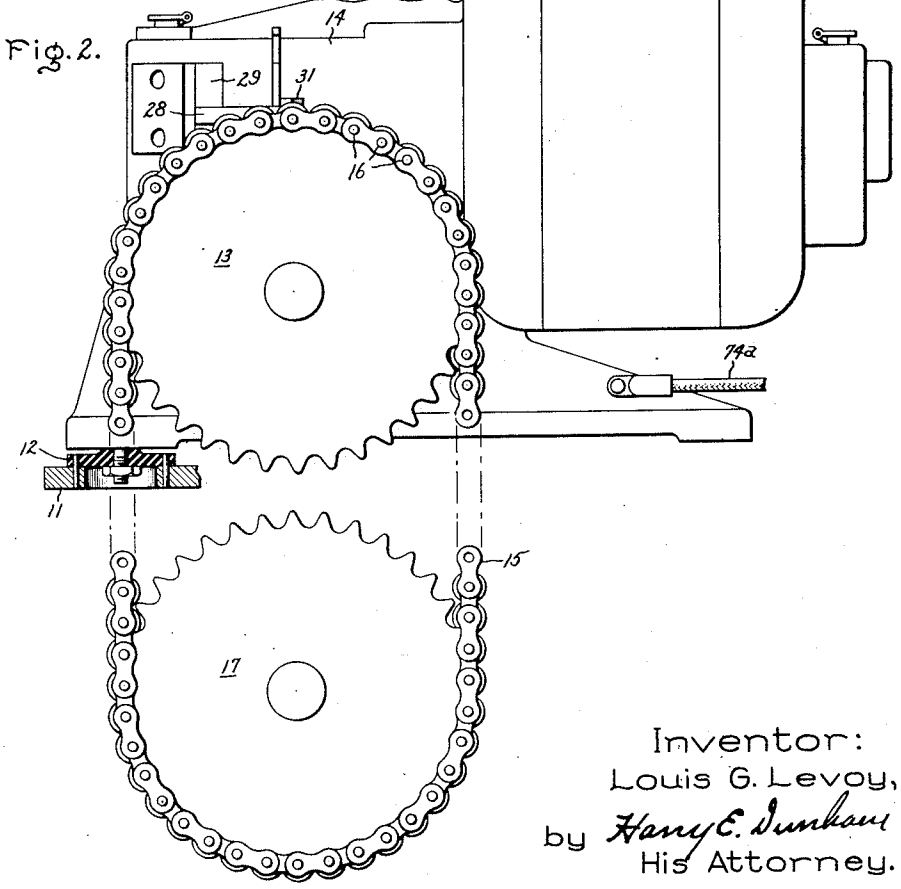


Fig. 2.



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Fig. 3.

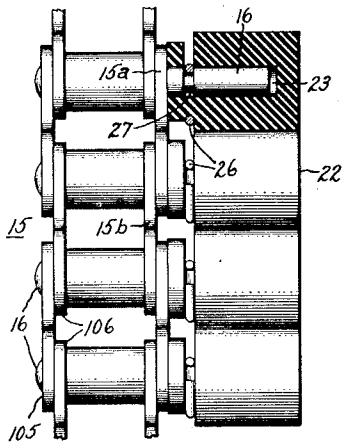


Fig. 4.

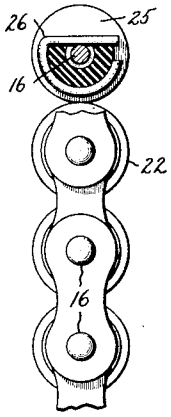


Fig. 5.

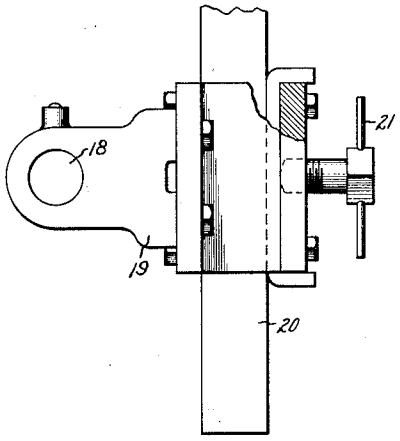


Fig. 6.

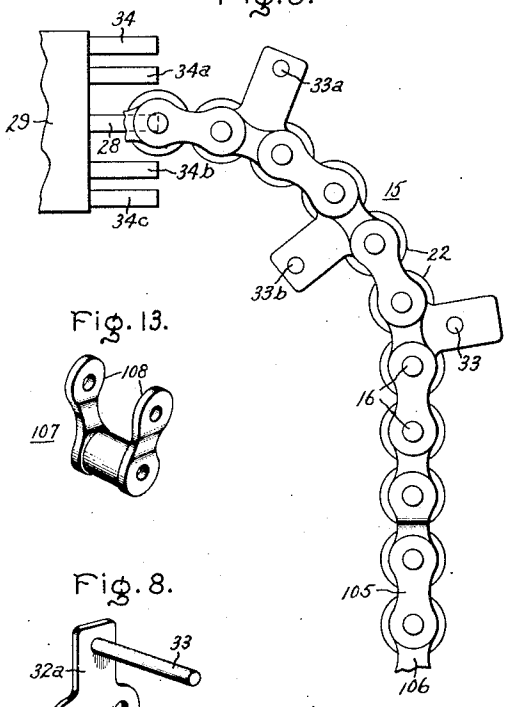
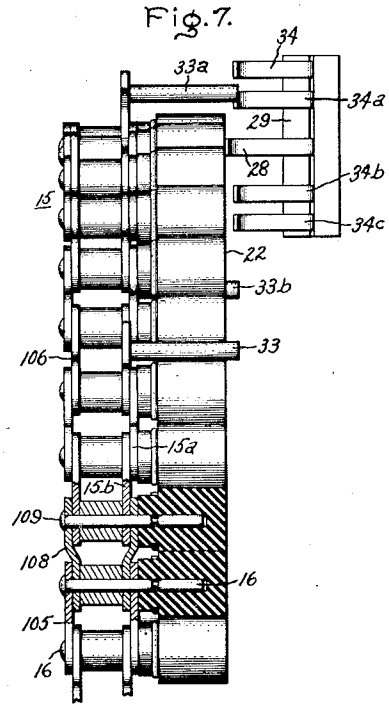


Fig. 13.

Fig. 8.

Fig. 7.



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Fig. 9.

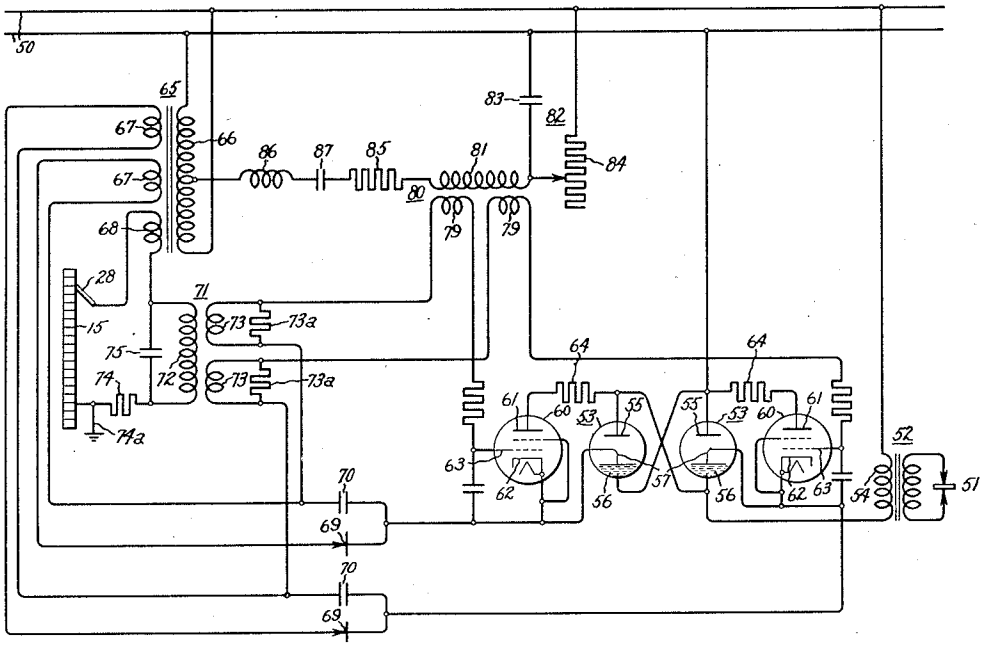


Fig. 10.

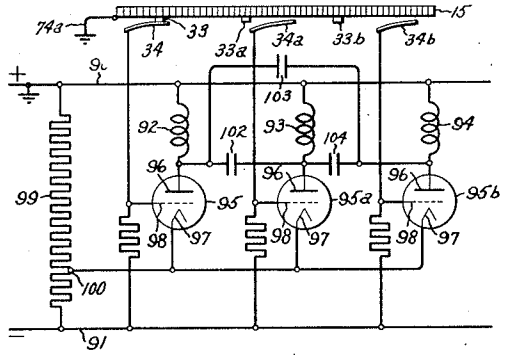


Fig. 11.

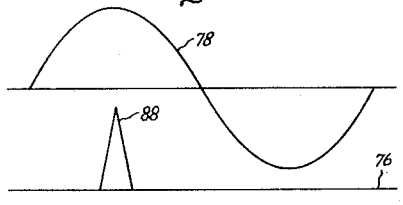
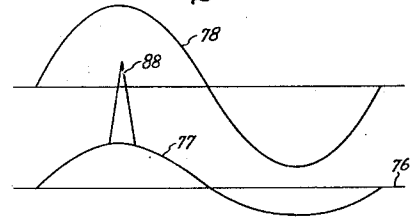


Fig. 12.



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Patented Oct. 7, 1941 2,258,253

UNITED STATES PATENT OFFICE

2,258,253

TIMING APPARATUS

Louis G. Levoy, Ballston Lake, N. Y., assignor to General Electrical Company, a corporation of New York

Application August 5, 1938, Serial No. 223,253

14 Claims. (Cl. 200—33)

My invention relates to timing apparatus and more particularly to repetitive timing apparatus for use in systems where the precise timing of the supply of current to a load from a source of alternating current during predetermined half cycles or portions thereof is required.

It is an object of my invention to provide new and improved apparatus having utility wherever regular or irregular timing patterns requiring precise timing, as in welding systems, are desired and which is flexible, simple and efficient.

It is a further object of my invention to provide improved timing mechanism of the type described which is particularly adapted to provide repetitive timing patterns.

It is also an object of my invention to provide improved timing apparatus which is readily and economically manufactured and installed.

Still another object of my invention is to provide improved apparatus for precisely controlling the flow of alternating current in a load circuit.

It is still another object of my invention to provide new and improved apparatus for permitting alternating current to flow in a load circuit only during certain particular half cycles or portions thereof.

It is another object of my invention to provide a new and improved control element particularly adapted for use with resistance welding or similar apparatus, especially in seam welding operations.

Further objects and advantages of my invention will become apparent as the following description proceeds and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention reference may be had to the accompanying drawings in which Fig. 1 is a plan view of apparatus embodying my invention; Fig. 2 is a side elevational view, partly broken away, of the apparatus illustrated in Fig. 1; Fig. 3 is an enlarged view, partly in section, of a portion of the chain and buttons shown in Figs. 1 and 2; Fig. 4 is an end view of the detail shown in Fig. 3; Fig. 5 is a detail of my invention; Fig. 6 is an end view of a chain as shown in Fig. 1 equipped with special links; Fig. 7 is a side view of the apparatus shown in Fig. 6; Fig. 8 is a view in perspective of one of the special links illustrated in Figs. 6 and 7; Fig. 9 is a suitable circuit which may be employed in applying my invention to a welding system; Fig. 10 is an auxiliary circuit which may be used to give greater flexibility of operation; Figs. 11 and 12 illustrate certain operating characteristics of the circuit shown in Fig. 9; and Fig. 13 illustrates a special link also shown in the chain of Figs. 6 and 7.

I have provided a master control element which may be employed in systems where precise timing of the supply of current to a load from a source of alternating current during predetermined half cycles or portions of half cycles of the source in order to control a sequence of electrical or mechanical or both electrical and mechanical operations. This control element comprises a supporting element 15 such as a longitudinally extending strip in the form of a belt or chain, for example, and, for convenience generally termed a "belt" hereinafter, preferably of the endless type, to which suitable operating members 22 are attached. For controlling electric circuits I have provided means on the belt or chain 15 to vary the flow of current within an electric control circuit. In the embodiment of my invention herein described, I provide a chain 15 in which the links of the chain carry extended pins 16 arranged to receive the operating members 22 which may be buttons or blocks, preferably removable, of either insulating or conductive material. Circuit means such as a conducting strip or brush 28 is provided to make electrical contact with the buttons as the buttons or members are carried into the vicinity of the circuit means, for example, are driven past the brush. It will be apparent that a control circuit including the buttons and the brush will be completed when the brush is in contact with a conducting button. Accordingly, the positions of the conducting blocks 22 on the chain determine the timing pattern and the rate at which the buttons pass a fixed reference point will determine the timing of the pattern. Instead of an electrical pick-up including a brush other means to apply a predetermined timing pattern for controlling an electric circuit may be used as, for example, magnetic, electrostatic or photoelectric pick-up arrangements.

By employing auxiliary brushes and operating arms 33, my invention may be employed not only to time the occurrence of the predetermined cycle of events but may be used to control any desired auxiliary operations as a counting device, for example, or to start and stop any associated apparatus. Other applications of such a mechanism will readily occur to those skilled in the art.

In resistance welding systems of certain types

the current is applied intermittently and in such apparatus it is advantageous to be able to simply and quickly change the particular welding cycle to any other cycle without the necessity or inconvenience of gear changing. In such an application, I contemplate the employment of my invention to control the excitation of a circuit adapted to supply current to an electric welder. A suitable supply circuit includes a pair of reversely-connected electric valves 53 (see Fig. 9) and includes means to select the particular interval of time such as a half cycle, cycle or group of cycles during which the valves are rendered conductive and also the instant in the chosen half cycle, cycle or group of cycles at which the valve becomes conductive. This means includes in the illustrated embodiment an endless chain 15 which passes over a sprocket 13 driven at a predetermined average rate as, for example, through a speed-changing device by a synchronous motor 10. If the motor is arranged to drive the chain at a speed such that $2f$ buttons or blocks pass a given stationary point per second, where f is the frequency of the alternating current motor supply, each block or operating member will represent one-half cycle. If control in steps of one cycle is sufficient, the speed may be such that f members pass the reference point per second instead of $2f$ members. In other words, each block or member represents a whole cycle instead of a half cycle.

Any suitable means may be provided on the chain to enable the user to prepare the chain for controlling the above referred to circuit. I prefer to use the above-mentioned circuit controller and brush arrangement. With this arrangement the particular half cycles during which the valves will be rendered conductive will depend upon the position in the chain of the conducting links. This mechanism will accomplish anything required in modern welding cycles with no gear changes. Any number of complete cycles may be set up since the chain can be almost any length.

I also intend to use special indexing or signal links 32 for such purposes as indexing irregular timing patterns, changing the effective heat for different groups of speeds in any desired sequence, and so on, as will occur to those skilled in the art.

In order to select the particular instant in the desired half cycle at which the valves become conductive, I intend to employ a suitable phase shifting circuit, illustrated herein as exciting a peaking transformer thereby producing peak voltages of variable phase.

In the specific embodiment of my invention herein illustrated and described, I have provided a synchronous motor 10 supported from the base 11 by means of vibration absorbing pads 12. The motor 10 is arranged to drive a sprocket 13 through a suitable system of gears included within the gear box 14. The gears are selected so that the motor 10 will drive the sprocket 13 at such a speed that the product of the number of sprocket teeth and the speed in revolutions per second of the sprocket is equal to $2f$ where f is the frequency of the supply system in cycles per second assuming that half cycle control is desired. If cycle control is to be employed, the speed in revolutions per second of the sprocket 13 need only be half as great as when half cycle control is employed. In other words, for half cycle control, assuming a 60 cycle supply voltage, 120 blocks should pass the reference point each second while for cycle control only 60 blocks per second will be required to give the necessary control. Sprocket 13 is adapted to drive an endless chain 15 of the roller or bushing type except that the pins 16 connecting the links of the chain are extended as indicated in Fig. 3. The length of the chain is determined by the length of the work cycle, since one link or one circuit controller button must be provided for each half cycle in the work cycle.

In order to keep the chain 15 taut during operation of the mechanism I provide an idler sprocket 17. I have found that in most cases it is unnecessary to provide any support for the idler sprocket 17 other than the chain 15. However, if an unusually long chain is employed, there may be some whip present or if the floor is not level, the apparatus may be tipped in such a direction that the chain will tend to fly off the driving sprocket 13. In such cases, I provide a bearing 18 for the sprocket 17, as shown in Fig. 5, which is carried by a bracket 19 adapted to slide on a guide 20 which may be attached at its upper end to base 11. Ordinarily, the weight of the bracket 19 and sprocket 17 is sufficient to keep the chain taut but I have provided clamp 21 so that the bracket 19 may be secured against vertical movement whenever desired. When chains of different lengths are to be interchangeably used, it is advantageous to employ a bracket 19 which is permitted to slide on the guide 20 because of the saving in time which might otherwise be required for loosening and re-tightening clamp 21.

The buttons 22 which are employed in constructing the circuit controller, as best illustrated in Figs. 3 and 4, are drilled as indicated at 23 to receive the pins 16 and provided on the outside with an annular groove deepened on one side as indicated at 25 for reception of a spring clip 26 which is arranged to engage an annular groove 27 in the pins 16. This arrangement permits ready removal and placement of the buttons or blocks 22 while insuring a firm engagement with the pins. Conducting material, such as iron or brass, is used for at least a portion of the members representing those intervals of time in which it is desired to render the valves conducting while a button or block of relatively non-conducting or insulating material, such as a non-metallic resinous substance, will be applied to the chain corresponding to those portions of the cycle in which it is desired to maintain the valves non-conducting.

I have provided a brush contact element 28 to engage the buttons or blocks 22 of the circuit controlling device. As best seen in Figs. 1 and 3, the blocks or members 22 are arranged closely adjacent the members on either side so that a substantially continuous or smooth surface is presented to the brush or electrical contact element 28. This brush is supported in a brush holder 29. Contact with the external control circuit is made through a clamping screw 30 and a terminal 30a. The holder 29 may be secured to the gear box 14 or in any suitable manner. I have provided means for properly positioning the brush 28 to minimize sparking between the brush 28 and the buttons 22. This may be done either by adjusting the extent to which the brush 28 projects from the block 29, after first loosening the screw 30, or else by setting brush 28 in a suitable position and turning slightly the sprocket 13 on its shaft. After the best position for minimum sparking is determined, an indicator 31 is

suitably secured to indicate the proper position of the brush. Thereafter as wear of the brush occurs the brush **28** may be moved to the proper position indicated by the indicator **31**. Adjustment may also be obtained by turning the sprocket with respect to its shaft.

The steps in setting up the welding cycle will now be briefly described. Assuming that the speed of the apparatus is such that each block represents a half cycle of the supply current, if only conducting blocks are used, current will be supplied to the welder during each half cycle. However, it is more usual to require the intermittent application of current. For example, suppose that it is desired to render the tubes conductive for two half cycles, non-conductive for three half cycles, conductive for two half cycles, non-conductive for three half cycles, and repeat. Two conducting blocks will be snapped into place on successive pins **16**. Insulating buttons will be inserted on the three pins next following and so on until the cycle is completed. Since the cycle is to be repeated after the second group of three insulating buttons is applied, the operator will add two conducting buttons, three insulating buttons and so on. When the complete cycle has been set up, the last link is joined to the first link to complete the endless chain. It will be apparent to those skilled in the art that anti-polar or uni-polar starting may be had by arranging the conducting members in a suitable sequence.

The connecting links **105**, as shown in Fig. 7 have two pins **16**, one at each end, and each link **105** is empolyed to join roller or bushing links **106** by means of pins **16**. In order to provide a chain in which there is a minimum of backlash or play between the parts or links thereof and thereby retain the members sufficiently firmly so that precision control of the welding circuit is made possible, the roller or bushing elements separating and spacing the links **15***b* and **106** closely fit the pin **16** and **109**. Moreover, the openings in the links **106**, **15***a* and **15***b* also closely fit the pins passing therethrough. If the links **105** are used throughout, an even number of buttons must be used. It may happen, however, that an odd number of members or buttons is desired. For such a case, auxiliary connecting links **107**, as shown in Figs. 13, 6 and 7, are provided. Auxiliary links **107** are U-shaped and similar to connecting links **106** at one end, but the side pieces **108** are spread out or offset at the opposite end to fit the end of a link **106**. A pin **109**, similar to pins **16**, is run through openings in arms **108** and link **106** to provide one additional block holding pin.

In many instances it may be desirable to control some auxiliary operation. For instance, it may be desirable to change the speed at which the work is advanced to the welding electrode or it may be desired to change the amount of heat during the welding cycle. For any such purpose I have provided special links or cover plates **32** having offset ears or lugs **32***a* arranged for carrying pins or arms **33** as shown in Fig. 7. It will be understood that special links **32** are interchangeable with the cover plates or links **15***a* or **15***b* of the chain **15**. It will also be apparent that the chain can be assembled with links **15***a* and **15***b*, Fig. 7, as separable parts of the chain to provide the maximum degree of flexibility. These pins **33** are adapted to engage auxiliary brushes **34** which may be suitably connected into an auxiliary circuit as will be described later. While in Fig. 8 I have shown a special link **32** carrying a single pin **33**, it will be apparent that any number of pins might be provided for. Furthermore, it is not necessary that pins **33** extend beyond the faces of blocks **22** as shown in Fig. 7. As indicated in Figs. 6 and 7, these auxiliary signals may be carried on either or both sides of the chain. If desired, a special link might be employed having extensions on both sides of the chain. Fig. 7 indicates a suitable brush rigging for these special links. A brush **28** is shown for engagement with the circuit controller buttons while two auxiliary brushes **34***b* and **34***c* are shown below brush **28** to engage auxiliary pins **33***b* and **33***c*, the latter not being shown in the drawing, respectively, below the commutator blocks and two similar auxiliary brushes **34** and **34***a* are arranged above the main brush **28** for engagement with pins **33** and **33***a*, respectively, carried outside the circuit controller blocks **22**. In some instances, it may be desirable to have a very slight time delay in the initiation of a certain operation, for example, it may be desired to use a signal to index the welding cycle or, in other words, to provide a contact finger or arm and auxiliary brush to prevent operation of the welder until the proper portion of the cycle is reached and to begin spot welding immediately thereafter, that is, within the first half cycle after reaching the indexing point. This can be accomplished by staggering a pair of pins **33** on one of the special links **32**, that is, by placing one of the pins **33** close to the leading edge of the special link while a second pin **33** will be placed near the lagging edge of the special link, each of the pins or arms **33** engaging a suitable auxiliary brush **34**. Other uses for auxiliary signals will be readily apparent to those skilled in the art.

A suitable circuit for controlling the operation of the above described application of my invention is shown in Fig. 9. An alternating current supply circuit **50** is connected to the load, a welding circuit **51** in the illustrated embodiment, through a transformer **52** and a pair of reversely-connected electric valves **53** which are connected in series relation with the primary **54** of the welding transformer **52**. The electric valves **53** are preferably of the type using an ionizable gas or vapor and include an anode **55**, a cathode **56**, and a control member **57** which may be of the make-alive or immersion ignitor type.

In order to control the energization of the control members **57**, I have provided excitation circuits which are associated with the valves **53**. The excitation circuits are similar in construction and arrangement and for the remaining description of the circuits I will describe but one of the excitation circuits. It will be understood, however, that the second excitation circuit operates in a similar manner, corresponding parts of each circuit being represented by the same numerals. A control electric valve **60** is provided in each excitation circuit in order to effect the energization of the control member **57** of the valve **53** at the proper times and during predetermined intervals. The control electric valve **60** is preferably of the type employing an ionizable medium and is provided with an anode **61**, a cathode **62** and a control member **63** which may be of the grid type. The anode of the control electric valve **60** is connected to the anode **55** of the electric valve **53** through a current limiting resistor **64**. The cathode of the control electric valve **60** is connected to the control member **57** of the electric valve **53**.

I have provided means for introducing into the

excitation circuit a biasing potential tending to maintain the control electric valve non-conducting. For this purpose, a transformer 65 having a primary 66 is connected across the supply lines 50. The voltage appearing at the terminals of the secondary winding 67 of the transformer 65 is rectified by means of a half wave rectifier 69 and applied to the excitation circuit across a condenser 70.

In order to introduce into the excitation circuit an applied voltage such as a predetermined number of half cycles of alternating current voltage which tends to render the valve 60 conducting I provide a transformer 71 having a primary 72 and secondaries 73 each of which is connected in series with the bias voltage across each condenser 70. A resistance 73a is connected across each secondary 73 to by-pass any high frequency surges appearing in the grid circuit and also to improve the power factor of transformer 71. In order to energize the primary 72 of transformer 71 I have provided a circuit including the circuit controller and chain 15 described above and a source of alternating current voltage. This source of voltage is derived from the secondary 68 of the transformer 65. The energization of primary 72 of transformer 71 is intermittent, the sequence and duration of the period being governed by the arrangement of conducting segments on the circuit controller. A resistor 74 in series with the primary 72 and a capacitor 75 connected in parallel with the primary 72 of transformer 71 are provided in order to smooth out any transients which may have developed in the circuit due to the make and break between brush 28 and the conducting buttons or blocks in the circuit controller. The above described means for suppressing transients caused by the circuit controller or make-and-break device is described and claimed in my copending application Serial No. 316,863, filed February 1, 1940, and assigned to the same assignee as the present invention. Lead 74a is shown as grounded. This ground connection is most conveniently made to the motor frame. The magnitude of the alternating current voltage in the excitation circuit occasioned by the voltage obtained from secondary 73 of transformer 71 is insufficient to overcome the negative bias due to the rectified current. Referring to Figs. 11 and 12 the D. C. bias applied across condenser 70 is indicated at 76 while the alternating current voltage derived from secondary 73 is indicated by the curve 77. The anode voltage is represented by the curve 78. It is apparent from these curves that the sum of voltages 76 and 77 is at all times insufficient to render the control member 63 of the tube 60 sufficiently positive to render the electric valve 60 conductive.

In order to render the electric valve 60 conductive I provide for the introduction of a second alternating current voltage to cooperate with the first alternating current voltage during predetermined intervals of time established by the voltage obtained from transformer 71. This voltage is obtained from secondary winding 79 of a peaking transformer 80 the primary of which is energized from phase shifting circuit 82. In order to impress an alternating current voltage on primary 81 of transformer 80 of a predetermined phase relationship relative to the voltage of the supply circuit and hence to control the amount of energy transferred to the load, I employ a phase shifting circuit 82 comprising a capacitor 83 and a variable resistor 84. The primary 81 of the transformer 80 is energized through the phase shifting network 82 and the primary 66 of the transformer 65, the circuit including a current limiting resistor 85, reactor 86 and capacitor 87. Reactor 86 and capacitor 87 constitute a tuned filter, the purpose of which is to prevent tooth harmonics or any other small distortion of the alternating current wave from affecting the narrow peaks generated in the secondary 79 of transformer 80. The peaks from the peaking transformer 80 appear in the grid circuit of the control electric valve 60 as represented by the numeral 88 in Figs. 11 and 12. As indicated by Fig. 11 the magnitude of the peak is insufficient to render the control electric valves conducting in the absence of the voltage developed in secondary 73 of transformer 71. However, when transformer 71 is energized, the effective bias on the control member 63 is reduced so that the effective voltage applied to control member 63 of electric valve 60 is sufficient to render the control electric valve 60 conductive.

I have shown an auxiliary control circuit in Fig. 10 which may be used for indexing irregular timing patterns, as for example for changing the effective heat for different groups of spots in any desired sequence or cycling the pressure to the weld. The circuit is provided with power, direct current in this exemplification, over a positive main 90 and a negative main 91 for the energization of any desired number of signal elements. I have illustrated three translating devices or signal elements 92, 93 and 94 which may be relays, windings on a saturable reactor, direct current windings for shifting the phase of a peaking transformer or any other desired translating device. In order to control the energization of the translating devices 92, 93 and 94 I have provided excitation circuits including control electric valves 95, 95a and 95b. The control electric valves are preferably of the type employing an ionizable medium and each is provided with an anode 96, a cathode 97 and a control member 98. The cathode 97 of the electric valves are connected to a tap 100 on the potential divider 99 connected across the D. C. supply source 90, 91 in order to maintain the control elements 98 of the electric valves normally negative with respect to the cathodes 97.

In order to vary the bias applied to the control elements 98 for rendering the electric valves 95 conductive, any suitable means may be used. I have shown the use of auxiliary brushes 34, 34a, and 34b adapted to engage signal arms 33, 33a and 33b extending from chain 15 as referred to above although any type switch circuit closing means may be used. These brushes preferably make momentary contact with the respective auxiliary or signal pins to trigger the associated electric valve.

In order that the ignition of one electric valve will extinguish any other electric valve which has been conducting previously, I have provided capacitors 102, 103 and 104.

The condensers are connected between the excitation circuits so that when one of the electric valves fires, as when brush 34 engages pin 33 to fire valve 95, all condensers will be charged. If, at a later time, a second brush as 34a engages its associated pin 33a the grid of the second tube is driven positive, momentarily, with respect to its cathode thereby rendering valve 95a conductive. This action drives anode 96 of valve 95 negative with respect to its cathode 97 by reason

of the discharge of condenser 102, thereby extinguishing valve 95.

Thus, assuming that none of the electric valves are conducting but that the chain 15 is running, as soon as brush 34 contacts its pin 33, the control member 98 of the electric valve 95 is grounded. Since positive main 90 is also grounded a positive potential of sufficient magnitude to render valve 95 conducting is applied to control member 98. The consequent flow of current energizes signal element 92 and charges capacitors 102, 103 and 104 as follows. After valve 95 becomes conducting practically the entire voltage drop between tap 100 and the positive lead 90 appears across device 92 since the arc drop in valve 95 is comparatively small. Therefore, the anode 96 of valve 95 will be at a potential different from that of the cathode 97 only by the amount of the arc drop. Condenser 102 may be considered as being connected in a series circuit from the tap 100 of potential divider 99 through valve 95, capacitor 102 and device 93 to the positive lead 90. Thus voltage is applied across capacitor 102 to charge the same. Capacitor 103 is similarly charged through signal member 94 and valve 95, and capacitor 104 is charged through signal element 94, capacitor 102, and valve 95. Assuming that valve 95*a* fires next, by reason of the engagement of brush 34*a* and pin 33*a* that side of capacitor 102 connected to anode 96 of valve 95*a* is connected to the cathode of valve 95 through the arc within valve 95*a*. Capacitor 102 tends to discharge through valve 95*a* and, momentarily, cathode 97 of valve 95 becomes positive with respect to anode 96 of valve 95. Obviously, valve 96 can no longer conduct current and the arc therein is extinguished. Since brush 34 engaged pin 33 only long enough to trigger valve 95, the circuit including brush 34 and pin 33 is now open and valve 95 remains non-conducting until brush 34 again engages pin 33. Thus, the ignition of electric valve 95*a* commutates out electric valve 95 by driving its anode 96 negative so that only one valve is conducting at any one time. It will be apparent that when valve 95*a* became conducting device 93 was energized and device 92 was deenergized. In the same manner, signal element or translating device 94 may be energized and signal element 93 deenergized, this process being repeated in any desired order depending upon the signal pin arrangements. The above-described auxiliary control circuit is described and claimed in my copending application 306,997, filed November 16, 1939, and assigned to the same assignee as my present invention.

Instead of using a brush having sliding contact with the circuit controller blocks, I may substitute a small metal disk spaced a short distance away from the faces of the blocks 22, thus providing a small capacitor in which the conducting blocks act as one plate of the condenser and the small metal disk as the other plate. This electrostatic pick-up arrangement amounts to the substitution of a small condenser plate for the brush 28.

A magnetic pick-up is an additional alternative means of control. In this modification permeable and impermeable buttons are used and the control voltage would be obtained from a pick-up coil wound on a magnetic core instead of from the brush and circuit controller arrangement described. A second winding is arranged on the core and separately excited by suitable means in order to provide the necessary magnetic field. As the buttons carried by the chain pass through the magnetic field, the reluctance of the magnetic circuit will be varied according to whether a permeable or impermeable button is passing, thereby varying the amplitude of the voltage in the pick-up coil which in turn is applied to the excitation circuit of the control electric valve, as described above.

With the electrostatic and magnetic arrangements the insulating blocks may be omitted since in the former modification the capacity of the condenser may be varied by increasing the gap between the chain and pick-up plate as the chain moves past the pick-up plate as well as by inserting an insulating block. From another viewpoint, it is just as practical, or perhaps more so, to insert an additional air dielectric as it is to provide some other dielectric material during those periods when the control circuit is to be broken. Similarly, with reference to the magnetic system, it is possible to vary the reluctance of the magnetic circuit by increasing the air gap between the chain and pick-up device as well as by inserting an impermeable block in the magnetic circuit. In both cases the air gap may be increased by omitting the insulating or impermeable buttons.

Alternately, instead of providing buttons on the belt or chain, I may use a photoelectric pick-up by providing obstructions on the belt or links of the chain to cut off a light beam for controlling an electric circuit as will be obvious to those skilled in the art.

It will be apparent that many other modifications of my invention are possible. For example, any sort of belt or tape may be used instead of a chain and any suitable material may be used. Obviously, an endless chain or belt is not necessary although preferred. Moreover, it is within the scope of my invention to provide a chain in which the links themselves are formed of either conductive or insulative material for the conductive pick-up or are formed of various sized links for the electrostatic, magnetic, or light sensitive pick-up. Instead of sprockets for driving the belt or chain, I may use any suitable driving means.

My invention may be used to initiate not only the supply of current to the welding circuit but also to start, stop and vary the speed of the work advancing mechanisms at predetermined times or close down the welding apparatus after a prescribed cycle has been completed. For example, a resistance welding machine may be used to give a preheating cycle, followed by a welding cycle, followed, in turn by an annealing cycle by proper indexing. In such a case signals could be used to index the pattern so that operation will begin with the preheating cycle, to vary the heat for each spot, as by phase control, and to vary the pressure of the electrodes against the work.

While I have shown a particular embodiment of my invention, it will of course be understood that I do not wish to be limited thereto since many modifications may be made both in the circuit arrangement and in the instrumentalities employed, and I therefore contemplate by the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

I claim:

1. In a timing device for precisely timing the connection of a load to a source of alternating

current during predetermined half-cycles of said source, the combination of a belt, a plurality of members carried thereby, the quantity and positions of said members corresponding to the timing pattern desired, means adjacent said belt, and synchronously driven means constructed and arranged for imparting motion to said belt at such a rate that each of said members is associated with said adjacent means during a predetermined relatively short time interval, said belt being adjustable in length for permitting variation of the length of the timing pattern.

2. In a timing device for precisely timing the connection of a load to a source of alternating current during predetermined half-cycles of said source, the combination of a supporting element, a plurality of members carried by said supporting element, the quantity and positions of said members corresponding to the timing pattern desired, means adjacent said supporting element, and synchronously driven means constructed and arranged for imparting motion to said supporting element at a rate such that each of said members is associated with said adjacent means during a predetermined relatively short time interval, said supporting member being adjustable in length to permit variation of the length of the complete timing pattern.

3. In a timing device for precisely timing the connection of a load to a source of alternating current during predetermined half-cycles of said source, the combination of a belt, a plurality of circuit control members carried by said belt, the quantity and positions of said members corresponding to the timing pattern desired, additional circuit control means adjacent said belt and cooperating with said members, and synchronously driven means constructed and arranged for imparting motion to said belt at a rate whereby each of said members is associated with said additional circuit means during predetermined ones of successive and equal time intervals, and auxiliary circuit control means comprising auxiliary members carried by said belt, and additional means adjacent said belt and cooperating with said auxiliary members.

4. In a control system for precisely timing the connection of a load to a source of alternating current during predetermined half-cycles of said alternating current, a timing device comprising a supporting element, a plurality of members removably carried thereby, some of said members being formed of an electrically insulative material, other of said members being formed of an electrically conductive material, the number of said members being equal to the number of time intervals utilized during a complete timing pattern and the disposition of said members being determined by the desired timing pattern, a contact element slidingly engaging said members, and synchronously driven means for causing relative movement between said contact element and said members at the rate of one member for each of said time intervals.

5. In a control system for precisely timing the connection of a load to a source of alternating current during predetermined time intervals, a timing device comprising a supporting element, a plurality of members removably carried thereby, some of said members being formed from an electrically insulating material, others of said members being formed from an electrically conductive material, said members being disposed according to a predetermined timing pattern, a contact element arranged to engage said members, and synchronously driven means for imparting motion to one of said elements in order to cause engagement between said elements, said removable members and said supporting element being arranged and constructed so that said members lie closely adjacent the members on either side thereof when assembled on said supporting element in order to present a substantially continuous surface to said contact element.

6. In a timing device for precisely timing the connection of a load to a source of alternating current during predetermined intervals of time, circuit controlling means comprising a belt having a plurality of members removably secured thereto in a predetermined order, some of said members being formed from an electrically insulative material, others of said members being formed from an electrically conductive material, the number of said members being equal to the number of time intervals utilized during a complete timing pattern, a brush arranged to slidingly engage said members, said belt being synchronously driven and arranged for causing said members to be moved into engagement with said brush at the rate of one member for each of said intervals of time.

7. In a timing device for precisely timing the connection of a load to a source of alternating current during predetermined half-cycles of said source, circuit controlling means comprising a belt having a plurality of members removably secured thereto in a predetermined order, some of said members being formed from an electrically insulative material, others of said members being formed from an electrically conductive material, the number of said members being equal to the number of time intervals utilized during a complete timing pattern, additional switching means including a brush arranged to slidingly engage said members, said belt being synchronously driven and arranged for causing said members to be moved into engagement with said brush at the rate of one member for each of said time intervals, said belt being adjustable in length for varying the duration of the timing pattern, said belt and said members being so constructed and arranged that said removable members lie closely adjacent when attached to said belt in order to present a substantially continuous surface to said brush.

8. In a timing device for precisely timing the connection of a load to a source of alternating current during predetermined half cycles of said source, the combination of a supporting element, a plurality of operating members carried by said supporting element, the quantity and positions of said members corresponding to the timing pattern desired, additional operating means adjacent said belt and cooperating with said members, synchronously driven means constructed and arranged for imparting motion to said supporting element at a rate whereby each of said members is associated with said additional operating means during predetermined ones of successive and equal time intervals, and auxiliary operating means comprising auxiliary members carried by said supporting element and additional means adjacent said supporting element and cooperating with said auxiliary members.

9. In a timing device, a chain comprising separable links, a plurality of electric circuit members of electrically conductive material attached to said links at predetermined intervals, an additional electric circuit member adjacent said

chain, means for moving said chain to bring said members into association with said additional member, one of said links having an offset portion, contact means attached to said offset portion, and a contact member arranged to engage said contact means when said movement of said chain moves said contact means into proximity with said contact member.

10. In a timing device, a chain comprising separable links, a plurality of electric circuit members of electrically conductive material attached to said links at predetermined intervals, an additional electric circuit member adjacent to said chain, means for moving said chain to bring said members successively into association with said additional member, auxiliary contact means offset with respect to said chain, and a contact member arranged to engage said auxiliary contact means when said movement of said chain moves said auxiliary contact means into proximity with said contact member.

11. In a control system for precisely timing the connection of a load to a source of alternating current during predetermined half cycles or portions thereof of said source, the combination of an adjustable length chain comprising a plurality of separable links, means for connecting together adjacent links, said connecting means and said links being so constructed and arranged that there is substantially no play between adjacent links, each of said connecting means being constructed for removably supporting a member, operating members removably disposed in association with certain of said connecting means, the quantity and positions of said operating members and the length of said chain being chosen according to the timing pattern desired, means adjacent said chain, and synchronously driven means constructed and arranged for imparting motion to said chain at a predetermined average rate in order to carry said operating members into association with said adjacent means in a predetermined order, each of said operating members being in association with said adjacent means during a predetermined time interval.

12. In a control system for precisely timing the supply of current to a load from a source of alternating current during predetermined half cycles or portions thereof of said source, the combination of an adjustable length, substantially rigid supporting element, means associated with said element for removably carrying a plurality of operating members, duplicate operating members removably disposed in association with certain of said carrying means, the quantity and positions of said operating members and the length of said supporting element being chosen according to the desired timing pattern, means adjacent said operating members, means constructed and arranged for imparting motion to said supporting element at a predetermined average rate in order to carry said operating members into association with said adjacent means in a predetermined order, each operating member being in association with said adjacent means during equal and relatively short time intervals.

13. In a control system for precisely timing the supply of current to a load from a source of alternating current during predetermined half cycles or portions thereof of said source, the combination of an adjustable chain comprising a plurality of separable links, means for connecting together adjacent links, said connecting means and said links being so constructed and arranged that there is substantially no play between adjacent links, each of said connecting means being constructed for removably supporting a member, operating members removably disposed in association with said connecting means, some of said members being formed of an electrically insulative material, others of said members being formed of an electrically conductive material, the quantity and position of said operating members and the length of said chain being chosen according to the timing pattern desired, means adjacent said chain and comprising a brush arranged to slidingly engage said members, and synchronously driven means constructed and arranged for imparting motion to said chain at a predetermined average rate in order to carry said operating members into association with said adjacent means in a predetermined order, each of said operating members being in association with said adjacent means during a predetermined time interval.

14. In a control system for precisely timing the supply of current to a load from a source of alternating current during predetermined half-cycles or portions thereof of said source, the combination of an adjustable length chain comprising a plurality of separable links, means for connecting together adjacent links, said means and said links being so constructed and arranged that there is substantially no play between adjacent links, each of said connecting means extending beyond said links, operating members removably disposed on certain of said connecting means, the quantity and positions of said members and the length of said chain being chosen according to the timing pattern desired for the work cycle of said apparatus, means adjacent said chain, and synchronously driven means constructed and arranged for imparting motion to said chain at a predetermined average rate in order to carry said members into the vicinity of said adjacent means in a predetermined order.

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