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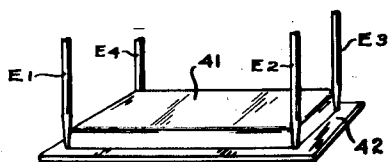
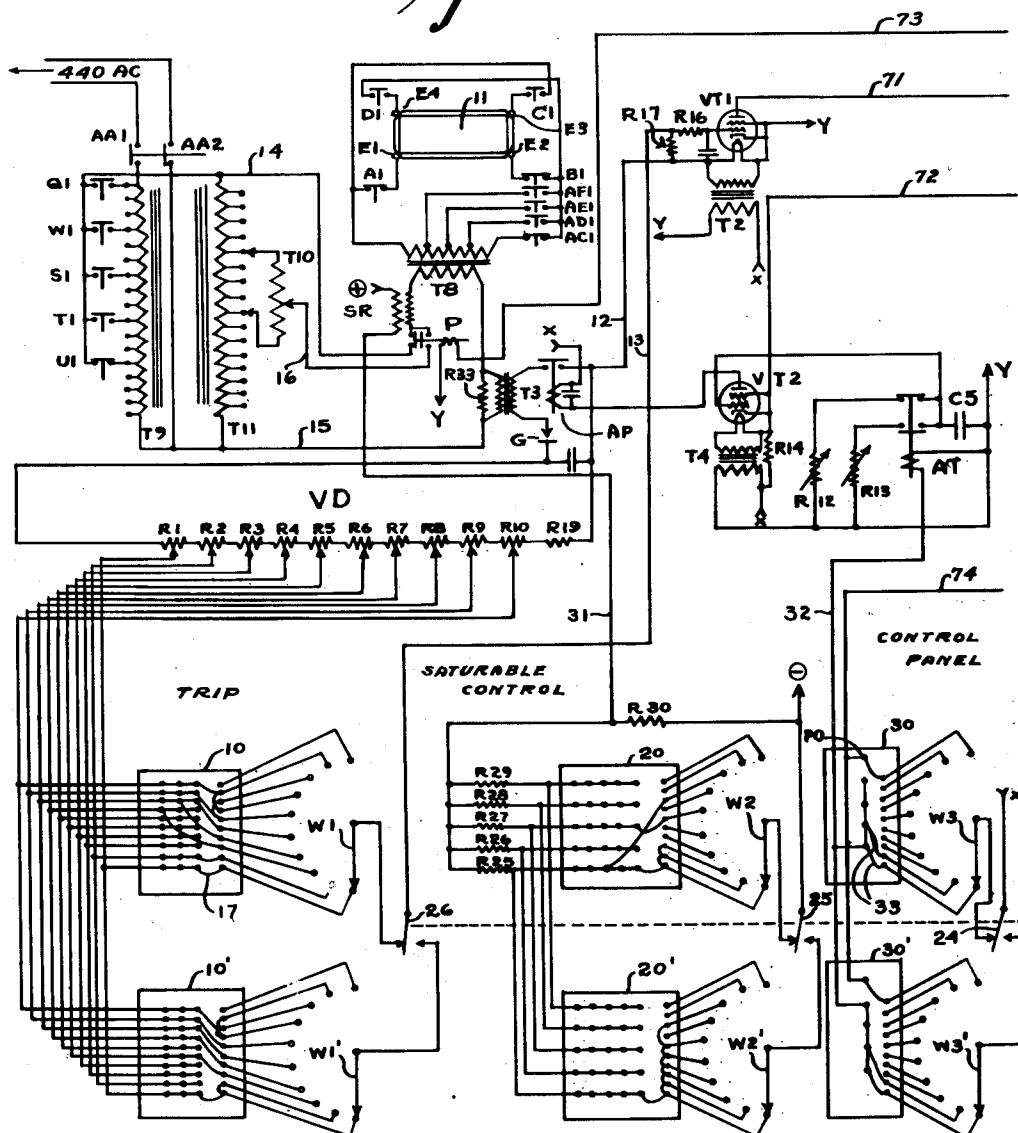


Fig. 2.

Inventors
**EDWIN M. GUYER
AND MORTON R. SHAW JR.**

F. H. Knight

Attorney

Feb. 5, 1946.

E. M. GUYER ET AL

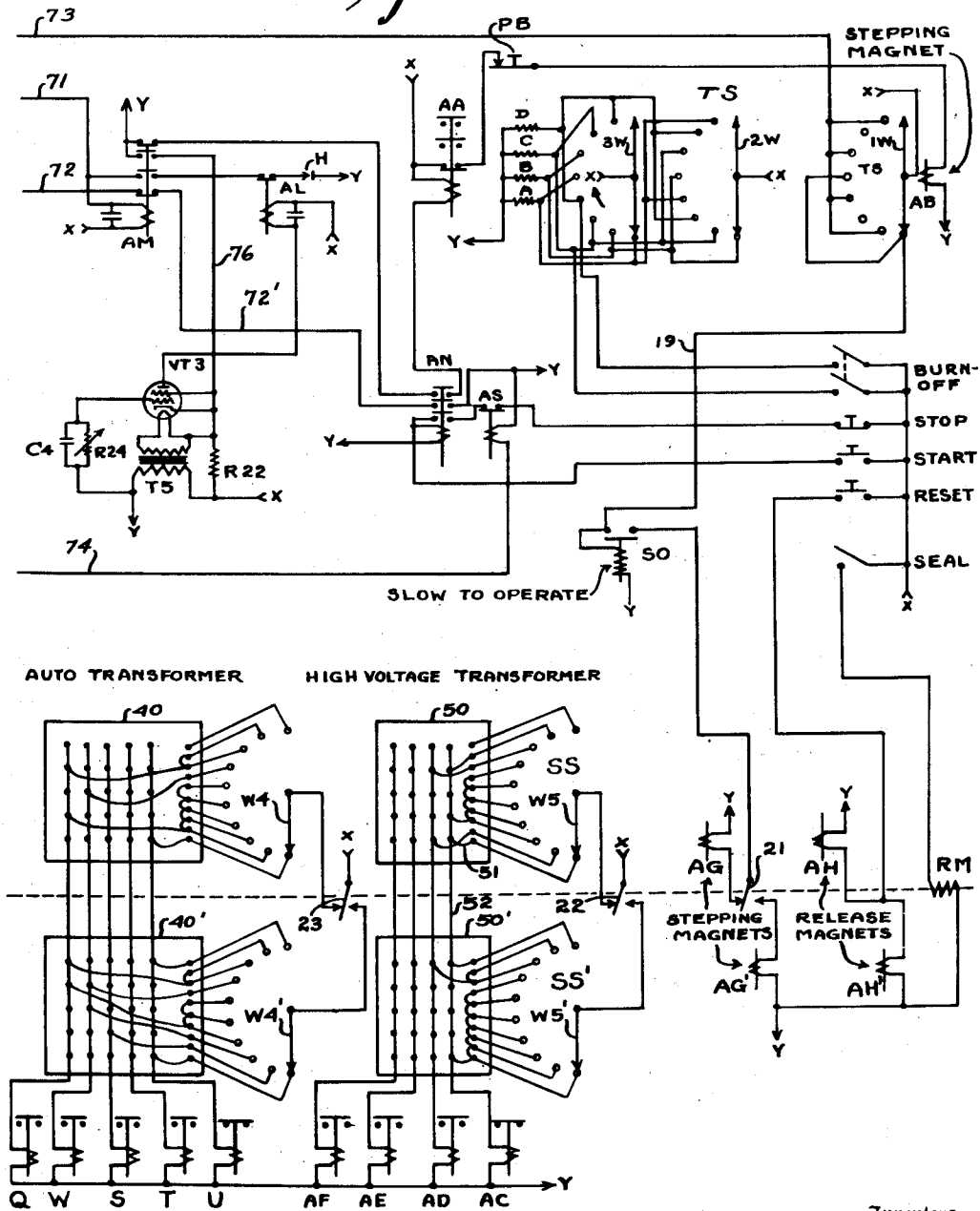
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METHOD AND APPARATUS FOR ELECTRIC GLASS WORKING

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2 Sheets-Sheet 2

Fig. 1a



Inventors

EDWIN M. GUYER
AND MORTON R. SHAW JR.

L. N. Knight
Attorney

UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR ELECTRIC GLASSWORKING

Edwin M. Guyer and Morton R. Shaw, Jr.,
Corning, N. Y., assignors to Corning Glass
Works, Corning, N. Y., a corporation of New
York

Application September 3, 1942, Serial No. 457,233

20 Claims. (Cl. 219—20)

The present invention relates to means and methods for the electrical heating of glass to temperatures proper for manipulation and fusion in which heat is generated in the glass itself by its resistance to the flow of an electric current.

By way of example the circuits of the present invention have been utilized to control the application of current to the marginal edges of a sheet of glass to be reshaped and then fused to a second sheet of glass to form a hermetically sealed double glazed unit, and to control application of the sealing current; the method of control being a refinement of those described in a co-pending Guyer et al. application Serial Number 438,036, filed April 7, 1942, owned by the assignee of the instant application.

In the aforesaid application current enters the glass to be reshaped at the four corners, through electrodes in contact with these points and is localized along the edges of the sheet by applying thereto an easily dissipated conducting stripe over which the current initially flows. As the current flows therein, the conducting stripe is heated to incandescence and in time heats the glass with which it is in intimate contact. A conducting path through the glass is thus formed by the time that the applied conducting stripe has been dissipated.

Since the applied conducting stripe is of relatively high resistance, although lower than the initial resistance of the glass, the process of current localization and ultimate transfer to the glass is not unlike the failure of a dielectric under electrical stress. The thermal electric theory of dielectric failure is based on the existence of some initial higher conductive region throughout the material which first creates a localized current path and finally leads to break down and a great increase in temperature. Such a failure is extremely erratic and for years has been the subject of study of those interested in dielectric theory. In order to profitably utilize this dielectric failure type of heating, it is necessary to have complete control of an inherently unstable process. In the case of the double glazing unit all four bounding edges or sides must be brought to the required temperature substantially simultaneously. It is further necessary that a reasonable speed of heating be obtained while still allowing sufficient time for the current to transfer from the initial conducting stripe to the glass.

Figs. 1 and 1a of the accompanying drawings together schematically illustrate circuits and apparatus embodying the invention meeting the above requirements, and include a plan view of a

sheet of glass with electrodes associated therewith to effect heating the marginal edges thereof; and,

Fig. 2 is a perspective view of the component parts of a double glazed unit with electrodes associated therewith in position to effect a seal between the parts under control of the circuits illustrated in Figs. 1 and 1a.

General description

10 The circuits of Figs. 1 and 1a meet the foregoing requirements for electric glass working by affording means for an electrical heating technique hereinafter referred to as "differential scanning." In this type of heating a potential is applied successively to each segment of the path to be heated in a glass body, potential being applied to each
15 segment of the path for the time period required to bring the current flow therein to some predetermined value. In the present disclosure the selective connection of electrodes E1 to E4 (Fig. 1)
20 to apply a potential to the respective edges of a sheet of glass 11 in the foregoing manner is through contacts A1, B1, C1 and D1 of relays A, B, C, and D (Fig. 1a) under control of an associated
25 step-by-step transfer switch TS (Fig. 1a). Since the current that a given voltage will produce in the glass depends on the resistance of the glass between electrodes and hence on its temperature, the conductive condition of a given path through
30 the glass itself is utilized to determine the duration of the power application over such path required to bring it to a desired temperature. Thus, by bringing up the current to some predetermined value on one edge of the sheet and tripping the
35 circuit to switch the current to an adjoining edge of the sheet when the glass reaches a certain temperature, and so continuing around the sheet repeatedly, the temperatures of all edges are maintained approximately uniform while being gradually
40 raised. Each time a complete cycle of all edges is completed a step-by-step sequence switch SS advances one step and functions, through the medium of its wiper W1 (Fig. 1) to so modify the
45 circuit that during the succeeding cycle the current flow must reach a predetermined higher value to trip. The net result is a corresponding increase in temperature during each succeeding cycle. Thus the heating is effected in a step-by-step
50 fashion, the time lapse between steps being determined solely by the temperature conditions existing in the glass and the value of temperature increments between the successive cycles; hence the term "differential scanning." In other words, it may be said that "differential scanning" is measured distribution of electrical heat to a plurality

of predetermined sections of a pyroelectrolytic body, by a series of steps or increments, the incremental values of which are regulated and controlled by local changes in resistance within the body itself brought about by increasing temperature.

An exception to the use of differential scanning is made during the first few cycles before the conducting stripe is entirely consumed for the reason that the first application of power finds the conducting stripe intact and consequently a heavy current flows. If this surge were allowed to trip the circuit thereby switching the power to the next edge the stripe would never be removed, therefore during the first few cycles the power is held on each side for a definite predetermined period of time determined by an electronic timing device rather than only long enough to bring the current to a predetermined value. The transfer to differential scanning is accomplished through wiper W3 of switch SS as will be fully brought out hereinafter.

When the conducting stripe is burned off and the current flow is solely through the glass, differential scanning is used and the temperature increased in steps as large as will still permit a reasonable heating speed and reasonably uniform heating of the respective edges. As the desired temperature is approached the temperature increments are made smaller which permits more rapid scanning resulting in greater uniformity of temperature in successive sections of the heated path.

As has been stated, the current value is increased on each cycle to bring about an increase in temperature; also on each cycle it is necessary to change other circuit constants to meet the constantly changing resistance of the load. These changes must be made periodically and are effected by wipers W2, W4, and W5 of the sequence switch SS which, as previously stated, advances one step at the completion of each heating cycle. For ease in connecting the various circuit constants so that they come up in proper sequence and for ease in changing these circuit constants for different types of work jumper panels, shown in the lower portion of Figs. 1 and 1a bearing appropriate labels, are provided where connections can readily be made between the sets of bank contacts of the several wipers of switch SS and the equipment it is desired to control through them, as will be more fully brought out hereinafter.

Before describing the circuits and their operation in detail the basic features of the system and its operation will be briefly discussed. The heating electrodes E1 to E4 in the upper part of Fig. 1 are shown associated with the sheet of glass 11 in readiness to have its marginal edges heated to a working condition preparatory to formation into the upper portion of a double glazed unit in any suitable manner, for example in the manner set forth in the referred to Guyer et al. application.

Briefly, the heating circuit comprises an auto transformer T9 (or, depending on dimensions of the glass, T11) directly connected to a 440 volt A. C. power line and, through a series reactor SR, supplying the primary of a step up transformer T8 whose secondary is directly connected to the electrodes E1 to E4 in contact with the glass to be heated. The remainder of the circuits shown in Figs. 1 and 1a are concerned with the control of the point of application, the voltage and the duration of application of the poten-

tial impressed on the electrodes. The conductors from the secondary of transformer T8 are connected sequentially to pairs of electrodes by suitable operation of relays A, B, C, and D under the control of transfer switch TS. The voltage actually impressed on the electrodes is partially determined by a series of taps on the secondary of transformer T8 which are connected and disconnected by a series of relays AC, AD, AE, and AF under control of wiper arm W5 of switch SS. The voltage impressed on the primary of transformer T8 is determined by a series of taps on auto transformer T9 which are connected and disconnected by a series of relays Q, W, S, T, and U under control of wiper arm W4 of switch SS.

Switching of the impressed potential from one pair of electrodes E to another is under the control of a thyatron tube VT1 which is caused to fire when the current in the power circuit reaches a predetermined value. The circuit for the grid of VT1 includes a transformer T3 shunted across resistance R33 in the primary circuit of high voltage transformer T8, a voltage divider VD, and an interrupting relay AP. The plate circuit of VT1 actuates relay AM and through it transfer switch TS. The value of current in the power circuit which causes VT1 to function is determined by the tap on voltage divider VD to which the grid of VT1 is connected through wiper arm W1 of switch SS.

For the first few cycles of operation the current flow through the applied resistance stripe is greater than that required to actuate VT1. Accordingly an auxiliary timing device built around thyatron VT2 is provided which controls the actuation of relay AP in the grid circuit of VT1. When VT2 fires relay AP completes the grid circuit of VT1 permitting it to fire as soon as the current in the power circuit reaches the predetermined value. Actuation of VT2 is controlled by discharge of condenser C5 through variable resistance R12 or R13. The value of R12 is such that an appreciable time interval elapses before VT2 functions while the value of R13 is such that VT2 fires almost immediately. R12 or R13 are placed in the grid circuit of VT2 at will by actuation of relay AT under the control of wiper arm W3 of switch SS. R12 is operative until the resistance stripe is burned off while R13 is utilized after the current starts to flow through the glass. In each case VT2 controls the actuation of VT1 through relay AP but in the first current conditions in the power circuit are such that VT1 functions immediately on closure of AP while in the latter a time interval elapses between closure of AP and the building up of current conditions in the power circuit which will cause VT1 to function.

A third thyatron VT3 is provided which controls the actuation of relays AL and AM so as to prevent restoration of power to electrodes E through relay AA before the various switching operations are completed.

Throughout the circuit diagram relays and their associated contacts may be shown at separate places for simplification of circuits. In these instances similar identifying letters are used; for example, relay A in Fig. 1a and contacts A1 in Fig. 1. Attention is also directed to the fact that heating current is supplied over the conductors at the upper left corner of Fig. 1 labeled 440 AC. Also in Fig. 1 a single instance of use of a supply of direct current is indicated by leads bearing positive and negative identifications. A supply of

110 A. C. current is extensively used and the terminals thereof are designated throughout the drawings by the letters X and Y.

Circuits established preceding heating operations

The circuits are illustrated as being in the condition immediately preceding a heating cycle. Under these circumstances, in Fig. 1 the relay AT is in energized condition, in the center and lower portions of Fig. 1a the slow to operate relay SO and relays U and AC are in energized condition, while in the upper portion of Fig. 1a relays A and B of a group A, B, C, D, and stepping magnet AB of switch TS are in the energized condition.

The circuit for relay AT extends from an X terminal through the armature spring 24, of a relay RM, and its break contact, wiper W3 and its first bank contact, jumper 33, conductor 32 and through AT to a Y terminal. The circuit for relay SO extends from an X terminal through wiper 1W and its first bank contact over conductor 19 and the winding of SO to a Y terminal. The circuit for relay AC extends from an X terminal through the armature spring 22 of relay RM and its break contact, wiper W5 of switch SS and its first bank contact, jumper 51, conductor 52 and through the winding of relay AC to a Y terminal. The circuit for relay U is similar to that traced for AC except that it includes the armature spring 23 of relay RM and its break contact and wiper W4. The circuit of relay A extends from an X terminal through wiper 3W of transfer switch TS and its first bank contact, while that of relay B extends through wiper 2W and its first bank contact. The circuit for magnet AB includes the break contacts of relay AA and a push button switch PB.

As will be noted, relay AC is one of a group AC, AD, AE and AF employed to make all or only a selected portion of the secondary winding of transformer T8 (Fig. 1) available to electrodes E1, E2, E3, and E4 in accordance with the voltage desired to be applied, and at its contacts AC1 connects the right terminal of the secondary of T8 to relay contacts B1 and D1 of relays B and D. B and D are relays of the group A, B, C, and D (Fig. 1a) selectively energized through wipers 2W and 3W of switch TS to make the proper pairs of electrodes E1 to E4 available to the transformer T8. Modification of the selection of voltage range available from transformer T8 is made easy by providing (Fig. 1a) a high voltage transformer panel 50 where jumper connections between relays AC, AD, AE, and AF and the bank contacts to which wiper W5 has access can readily be changed.

Relay U is one of a group Q, R, S, T, U which is selectively energized through W4 of switch SS to enable a tapped autotransformer T9 (Fig. 1) to provide a desired range of voltages, and at contacts U1 makes the lower section of T9 and associated tapped autotransformer T11 available to the 440 A. C. line. Modification of the selection of the voltage range available from autotransformer T9 is made easy by providing an autotransformer jumper panel 40 where connections between relays Q, W, S, T, U and the bank contacts to which wiper W4 has access can be readily changed. The autotransformer T9 supplies high voltage transformer T8 via conductor 14, break contacts of relay P and the alternating current winding of series reactor SR and via conductor 15 the primary winding of a trip control transformer T3 and resistance R33 in multiple. Alternative to the path traced through conductor 14 is a path

through a tapped section of T11, an autotransformer T10, conductor 16, the make contacts of P and the alternating current windings of SR. It will be evident therefore that the position of relay P determines whether the whole or a fraction of the voltage across T11 will be employed. If the edges of the sheet of glass to be heated were of equal length the entire voltage of T11 would always be applied and could as well be supplied directly from transformer T9.

In the present instance the use of the two autotransformers T9 and T11 is however necessary to provide voltages which are proportional to the lengths of the respective sides of the glass sheet. For example in heating a sheet of glass assumed to be 8' x 12' the voltage applied to the short side must be 66% of that applied to the long side. The tapped autotransformers T9 and T11 provide the approximate necessary range of voltages, while exact voltage adjustment is made possible by the use of variable autotransformer T10 in conjunction with T11. The high voltage is applied to the sheet of glass 11 through contacts A1, B1, C1, and D1 which are closed in pairs in the proper order by switch TS to provide successive power transfer from one side of the sheet to the next around the loop formed by its bounding edges.

Considering further circuit conditions existing prior to the commencement of a heating operation it is to be noted that in Fig. 1 the thyatron tube VT1 has its filament supplied with current from a transformer T2 so that whenever current of a predetermined value flows to the tube, via associated conductors 12 and 13 through a filter unit comprising resistances R16, R17 and the associated condenser, operating current for relay AM will flow from an X terminal through relay AM and over conductor 71 to the anode of the tube and from there to the cathode of the tube to a Y terminal. The above filter circuit is interposed between a voltage divider VD and tube VT1 to eliminate the effects of any voltages induced in the line connecting VD and the tube VT1. In addition the filament of timer tube VT2 (Fig. 1) is being supplied with current from a transformer T4 and in Fig. 1a the filament of timer tube VT3 is being supplied with current from a transformer T5.

The grid of VT3 is connected to a Y terminal through a condenser C4 and variable resistance R24 in multiple while current is being supplied to the cathode from an X terminal through a resistor R22 so that condenser C4 becomes so charged that the grid potential of the tube becomes negative with respect to the cathode. As a consequence whenever a Y terminal is connected to the cathode, which is possible via conductor 76 and the upper make contacts of relay AM, the condenser C4 will no longer receive a charge and will commence to discharge through resistor R24 at the completion of which the tube will supply a return circuit to the Y terminal through its cathode and anode to operate a relay AL whose function is to effect the restoration of relay AM. The period of delay of operation of AL will depend upon the resistance of R24. The tube VT2 operates in the same fashion as VT1 to supply operating current to a relay AP a selected period of time after VT2 receives current over conductor 72.

The function of relay AP is to sensitize the trip circuit of VT1 by completing the voltage divider circuit. As previously stated, for a few cycles prior to differential scanning heat is applied to

each edge of the sheet for a predetermined time period so as to fully dissipate the conducting stripe. With relay AT energized resistance R12 is in multiple with the condenser C5 associated with VT2 and is of such value as to cause the lapse of the desired heating period before VT2 can supply current to relay AP. Consequently, with relay AT energized the relay AP does not become energized to sensitize the trip circuit until the desired predetermined time has expired. On the other hand, during differential scanning relay AT is in the de-energized condition so that resistor R13 is in bridge of condenser C5. The resistance of R13 is very low compared to that of R12 and accordingly condenser C5 is discharged relatively quickly to sensitize the trip circuit before the value of heating current applied to an edge of the sheet has attained the value necessary to trip tube VT1.

The saturable reactor SR is associated with transformer T3 to produce a stabilizing effect on the heating circuit so as to offset the instability of the load. Direct current continuously flows through the reactor SR and a resistor R30 in series over a conductor 31; the value of direct current flow is however selectively modified by connecting one or another of a group of resistors R25 to R29 in multiple with resistor R30 by means of jumpers arranged on a saturable control panel 20 connected to selected bank contacts to which wiper W2 has access.

The differential scanning action is set in motion by the voltage built up across the resistor R33 which bridges the terminals of the primary winding of a transformer T3 whose secondary winding feeds the stepped up voltage through a rectifier G and the contacts of relay AP to the voltage divider VD, which comprises a series of resistors R1 to R10 and R19. The resistors R1 to R10 are in turn connected with terminals of a "trip" jumper panel 10 where access is had to the bank contacts available to wiper W1 connected to the control grid of tube VT1, via conductor 13 whereas the cathode of tube VT1 is connected via a conductor 12 to the R19 end of VD. Thus when the grid is connected to the R1 resistor through wiper W1 and a jumper 17, for example, a maximum voltage will be applied between the grid and cathode, and when applied through one of the remaining resistors R2—R10 some fraction of the total voltage is applied to the grid and a higher overall voltage across the voltage divider VD is required to make the tube fire. In other words, the amount of resistance included between the grid and cathode of the thyatron VT1 determines the heating current value at which transformer T3 will be rendered capable of supplying the necessary voltage to make VT1 fire.

Heating operation

The heating of the marginal edges of the sheet 11 with which heating electrodes E1—E4 are shown associated is initiated and carried through to completion following the momentary actuation of the "Start" button shown at the right of Fig. 1a. When this button is actuated relay AN is energized directly through the start button contacts and completes a locking circuit for itself including its lower make contacts, the break contacts of relay AS and the contacts of a button labeled "Stop." Relay AN at its upper contacts completes a circuit for relay AA including the upper break contacts of relay AM, and at its middle contacts connects a Y terminal to the cathode of tube VT2 via conductor 72' the lower break

contacts of relay AM and conductor 72. When the relay AA operates, its break contacts interrupt the circuit of magnet AB, which merely restores the AB armature preparatory to advancing the switch upon the next energization of the magnet, and at contacts AA1 and AA2 (Fig. 1) connects the 440 AC line to the autotransformer T9. Since at this time contacts A1, B1, and AC1 are closed heating current flows to electrodes E1 and E2; and since relay AT is in the energized condition firing of the tube VT1 is delayed as required to allow time for dissipation of the conducting stripe to get under way before relay AP is energized to close the firing circuit of VT1.

When tube VT1 fires the relay AM becomes energized over the circuit established for it by VT1 as already described and is held energized through its lower make contacts, contacts of relay AL and rectifier H, and completes a circuit to the cathode of timer tube VT3 at its upper make contacts and over conductor 76 so that VT3 will fire following the time delay required for the discharge of condenser C4 through resistor R24, as already described. Relay AM also at its lower break contacts interrupts the feed circuit to the cathode of tube VT2 so that relay AP becomes de-energized to disconnect the T3 transformer secondary from association with the trip tube VT1 to positively prevent transient currents from causing its premature operation. Finally relay AM at its upper break contacts interrupts the current for relay AA. When relay AA restores it removes the 440 AC line leads from the circuits by opening contacts AA1 and AA2 and sends a pulse to the stepping magnet AB of transfer switch TS by closing its break contacts. Switch TS accordingly advances its wipers 1W to 3W into engagement with their second bank contacts whereupon relay B is maintained energized through wiper 3W and a circuit is established for relay C through wiper 2W. Finally, VT3 fires causing relay AL to energize and open the circuit for relay AM which restores whereupon relay AA again becomes energized. With relays B and C energized, electrodes E2 and E3 are connected with the secondary winding of transformer T8 through contacts B1 and C1.

Wiper 1W upon leaving its first bank contact interrupts the circuit of the slow to operate relay SO which accordingly restores its contacts to prepare an operating circuit for the stepping magnet AG of switch SS. As the switch TS advances its wipers to their second bank contacts a circuit for relay P is completed through wiper 1W, its second bank contact, conductor 73 and the winding of relay P. As has been previously mentioned, the function of relay P is to properly proportion the voltage applied to the respective sides of the sheet. As will be noted with P energized the current to the primary winding of T8 is supplied through autotransformer T10 and is that which is suitable for heating the short edge by electrodes E2 and E3 or E1 and E4, in the present instance the current being supplied to E2 and E3.

As will be understood when the current flow again reaches a predetermined value relay AA will again become de-energized and switch TS will advance its wipers to their third bank contacts. With wiper 1W in engagement with its third bank contact relay P is de-energized so that energized relays C and D supply proper voltage of current to electrodes E3 and E4. With wiper W1 engaging its fourth bank contact relay P is energized and heating current is supplied to

electrodes E4 and E1 by relays A and D to complete the first heating cycle. The sequence switch SS as previously mentioned is advanced at the completion of each cycle, under control of wiper 1W of switch TS, to establish the circuit constants for the next cycle. As the wiper 1W advances to its fifth bank contact it again completes a circuit for relay SO. With the contacts of SO closed current is supplied to magnet AG through armature spring 21 of relay RM and its break contact causing switch SS to advance its wipers to their second bank contacts before relay SO has had time to break the circuit for AG. It will be noted that all of the changes occur with relay AA de-energized so that the 440 AC heating current supply line is disconnected and switching transients are prevented from influencing the trip circuit.

In the present disclosure it will be noted that jumpers 33 connect the operating conductor 32 for relay AT with the first and second contacts accessible to wiper W3 and accordingly during the first two heating cycles tube VT2 is slow to fire and the trip circuit is rendered ineffective long enough to assure complete dissipation of the conducting stripe during the first two heating cycles. During the remaining heating cycles relay AT remains de-energized and establishes the condition in which VT2 fires relatively quickly to sensitize the trip circuit before the heating current reaches the necessary value to fire tube VT1.

When the glass has been brought up to the desired temperature the power is removed and the control circuits rendered inoperative by energizing relay AS (Fig. 1a) over conductor 74 by establishing a circuit for it through a suitable jumper on control panel 30. Thus if it is known that the desired temperature will be attained by the completion of the 9th cycle the jumper is used to connect the 10th bank contact accessible to wiper W3 to the power off terminal PO as shown. Accordingly when the wiper W3 engages its 10th bank contact relay AS becomes energized thereby breaking the holding circuit for relay AN to stop the operation. Obviously the operation can also be stopped at any time by actuation of the stop button which in like fashion interrupts the holding circuit of relay AN.

During the heating operation the electrodes E1 to E4 become attached to the adjacent glass. To remove them from the glass at the completion of the heating operation, it has been found desirable to raise them slightly pulling out a thin filament of glass and to then disrupt this filament by a short pulse of current. This current is supplied by closing the switch (Fig. 1a) labeled "Burn-off" to directly energize relays D and C while relays A and B are energized through wipers 2W and 3W so that relays A, B, C, and D are all energized simultaneously and the transformer T8 is thus connected to the electrodes E1 to E4 at once. A short pulse of power is then supplied to all electrodes by momentarily depressing the start button to energize relay AA when AN picks up and is removed when the button is released because the locking circuit for relay AN is, under these circumstances, held open at the contacts of relay AS.

The switch SS is restored to the position shown by actuating the button labeled "Reset" which completes a circuit for release magnet AH of switch SS thus enabling the return of its wipers to their first position under influence of a return spring (not shown). The wipers of switch TS

are of the double ended type and are advanced to the position shown upon completion of each alternate heating cycle. If for any reason the wipers 1W to 3W become improperly positioned, for example by a pulse resulting from a temporary current interruption not under control of relay AA, the push button PB may be operated at will to pulse magnet AB as required to advance the wipers to the desired position.

In the instant disclosure it has been assumed that sealing together of the respective cell parts 41 and 42 arranged as shown in Fig. 2 can be best accomplished by a heating schedule differing from that considered best for heating the marginal edges of a glass sheet. Therefore to enable one to set up the desired circuit arrangement for use in sealing, without destroying that set up for sheet heating, a switch SS' duplicating SS is provided and has its wipers W1' to W5' and operating magnet AG' available through the armature springs 21 to 26 of relay RM and their front contacts. By means of a "Seal" switch relay RM may be energized and switch SS' thus substituted for switch SS. The various control circuits are then selectively connected to bank contacts of switch SS' by means of jumpers in the manner best suited for the sealing operation. The release magnet AH' of switch SS' is connected in multiple with magnet AH so that irrespective of which of the switches SS or SS' has been operated operation of the reset button effects the release of the operated switch.

Although in the foregoing there has been described the preferred embodiment of our invention, it is to be understood that minor changes may be made in the circuits and/or apparatus without departing from the spirit and scope of our invention.

What is claimed is:

1. The method of heating a restricted path in a glass body which comprises causing a current of electricity to flow through said glass body along a section of said restricted path, causing a current of electricity to flow in another section of said restricted path after said first current has ceased to flow in said first path and transferring the application of current from said first section to said second section in response to the attainment of a current flow in the first section of a predetermined value.

2. The method of heating a restricted closed path in a glass body which comprises initially passing an electric heating current along sections of said path for predetermined periods of time and subsequently under control of the temperature characteristics of the sections passing the heating current therethrough for times sufficient to bring said entire path to a predetermined temperature.

3. The method of heating a series of sections of glass to a predetermined temperature which involves first feeding current through the sections in sequence for predetermined time periods and subsequently placing the time of application of feeding current to each section under control of the temperature characteristics of such section.

4. The method of electrically heating a series of sections of glass to a desired equalized temperature which involves heating the sections in succession in a succession of cycles, cutting off the heating current from each section upon its reaching a predetermined temperature during the first heating cycle, and increasing the cut-off temperature for the several sections at the comple-

tion of each subsequent cycle until all sections have attained the desired ultimate temperature.

5. The method of heating a restricted closed path in a glass body which comprises passing electric current sequentially through limited sections of the glass in said path to generate heat in the sections sequentially and repeatedly until a predetermined temperature is attained and utilizing the temperature developed in the respective sections while attaining the desired temperature to determine the periods of time of current application thereto.

6. The method of providing uniform and controlled electrical heating of the peripheral edges of a sheet of glass to a temperature proper for manipulation and fusion which includes passing current sequentially through limited sections of said peripheral edges to generate heat therein in succession and repeatedly until the temperature proper for manipulation and fusion is attained and utilizing the temperature developed in the respective sections while attaining the desired temperature to determine the time periods of current application thereto.

7. The method of heating the marginal portion of a glass article to a desired temperature which includes dividing the marginal portion into sections, heating the sections in succession and repeatedly for predetermined time periods through a predetermined number of cycles, thereafter placing the heating time periods under the control of the temperature of the sections and reducing the temperature increments from cycle to cycle and thus speeding up the frequency of application of heat to the sections as the desired temperature of the sections are being approached.

8. In an electric glass working apparatus, a series of electrodes positioned adjacent the ends of a series of connected glass sections, means for passing an electric current through said electrodes and the glass of said sections, means for supplying current to said sections in succession, and means for cutting off the current from and switching current to the respective sections in response to the establishment of predetermined temperatures of the glass therein.

9. In an electric glass working apparatus for heating the peripheral edges of a sheet of glass to a working temperature, a set of electrodes spaced along the path to be heated, a transformer whose secondary winding is adapted to supply current to selected pairs of said electrodes, relays for selectively connecting pairs of said electrodes to said transformer, a switch for operating said relays in succession, and means controlled by the temperature of a section being heated for determining the heating period of that section.

10. In an electric glass working apparatus, the combination with a plurality of electrodes between which sections of a glass article to be heated are arranged, of means for establishing circuit connections to said electrodes from a suitable current supply in such a manner that the sections of glass are successively and repeatedly heated, means for predetermining the heating periods of the respective sections until they have been heated a predetermined number of times and means for thereafter placing the control of the time period of heating of the respective sections to temperatures attained by them.

11. In an electric glass working apparatus, the combination with a series of electrodes un-

equally spaced along a path of glass to be heated by heat generated in the glass itself by its resistance to flow of an electric current, of means for applying voltage in such a manner that current flows through the respective sections in succession repeatedly until the respective sections have attained a desired ultimate temperature, and means for applying voltages to the respective sections which are proportional to the lengths of the sections so that their ultimate desired temperatures are established substantially at the same time.

12. The combination with a series of electrodes unequally spaced along a path of glass to be heated by heat generated in the glass itself by its resistance to flow of an electric current, of means for applying voltage in such a manner that current flows through the respective sections in succession repeatedly until the respective sections have attained a desired ultimate temperature, means for applying voltages to the respective sections which are proportional to the lengths of the sections so that their ultimate desired temperatures are established substantially at the same time, and means under control of the temperature of a section for terminating the supply of current thereto and for initiating the application of current to an adjoining section.

13. In an electric glass working apparatus a plurality of heating electrodes positioned along a band of glass and dividing it into sections, means for supplying heating current to said electrodes in such a fashion that the sections of glass receive heating current in succession and repeatedly, and means for progressively shortening the heating periods as the respective sections approach the desired temperature.

14. In an electric glass working apparatus, the combination with a plurality of electrodes arranged about a sheet of glass to impart heat to its marginal edges by heat generated in the glass itself by its resistance to the flow of electric current between said electrodes, of means for applying power to pairs of said electrodes in succession and repeatedly until all marginal edges of the sheet have been heated to a desired ultimate temperature and means for increasing the maximum permissible value of current at the beginning of each repetition of a heating cycle.

15. In an electric glass working apparatus for heating the marginal portions of a glass article to a suitable temperature for working, a group of electrodes associated with marginal portions of the article, switching means under whose control pairs of said electrodes are successively and repeatedly connected to a source of heating current, and switching means under control of which the voltage applied to said pairs of electrodes is modified from time to time.

16. In an electric glass working apparatus for heating the marginal portions of a glass article to a suitable temperature for working, a group of electrodes associated with marginal portions of the article, a switch under control of which pairs of said electrodes are successively and repeatedly connected to a source of electricity, a second switch under control of which the voltage applied to said pairs of electrodes is modified from time to time and further means under control of one of said switches for modifying the voltage applied in accordance with the relative spacing of the pairs of electrodes.

17. In an electric glass working apparatus for heating the marginal edges of a polygonal glass article, a group of heating electrodes one at each

corner of the article, a transformer for supplying heating current to said electrodes having a tapped secondary winding, means for connecting the entire secondary winding to pairs of said electrodes in succession until each marginal edge of the article has been subjected to current supplied to a pair of said electrodes, and means for so modifying the circuits that only selected portions of said secondary winding are connected to pairs of said electrodes as they are connected to pairs thereof in succession.

18. In an electric glass working apparatus for controlling the application of heating current to electrodes arranged about the marginal edges of a glass article to heat its edges to a temperature proper for fusion or working, a transformer for supplying heating current to said electrodes having a tapped secondary winding, means for successively connecting pairs of said electrodes with said secondary winding in such a fashion as to heat the respective sections of glass therebetween successively and repeatedly until the marginal edges attain a desired temperature, and means for varying the portions of the secondary winding which are connected to the electrodes in the meantime to selectively regulate the rate of temperature rise of the sections.

19. In an electric glass working apparatus, a

series of electrodes positioned at spaced points along a closed path adjacent a glass body, means for applying voltage sequentially to pairs of said electrodes to place the entire path under the influence of said voltage, means for repeating the application of voltage to said electrodes in a predetermined number of complete cycles about said path and means operable upon completion of a cycle for modifying the voltage to be applied to the electrodes during another cycle of operation.

20. In an electric glass working apparatus, a series of electrodes positioned at spaced points along a closed path adjacent a glass body, means for causing current to flow between a pair of said electrodes through said glass body, means for switching said current from one pair of electrodes to another until it has flowed through all portions of said path, means operable upon completion of one full traverse of the path by said current for varying the maximum permissible value of said current, and means thereafter operable to cause said current again to flow through said path, the means for switching said current being operable when said current reaches said maximum permissible value.

EDWIN M. GUYER,
MORTON R. SHAW, JR.