(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 038 407**
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 81101209.5

(22) Date of filing: 20.02.81

(51) Int. Cl.³: H 05 B 3/60
H 05 B 3/00

(30) Priority: 17.04.80 US 140461

(43) Date of publication of application:
28.10.81 Bulletin 81/43

(84) Designated Contracting States:
BE DE FR GB IT

(71) Applicant: Société Francaise des Techniques Lummus
Tour Franklin Cedex No.11
F-92081 Paris La Defense 8(FR)

(72) Inventor: Purcell, Joseph
P.O. Box 199
South Wales New York(US)

(54) Control for high-temperature electric refractory furnace.

(57) A control apparatus, for starting and operating a high-temperature electric furnace (F) for melting refractory materials, includes a three-phase power supply (Phase A, Phase B and Phase C) for supplying energy to three electrodes (E1, E2 and E3) of the furnace. Included in the connections between the power supply and the furnace electrodes are three input transformers (T1, T2 and T3) one for each phase. The primary of each transformer includes a tap-changer section. Connected between the power supply and the tap-changer are two current paths connected in parallel. The first current path is non-inductive. It includes at least one silicon controlled rectifier (SCR-A, SCR-B and SCR-C). This path is used after steady state conditions have developed. The second current path is highly inductive. The inductance is controlled by a continuously variable transformer (BT-A, BT-B and BT-C) commonly known as a Variac. This path is used during start-up. The combination, in series, of the tap-changer and Variac controlled inductance in a second path which is used during start-up, provides a vernier control of the voltage, and, hence, the current, applied to the furnace electrodes (E1, E2 and E3) during start-up, with the inductance providing protection against sudden current surges which would otherwise tend to blow fuses and open circuit breakers (CB1, CB2 and CB3).

./...

EP 0 038 407 A2

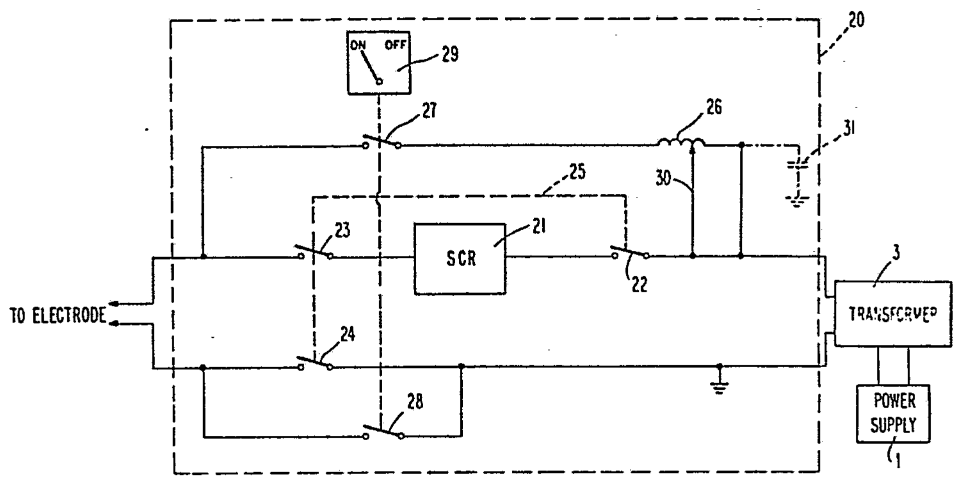

20
ON
OFF
29
27
26
31
25
30
23
SCR
21
22
TO ELECTRODE
3
TRANSFORMER
24
28
POWER SUPPLY
1

Fig. 2

CONTROL FOR HIGH-TEMPERATURE ELECTRIC REFRACTORY FURNACE

Background of the Invention

This invention relates to the placing in operation of high-temperature electric furnaces for melting refractory materials. Such furnaces are well known in the art, as exemplified by the apparatus disclosed in the patents to de Bussy, United States Patent Nos. 3,147,328 and 3,659,029. Furnaces of this type generate extremely high temperatures in their interiors, of the order of 2,000°C. Such temperatures are necessary to melt materials such as mullite, a combination of aluminum oxide (Al_2O_3) and silicon dioxide (SiO_2) which is used in the manufacture of ceramic fibers. Heating in such furnaces is accomplished through the use of electrodes which lie submerged in a bath of molten material within the furnace. It is common to find three electrodes in such a furnace, spaced at equal intervals around a furnace vessel. Also, in some furnaces, the output nozzle, through which molten material leaves the furnace, also functions as an additional electrode. The electrodes deliver power on the order of 500 kilowatts to the furnace. Because of the extremely high temperature involved, it is necessary and desirable to control precisely the shape and the location of the pool of molten material within the furnace. These parameters are controlled by adjusting the positions of the electrodes within the molten pool.

Although the melting of refractory materials is very simple in theory, the actual placing in operation of an electric furnace presents serious difficulties. Before current is supplied to the electrodes, a "starter" material, such as cullet (made from broken or crushed glass) is placed within the furnace and melted by propane or acetylene torches. The cullet will melt at about 300°C, at which point current may be supplied to the electrodes. The presence of the molten cullet facilitates the transmission of heat to the still solid mullite surrounding the cullet. While the mullite is still solid, its resistance is relatively high, but as it melts, the resistance declines. Because of the inhomogeneity of the mullite, and also because of the movement of the electrode which is necessary to control properly the position of the molten pool the resistance of the mullite, as seen by the electrodes, is not constant during the start-up procedure. As an electrode is being moved through a region which happens to have experienced melting faster than another region, a sudden surge of current appears in the electrode, and the delicate balance of current in the electrodes, which is necessary for the proper positioning of the molten pool, is upset.

While the electrode furnace is operating, the current supplied to the electrodes is carefully regulated, typically by the use of silicon-controlled rectifiers. But while the furnace is being started, the silicon-controlled rectifiers are endangered by the sudden surges of current as described above. It is a common practice to place fuses in series with the silicon-controlled rectifiers. But because of the sudden surges of high current, these fuses must be capable of withstanding large flows of current. To replace several fuses which have blown, each time a furnace is started, would involve loss of time and considerable expense. Furthermore, the surges that can occur may be so sudden that they can destroy the silicon-controlled rectifiers before the protective fuse has a chance to break the circuit. The destruction of these silicon-controlled rectifiers, which have been designed to handle power of the order of 500 kilowatts, would also be a very costly accident.

When the mullite and the other refractory material within the furance has been melted, and the electrodes have been adjusted to provide the desired size and shape of the molten pool, there is no longer any considerable danger of sudden current surges. The electrodes no longer need be moved, and the pool of molten material retains a relatively stable shape. During this steady-state operation, there is little danger of sudden surges in current, and the silicon-controlled rectifiers may be used without undue risk of damage. The silicon-controlled rectifiers are useful in precisely regulating the amount of current supplied to the electrodes.

Summary of the Invention

It is a primary object of the present invention to provide improved control apparatus for starting and operating high-temperature electric furnaces for melting refractory materials.

A more specific object is to provide control apparatus for starting and operating high temperature electric refractory furnaces so as to avoid the sudden current surges which have heretofore occurred during the starting up of such type furnaces and which have caused fuses to blow or breakers to open.

A further object is to provide an apparatus such as described above which, once the start-up high-current surge stage has been passed, can be switched to a control system wherein the supply of electric current is regulated by silicon controlled rectifiers, as is desirable.

The foregoing objects are achieved, in accordance with the present invention, by providing, between the power source and each electrode of the furnace, a first non-inductive current path which includes a pair of parallel connected silicon-controlled rectifiers (SCR's) for controlling the amount of current supplied to the tap-changer primary of said input transformer, and a second inductive current path which includes a continuously variable transformer for controlling the amount of inductance which is placed in series with a tap-changer primary of the input transformer. Also provided are, of course, the necessary switches and switch controls for selecting either the inductive path or the non-inductive current path. During startup, power is supplied through the inductive path which is controlled by the continuously variable transformer; the second path is open. Following startup and during steady state operation, the non-inductive path is closed and the inductive path is open. Power is then supplied to the furnace electrode through the silicon controlled rectifiers and the tap-changer primary of the input transformer.

Brief Description of the Drawings

Fig. 1 is a diagram of a control panel according to the present invention;

Fig. 2 is a schematic diagram of the control circuitry according to the present invention;

Fig. 3 is a diagram illustrating the switches and relays which are operated by the control knobs located on the control panel.

Detailed Description of the Preferred Embodiments

Referring first to Fig. 2, a refractory furnace F is shown as having three electrodes E1, E2 and E3 at approximately 120° spacing. As has been indicated previously, each of these electrodes is adjustably movable to a limited extent to the right or to the left so that the operator may find the position which is best, at the moment, for the particular condition of melt of the refractory material in the furnace.

Power to the three electrodes of furnace F is supplied from a three-phase electric power line. While not intending to be limited to any particular value of voltage, it may be said that in one particular installation the line voltage between each phase of the three-phase power supply is 480 volts AC.

Three main circuit breakers, identified CB1, CB2 and CB3 in Fig. 2, control the connection of the power supply to the control circuitry provided by the present invention and which is connected between the main circuit breakers and the three electrodes of the furnace.

Each of the three electrodes E1, E2, E3, is supplied directly from the secondary winding of an input transformer, T1, T2 and T3, respectively. One end of each secondary winding is connected to a common ground, as is the discharge nozzle N of the furnace F. Voltage meters and current meters are shown connected to the secondary winding of each input transformer so that the voltage and current to each electrode may be monitored. Each of the input transformers T1, T2, T3, has a primary winding which, as shown in Fig. 2, includes a tap-changer section having an adjustable arm.

Connected between each of the three main circuit breakers CB1, CB2 and CB3 and the arm of the tap-changer section of the primary winding of the respective input transformer T1, T2 and T3, are components which form two parallel current paths, for each phase. The first current path is non-inductive and includes silicon controlled rectifiers (SCR's) which control the current to the primary winding of the input transformer. The second path is inductive. The magnitude of the inductance is controlled by a Variac which is a well-known trade name for a continuously variable transformer. Only one of the two parallel current paths is used at any one time. The inductive path is used during start-up. This path is referred to herein as the by-pass. The non-inductive path is used during steady-state or "melt" conditions.

Reference is now made to the inductive path which includes, in parallel, the primary winding P and the paralleled secondary windings S1 and S2 of the continuously variable transformers BT-A, BT-B and BT-C. For convenience, these continuously variable transformers will sometimes be referred to as Variacs but it is to be understood that they may be products of manufacturers other than the owner of the trademark.

Assume that it is start-up and that the attendant will be using the inductive path. In such case, he closes the manually-controlled switch DS-1, and, as later described in more detail, he throws a control switch to energize a relay 1C to close the relay contactors 1C1, 1C2 and 1C3. The three-contact switch DS-2 is always closed and assuming the main breakers are closed, current flows through the primary and secondary windings of the Variacs. Since the line voltage applied to the secondary and primary windings of the Variac are in phase, the effect of moving the continuously movable slidable arm on winding S2 will be as follows: when the arm is all the way down (as viewed in Fig. 2) all the current from the power source flows through winding S2 and none flows through winding S1. In such case, since the secondary winding S1 is shorted, the mutual coupling of S1 with primary winding P is maximum, and maximum induced current flows through secondary winding S1. The voltage drop across the primary winding P is then minimum, and, since the Variac and the tap-changer secondary of the input transformer are in series in a voltage-divider arrangement, the voltage remaining for application across the input transformers T1, T2, T3 is maximum.

When the continuously slidable arm is placed at the uppermost point on winding S2, current flow through winding S1 originating from the power source is maximum, and the mutual coupling between S1 and primary winding P is minimum. The voltage drop across the primary P is then maximum, and the voltage remaining for application across the input transformer is minimum.

It will be seen from the foregoing, that when the inductive or by-pass path is being used, the position of the slidable arm controls the inductance of the continuously variable transformers BT-A, BT-B and BT-C and hence controls the voltage available for application across the tap-changer, and thus controls the voltage available for application to the electrodes of the furnace.

It will be seen that the combination, in series, of the Variac and the tap-changer primary of the input transformer, provides a Vernier type of control of the voltage developed across the secondary of the input transformers T1, T2, T3, for application to the electrodes E1, E2, E3 of the furnace. The tap-changer gives a step-by-step adjustment in relatively large incremental steps. The continuously slidable arm of the Variac gives a continuous and very fine adjustment.

Referring now to Fig. 1, provision is made on the control panel for manual control of the various circuits and components. The control panel includes, for example, (1) a BREAKER switch for controlling the condition of the main circuit breakers; (2) a MODE SELECT switch for controlling whether power to the tap-changer input transformer is supplied through a first path which is non-inductive or through a second path which is inductive; (3) an SCR switch for controlling the signal applied to the gate lead of the SCR's; (4) a TAP SELECT switch for selecting the tap position on the tap-changer primary of the input transformer; (5) a FREEZE-UP OFF-SET switch; etc.

Operation

Prior to the start-up, the attendant makes sure that the BREAKER SWITCH on the control panel (Fig. 1) is in the TRIP or OFF position. All three main circuit breakers CB1, CB2 and CB3 (Fig. 2) are open. The attendant puts the MODE SELECT switch on the control panel (Fig. 1) in the OFF position, and, if closed, he opens manually the DS-A, DS-B and DS-C circuit breakers (Fig. 2).

To start up the furnace, the attendant wants to first use the inductive path. He does this by first turning the MODE SELECT switch (Fig. 1) to the BY-PASS position (Figs. 1 and 3). This energizes the 3CR relay coil (Fig. 3) and closes the normally-open contacts 3CR1, 3CR2 and 3CR3 (Fig. 3). The attendant next manually closes the DS-1 circuit breaker (Fig. 2). Next, the attendant puts the BY-PASS switch (Fig. 1) in the HAND position. This allows manual adjustment of the three continuously variable transformers BT-A, BT-B and BT-C (Fig. 2). Next, the attendant puts the TAP SELECT switch (Fig. 1) in a desired position. This puts the arm of each of the three tap-changer primaries (Fig. 2) in the same position.

Having done the above, the attendant is now ready to turn on the power. He does this by turning the BREAKER switch (Fig. 1) to the CLOSED or ON position. This closes the three main breakers. Next, the attendant pushes the START button (Fig. 3). This energizes the coil of the 1C relay and causes the normally-open contactors 1C1, 1C2 and 1C3 (Fig. 2) to close and causes the normally-closed contactor 1C4 (Fig. 3) to open.

Since, as previously indicated, the DS-2 switch (Fig. 2) is always closed, the closing of contactors 1C1, 1C2 and 1C3 allows current to flow through the secondary windings S1, S2 of each of the Variacs. This current is in phase with the current through the primary winding P. Thus, the greater the flow of current (non-induced) through the secondary winding S1, the smaller the mutual inductance between windings S1 and P. The attendant first adjusts the TAP SELECT switch on the control panel (Fig. 1) to achieve approximately the results desired. Then he swings the Variac arms up and down to refine the desired result. In one particular installation, now being described, the line voltage between each phase of the three-phase power source is 480 volts. The swing of the Variacs is 17 percent of 480 volts, or a swing between 0 and 80 volts.

When the workers at the furnace notify the attendant that they are satisfied with the condition of the melt, the attendant does that which is necessary to switch from the inductive or by-pass path to the non-inductive or SCR path. To do this, he first turns the BREAKER switch to the TRIP or OFF position. This opens the three main circuit breakers. The attendant then manually opens circuit breaker DS-1 (Fig. 2) and he pushes the STOP-START switch (Fig 3) to the STOP position, thereby de-energizing the coil of the 1C relay (Fig. 3) and opening contactors 1C1, 1C2 and 1C3 (Fig. 2).

The attendant next turns the MODE SELECT switch (Fig. 1) from the BY-PASS to the MELT position. This energizes the coil of the 1CR relay (Fig. 3) and closes the normally-open contactors of that relay.

The attendant now turns the BREAKER switch (Fig. 1) to the CLOSED or ON position, thereby closing the three main circuit breakers. Next, the attendant manually closes the breakers DS-A, DS-B and DS-C. He next turns the MELT sub-switch of the MODE SELECT switch to the RESET position (Fig. 1). This fires up the three SCR's, namely SCR-A, SCR-B and SCR-C (Fig. 2). The MASTER KW regulator (Fig. 2) or the manual knob on the control panel controls the signal to the gate leads of the SCR's and the SCR's control the current to the tap-changers of the three input transformers. In this manner, the voltage and current to the three electrodes of the furnace are controlled during the "Melt" phase of the operation.

Claims

1. An apparatus for controlling the start-up and operation of a high temperature electric furnace for melting refractory materials, said furnace (F) having a plurality of electrodes (E1, E2 and E3), said control apparatus comprising a source of AC line power, an input transformer (T1, T2 and T3) having a primary winding and a secondary winding, a first current path connected between said source of line power and the primary of said input transformer (T1, T2 and T3), said first path being relatively non-inductive, at least one silicon controlled rectifier (SCR-A, SCR-B and SCR-C) in said first path, control means for varying the signal on the gate lead of said silicon controlled rectifier (SCR-A, SCR-B and SCR-C), thereby to control the current to said input transformer (T1, T2 and T3), means for applying the voltage developed in the secondary of said input transformer (T1, T2 and T3) to an electrode (E1, E2 and E3) of said furnace (F), characterized by a tap-changer section and an adjustable arm associated with said primary winding of said input transformer (T1, T2 and T3); a control means for varying the position of said adjustable arm on said tap-changer; a second current path connected between said source of line power and said adjustable arm on said tap-changer, said second path containing an inductance; a continuously variable transformer (BT-A, BT-B and BT-C) operatively associated with said inductance for controlling the magnitude of said inductance; a control means for varying said continuously variable transformer (BT-A, BT-B and BT-C) for controlling the magnitude of the inductance in said second path thereby to control the magnitude of the voltage applied across the primary of said input transformer (Ti, T2 and T3); and means for completing said second current path and interrupting said first current path during start-up and for interrupting said second current path and completing said first current path after steady-state conditions have developed.

2. An apparatus as in Claim 1, characterized in that the continuously variable transformer (BT-A, BT-B and BT-C) includes a secondary winding having a continuously slidable adjustable arm in contact therewith.

3. An apparatus as in Claim 1 or 2, characterized in that said first path includes a pair of silicon controlled recitifiers (SCR-A, SCR-B and SCR-C) in parallel.

4. An apparatus as in Claim 1, 2 or 3, characterized in that there are at least three of each: sources of AC power; electrodes (E1, E2 and E3); input transformers (T1, T2 and T3); said first current paths; said second current paths; continuously variable transformers (BT-A, BT-B and BT-C); control means for varying the position of said adjustable arm on said tap-changers; control means for varying said continuously variable transformers (BT-A, BT-B and BT-C); means for closing the second current paths and opening the first current paths during start-up, and for opening the second current paths and closing the first current paths after steady-state conditions have developed; and means for applying the voltage developed in the secondary of the input transformers (T1, T2 and T3) respectively to one electrode (E1, E2 and E3) of said furnace (F).

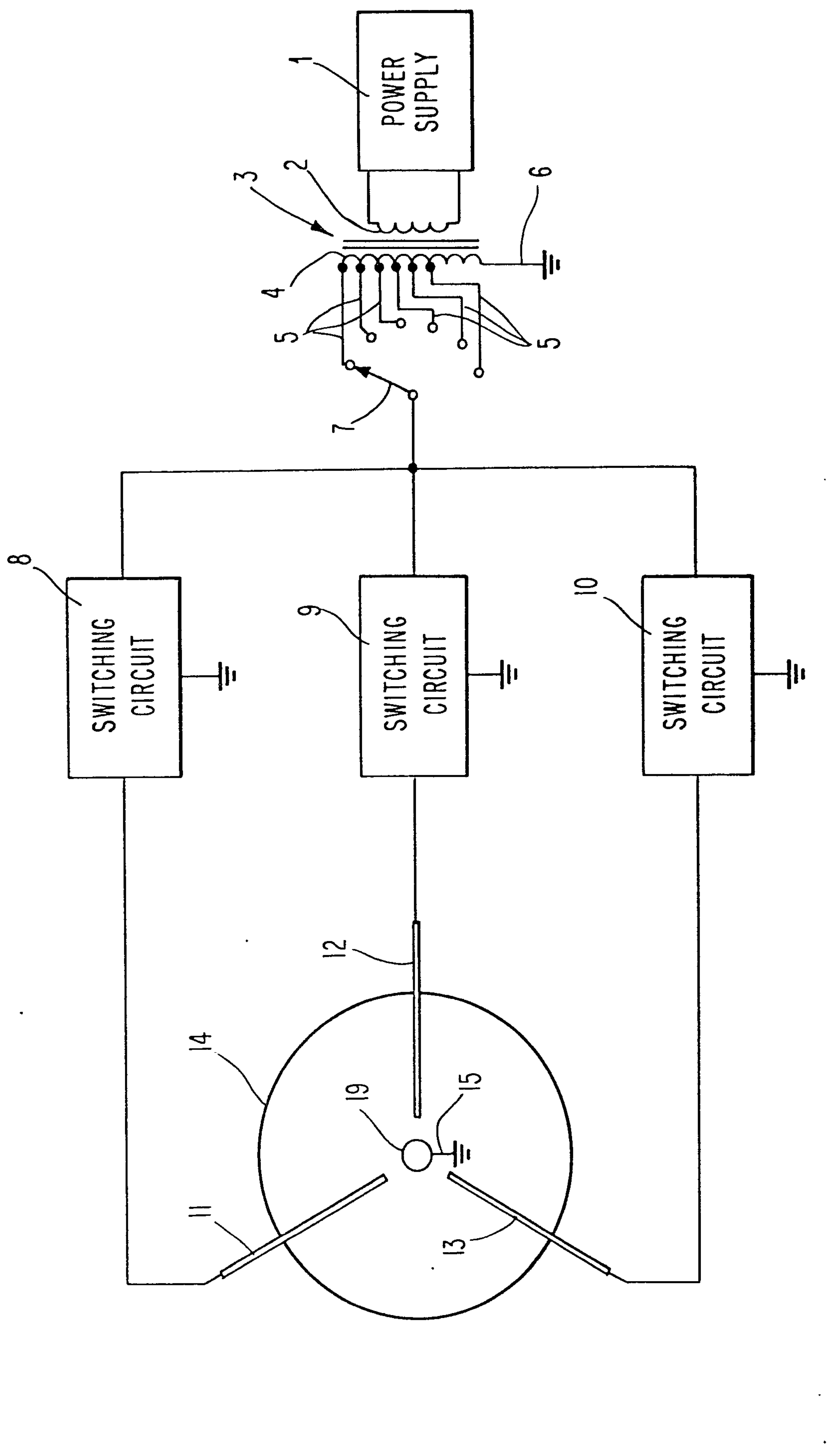
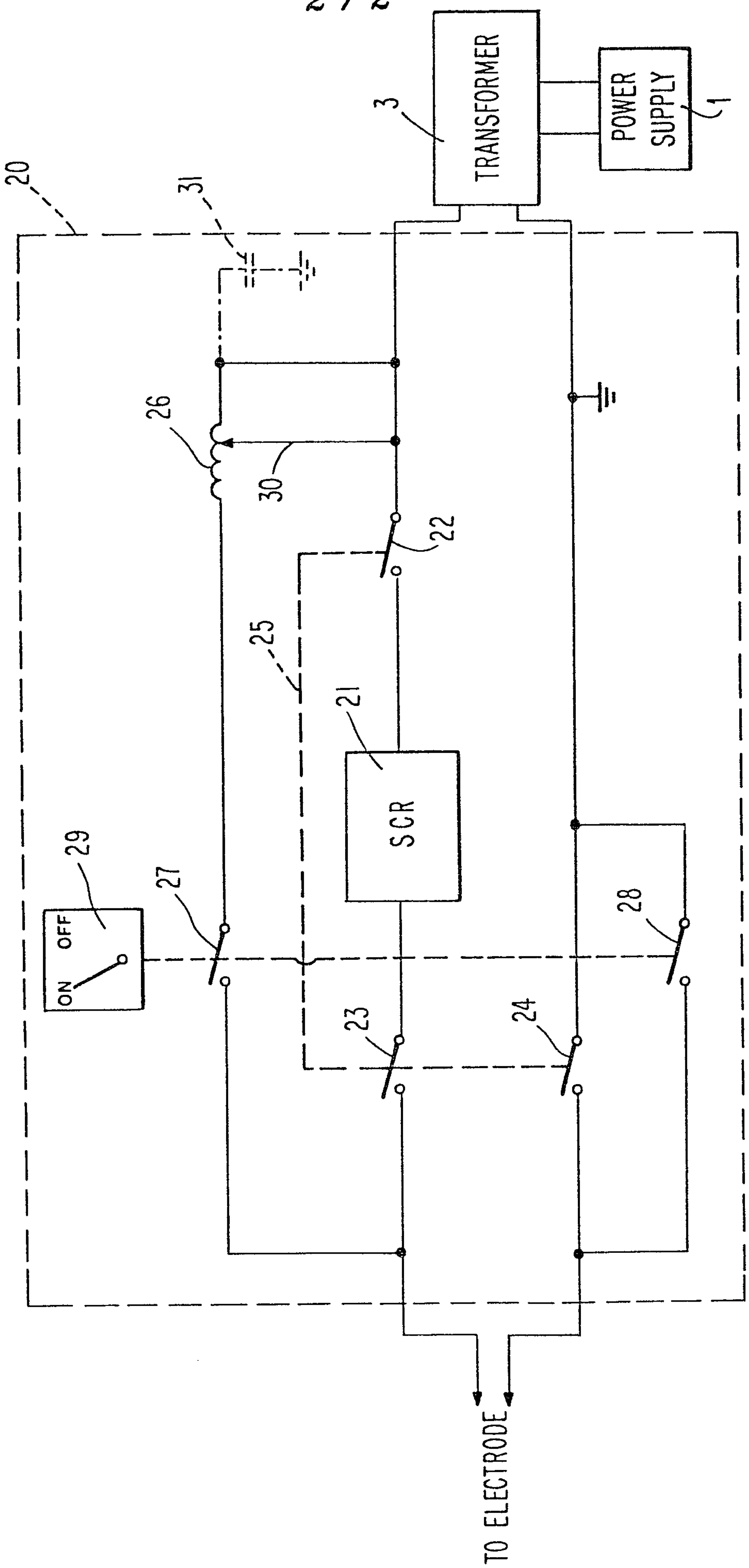

POWER SUPPLY
1
2
3
4
5
5
6
7
SWITCHING CIRCUIT
8
SWITCHING CIRCUIT
9
SWITCHING CIRCUIT
10
11
12
13
14
15
19

Fig. 1



TRANSFORMER
POWER SUPPLY
1
3
20
31
26
30
22
25
21
SCR
29
ON
OFF
27
28
23
24
TO ELECTRODE

Fig. 2