

June 2, 1964

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3,135,677

DURABLE ANODE PROTECTIVE SYSTEM

Filed Feb. 2, 1961

2 Sheets-Sheet 1

FIG. 1

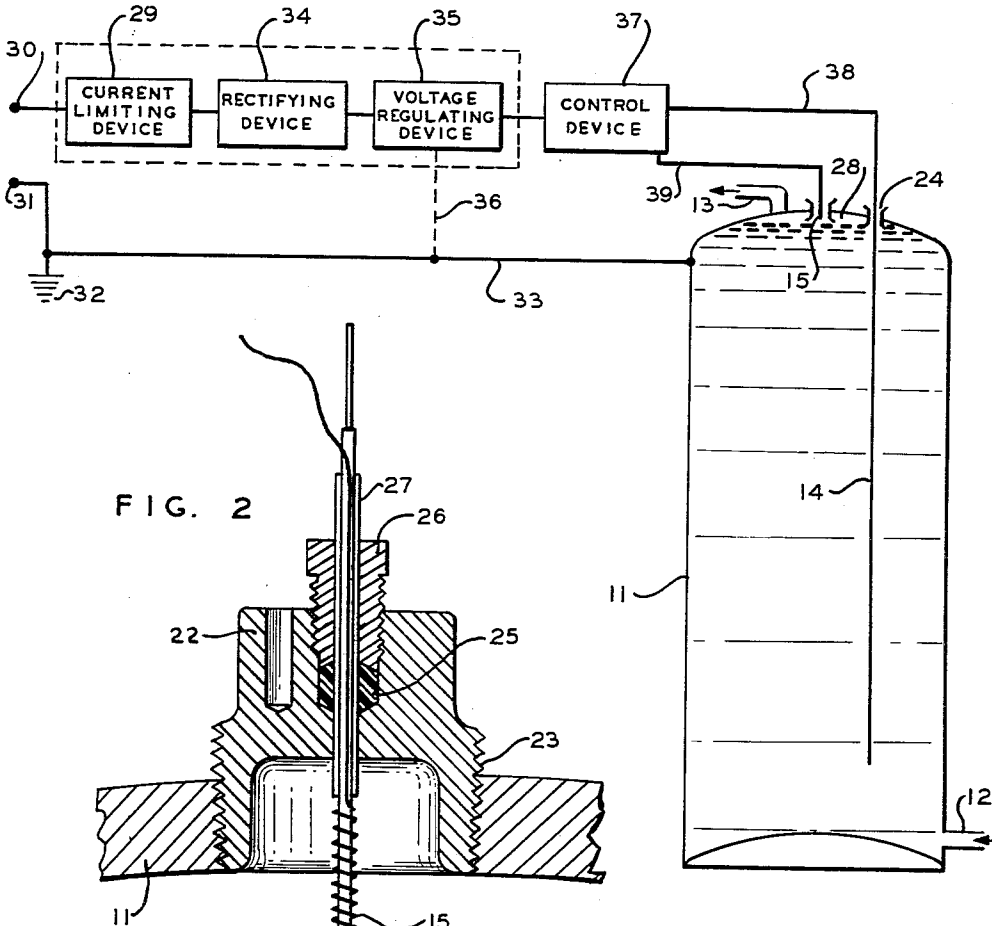


FIG. 2

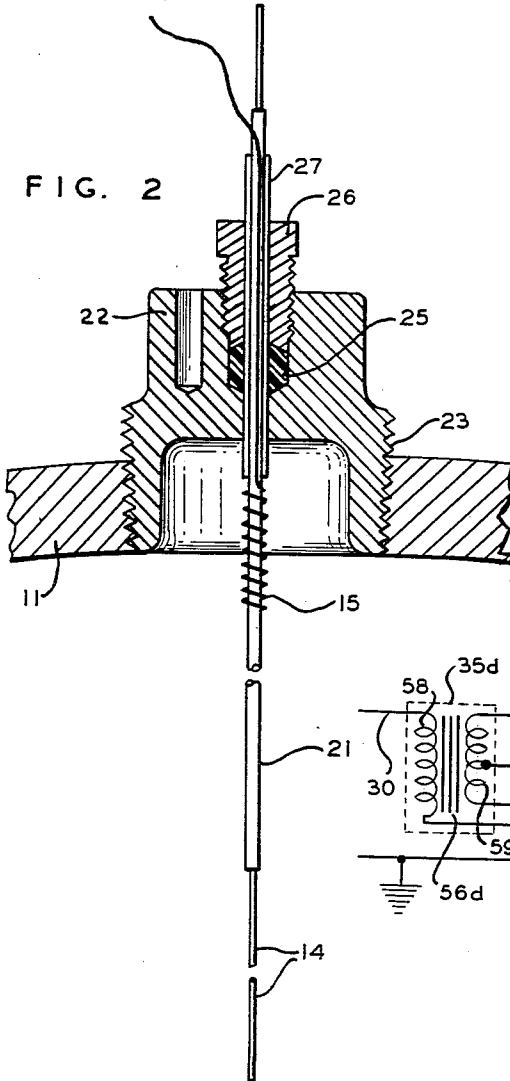
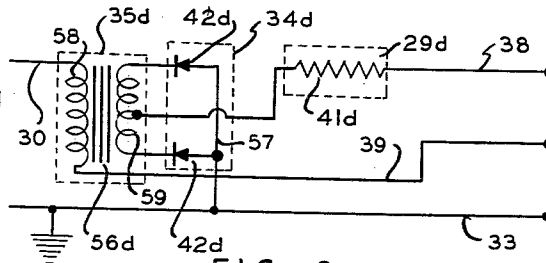


FIG. 8



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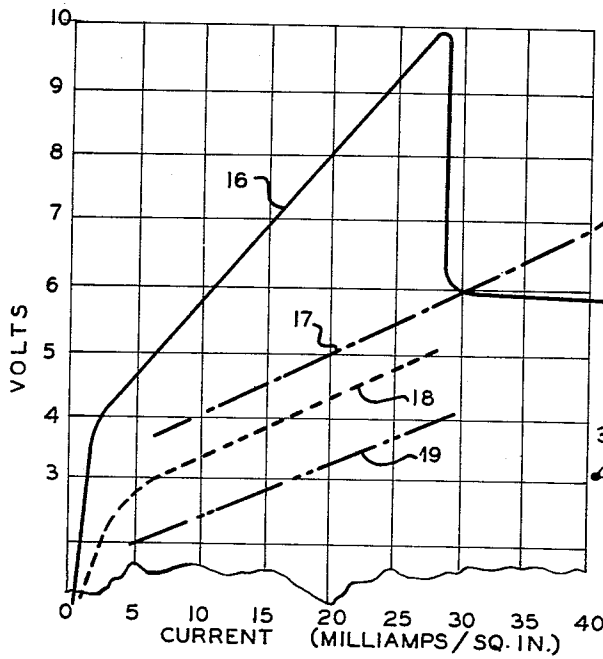


FIG. 3

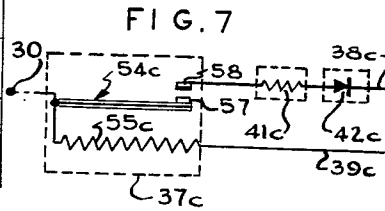


FIG. 7

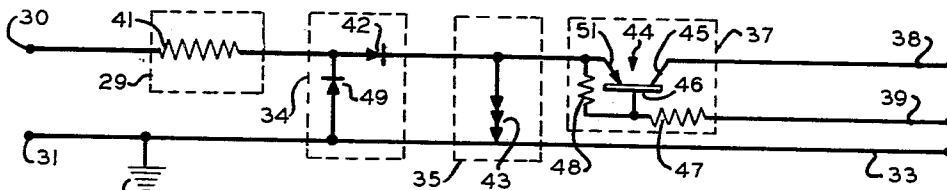


FIG. 4

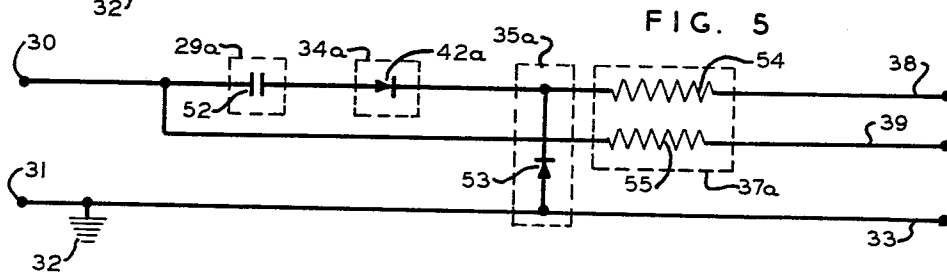


FIG. 5

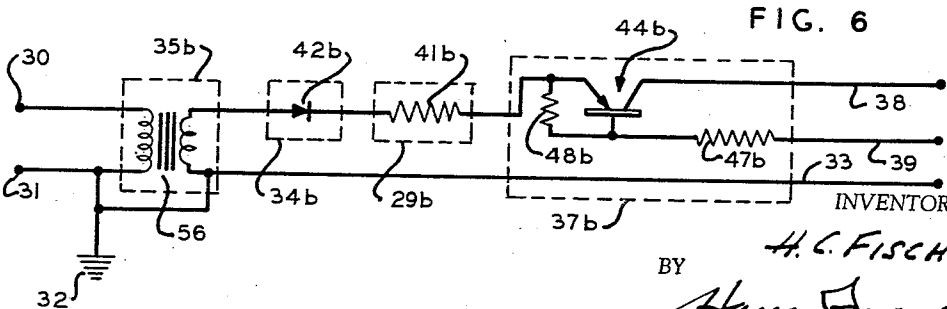


FIG. 6

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DURABLE ANODE PROTECTIVE SYSTEM

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3 Claims. (Cl. 204-196)

This invention relates to an impressed current cathodic protection system for hot water tank heaters and is particularly adapted for use with dielectric lined hot water tanks.

By impressed current cathodic protection is meant the use of a unidirectional current to prevent corrosion of a metal in an electrolyte by making such metal the cathode.

In recent years the use of glass-lined hot water tanks has become prevalent. While theoretically a coating of glass, or other protective dielectric material, upon the interior surface of such tanks will prevent the covered metal surface from corrosion, in practice this is not completely accomplished. Minute spots of metal are generally left uncovered and these bare areas, called "holidays," corrode, causing the tank to deteriorate and eventually leak, even though the glass-covered portion of the tank is perfect.

Sacrificial anodes, such as those of magnesium, have been widely used and generally perform satisfactorily in protecting the bare metal areas. A number of difficulties arise with the use of such anodes. First, there is the replacement problem. In some waters magnesium corrodes very rapidly, while in others it will not corrode at all and thus will not give protection. Furthermore the presence of sulphur in the water will result in a bad taste and a disagreeable odor. Local cells caused by impurities in the anode tend to consume it and thus shorten its protective life. Corrosion products of the anode fall to the bottom of the tank and may cause popping noises in gas hot water heaters. When a magnesium anode is consumed, the homeowner is generally not aware of it and, since he does not replace it, all protection is lost.

With glass-lined tanks there is, at most, a few square inches of bare metal that requires protection. With this small area, an impressed-current cathodic system is economical when compared with a sacrificial anode.

An object of the invention is to provide for economical protection of glass-lined hot water heaters over a long period of time.

Another object of my invention is to provide a system of cathodic protection in which the impressed current is virtually discontinued, as during non-use of the hot water tank, upon accumulation of electrolytic gases in the top portion of said tank.

A further object of my invention is to provide a control system for the impressed protective current which passes to a hot water tank, to thereby stop such current, if gases accumulate in the top portion of the tank to a predetermined extent, and reinstate such current when the tank is used sufficiently to remove the accumulated gases.

A still further object of my invention is to provide a hot water heater, the tank of which is protected by two electrodes depending thereinto, one of which is desirably formed of titanium and normally maintained as an anode with respect to the tank wall as a cathode, and the other one of which is desirably formed of platinum-plated-titanium and connected so as to substantially shut off the action of the anodic electrode when gas accumulates at the top of the tank to a predetermined extent.

These and other objects and advantages will become apparent from the following detailed description when taken with the accompanying drawings. It will be understood that the drawings are for purposes of illustration

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and do not define the scope or limits of the invention, reference being had for the latter purpose to the appended claims.

In the drawings, wherein like reference characters denote like parts in the several views:

FIGURE 1 is a diagrammatic representation of a hot water tank with a control circuit embodying my invention, the means for heating the water in the tank not being shown,

FIGURE 2 is an enlarged axial sectional view of control electrodes embodying my invention,

FIGURE 3 is a chart showing the current voltage relationship of titanium electrodes when in cold water and when in hot water of various temperatures, in comparison with that of a titanium electrode plated with platinum,

FIGURE 4 is a wiring diagram, supplementing FIGURES 1 and 2, showing details of one embodiment of the control circuit of said FIGURE 1,

FIGURE 5 is a wiring diagram, also supplementing FIGURES 1 and 2, showing details of another embodiment of said control circuit,

FIGURE 6 is a wiring diagram, further supplementing FIGURES 1 and 2, showing details of a further embodiment of said control circuit,

FIGURE 7 is a fragmentary portion of another wiring diagram, to supplement FIGURES 1 and 2, and show an additional embodiment of the control device, and

FIGURE 8 is a wiring diagram additionally supplementing FIGURES 1 and 2, showing details of a further embodiment of the control circuit. The current limiting, rectifying, voltage regulating, and control functions do not necessarily have to be in the order shown in FIG. 1.

Referring to the drawings in detail and first considering the embodiment of my invention as illustrated in FIGURE 1, there is shown, as in vertical section, the tank 11 of the hot water heater. The means for heating the water in the tank is not illustrated but the heating may be by electricity, gas or other desired means. The tank 11 is assumed to be glass-lined, to have a cold water inlet pipe 12, and a hot water outlet pipe 13. Extending into the tank a relatively great distance from above and insulated therefrom is a main durable protective anodic electrode 14, desirably formed of titanium. An auxiliary durable control electrode 15, desirably formed of platinum-plated titanium, also extends from above and projects to normally engage the tank-contained water, but only a relatively small distance into the tank and is insulated therefrom and from the main electrode 14.

It was originally thought that it would be necessary to platinum-plate or use platinum facing on titanium anodes, if used, to make them operate satisfactorily, because titanium is one of the so-called "valve" metals. Such metals have the characteristic that when they are used as anodes in water they build up on their surfaces very tenacious dielectric oxide coatings, which prevent passage of current from an anodic surface to a cathode, but do not prevent the passage of current in the opposite direction. The characteristic of such metals is that after a critical potential is reached, in the case of tantalum about 70 volts, the oxide film breaks down and rapid corrosion results. In the case of the preferred titanium anode, this breakdown potential is around 10 volts.

Referring now to FIGURE 3, there is shown a curve 16 indicating that as the voltage on a titanium anode in water increases, the current therefrom to a cathode increases until a critical voltage of about 10 is applied and the oxide coating, formed on the titanium metal surface, breaks down. In this case, the breakdown occurs in cold water with a drop in voltage when the current flow is between 25 and 30 milliamps/sq. in., and rapid corrosion results at the considerably lower voltage indicated. The

curves 17 and 18 in FIGURE 3 represent the results with a titanium anode, as in curve 16, except that instead of being immersed in cold water, it is immersed in hot water of different temperatures. For example, the curve 17 represents the results with a titanium anode in water at a temperature of about 140°, while the curve 18 represents the results with a titanium anode in water of about 160°. Curve 19 represents the results with a titanium anode which is clad or coated with platinum, as by plating.

As represented by the dotted continuation of curve 17, the breakdown is at the same voltage but at a considerably higher current than when the titanium anode is in cold water, as in curve 16. It will, therefore, be seen that the protective surface film on titanium has peculiar properties. It is resistant to the passage of current into an electrolyte, but has low resistivity when a second metal, such as platinum, makes contact with it. If an attempt is made to use titanium as an anode, this resistance to the passage of current into the electrolyte immediately becomes apparent.

As shown in FIGURE 3, as an increasing anodic current is applied, the voltage, to force the current through the surface film, rises until at the weakest point the film breaks down and intense local corrosion occurs. If, however, platinum is disposed on the surface of the titanium, most of the current passes out through the platinum at a considerably lower voltage and the titanium is uncorroded. I am making use of the peculiar properties of titanium in a preferred embodiment of the invention to be disclosed.

In the embodiment illustrated in FIGURE 2, the main anode 14 is desirably cold-drawn titanium wire. This is passed through an insulating sleeve 21, desirably formed of Teflon. Said sleeve serves to insulate the anode 14 from a mounting plug 22 desirably carrying threads 23 for connecting to, and closing a correspondingly threaded opening 24 in, the top portion of the tank 11. The Teflon sleeve 21 also serves to prevent "short path" current from flowing from the anode 14 to the wall of the tank 11. The attempt in this case is to create an approximately equidistant path from the anode to the walls of the tank. For this purpose, the connection of the plug 22, although not so illustrated in FIGURE 1, is desirably on the axis of the tank 11, if the tank is cylindrical, with a vertical axis, and the anode 14 desirably terminates a distance from the bottom of the tank corresponding approximately with the tank radius.

The connection with the plug 22 is made watertight by employing packing 25, desirably of teflon, which is compressible by a nut 26 threaded into the plug 22 and apertured to receive the anode 14, the sleeve 21, and another sleeve 27. This other sleeve 27 surrounds the auxiliary electrode 15, or the extension therefrom to the control device. This auxiliary electrode is desirably platinum-plated titanium wire which is wound around the Teflon sleeve 21 and insulated from the mounting plug 22 by the sleeve 27, as well as from the compression nut 26. The nut 26 serves to compress and make leaktight, not only the anode 14 but also the auxiliary electrode or "trigger wire" 15. The purpose of the trigger wire 15 is to sense the presence of undesirable gases, indicated at 28 in FIGURE 1, in the top portion of the tank 11. Such gases would be normally due to the electrolytic process and thus consist of hydrogen and oxygen. If they accumulate to a sufficient extent, the auxiliary electrode 15 will not touch the water and thus cannot conduct any current. The fact that this happens makes it possible to control the current to the anode 14 so that only a very minimum amount of gas can ever accumulate in a hot water heater, even when idle.

During the normal operation of a water heater, all of the electrolytic gases produced, if any, are dissolved in the water flowing through the tank. It is only during periods of extended idleness that the water then becomes saturated and the electrolytic gases separate at the top

portion of the tank. It is during these periods of idleness, such as vacation periods, that it is desired to shut off the anode current. When the gases accumulate, this action is effected by means of the trigger or auxiliary electrode 15. Shut-off is accomplished, in accordance with my invention, through suitable relay-type action to be disclosed. Where the current used for protection is in excess of that permitted, in accordance with FIGURE 3, or where the voltage must be higher than 10 volts, platinum plating or platinum cladding of a portion of the anode will reduce the voltage required to supply the necessary current.

Referring now again to FIGURE 1, there is illustrated a generic form of a power supply which includes current-limiting means 29 between the anode 14 and pole 30 of a source of alternating current, such as conventional house lighting power. The other pole 31 is grounded, as indicated at 32, and electrically connected to the tank 11 by means of lead 33. Current from pole 30, after the current-limiting device 29, passes through a rectifying device 34 and then may pass through a voltage regulating device 35 having an electrical connection 36 to the lead 33. A connection is then made through a control device 37 which is, in turn, connected to both the main anode 14, by means of a lead 38, and the auxiliary or trigger electrode 15, by means of lead 39. The function of the control device is to discontinue the passage of current to the anode 14 when the trigger electrode 15 is uncovered, or at least discontinue the passage of such current except to a very minute extent. It will be understood that the electrodes 14 and 15 are desirably axial with respect to one another and the tank, as viewed in FIGURE 2, rather than side by side as viewed in FIGURE 1.

I have shown five wiring diagrams employing the same basic functions to accomplish the same purpose, these wiring diagrams being respectively illustrated in FIGURES 4, 5, 6, 7 and 8. In each case the connection to the anode 14 is such as to supply positive current thereto until such current is blocked by action of the auxiliary electrode 15.

In accordance with FIGURE 4, as supplementing the showing of FIGURES 1 and 2, the current-limiting device 29 is a resistor 41 which may have a value of about 6200 ohms. The rectifying device 34 is a diode 42 which may be one cell only, and the voltage regulating device 35 is a group of desirably selenium cells 43 or a silicon carbide varistor performing the same function. Such a regulating device prevents a high voltage build-up by passing more current at a higher voltage to ground, thus stabilizing the voltage being supplied to the control device 37 which, in this case, is PNP type transistor 44. Said transistor 44 will conduct current to the anode 14 from its collector 45 when the trigger or auxiliary electrode 15 is connected to its base 46, as through lead 39 and resistor 47, which may have a value of about 2500 ohms. The current flowing through the resistor 47 to the trigger electrode 15 will desirably be in the neighborhood of 200 microamperes, whereas the current flowing to the main anode 14 will desirably be in the neighborhood of 5 to 10 milliamperes. A resistor 48, which may have a value of about 3000 ohms, that is, greater than that of the resistor 47, is used to reduce the current flow to the anode 14 when the trigger electrode 15 is uncovered by the accumulation of gas 28.

The general concept behind the present embodiment, is that a regulated source of unidirectional current is applied to the PNP transistor 44. If there is not enough gas in the tank to cause an uncovering of the auxiliary electrode 15, the transistor will be biased toward conduction and power will be fed to the anode 14, thereby providing cathodic protection for the tank 11. If, on the other hand, gas accumulates to such an extent that the auxiliary electrode 15 breaks contact with the water in the tank, the transistor 44 will block and prevent an effective current

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from flowing to the tank through the anode 14 and thus no more gas will be accumulated.

During normal operation of the embodiment of FIGURES 1, 2 and 4, current is flowing from the pole 30 of the source of power, through resistor 41, diode 42, transistor 44 and lead 38 to the anode 14, and thus to the water in the tank 11, giving cathodic protection to the bare areas of the tank surface. By means of resistor 41 the current flow is limited and the effective voltage is dropped from that of the conventional supply, say about 110 volts, to approximately 4 or 5 volts. This action is effective because the resistor 41 is high enough for that purpose, say about 6200 ohms. At the rectifying diode 42 the current that is allowed to go to the transistor 44 is in the form of a halfwave unidirectional current, the plus component being fed to said transistor.

The negative component of the current is prevented from causing a high inverse voltage, as by a rectifying diode 49, which may also be one cell and connected to ground 32, as illustrated, and puts the negative component of the alternating current back on the line behind the diode 42. In this way it is possible to use single cell selenium diode rectifiers in place of multi-plate rectifiers. It is thus also possible to regulate the voltage that the transistor 44 sees to a value below its breakdown point. The element 43 regulates the forward voltage on the transistor by acting like a relief valve. If it comprises selenium cells in series, each adds .4 volt to the relief valve pressure so that any time the voltage on the line between the diode 42 and the transistor 44 exceeds a value of say 5 volts, all of the current will flow to ground through the varistor 43 of selenium cells. This is especially important when the transistor is in a blocking state due to the accumulation of gas in the tank.

If the element 43 were not there and the transistor in a blocking state, the voltage at the transistor 44 would rise to a point where it would break down and conduct in a forward direction due to such high voltage. The transistor is normally conducting when the tank is full of water because its base 46 is maintained at a minus potential with respect to its emitter 51, by a proper choice of values for the resistors 47 and 48. Thus most of the current will pass through the transistor 44 to the anode 14 and on to the tank. Only a small portion of the current, that is, approximately 5% of that passing to the anode 14, is conducted through resistors 47 and 48 to the trigger electrode 15.

If enough gas accumulates in the top of the tank to uncover the auxiliary electrode 15, the base 46 of the transistor 44 is no longer maintained negative with respect to the emitter since there is then no way of bleeding off the positive charge which comes thereto through the resistor 48. When the base 46 is positively charged due to the open circuit, the transistor 44 goes into a blocking state and no effective current goes to the anode 14. Thus for all practical purposes the anode 14 is then shut off and no more gas can accumulate so that the system remains in a safe condition.

After this blocking condition occurs, assume that the water heater is again put into use. Fresh water added to the tank, the old water being removed, dissolve the gases that have accumulated at the top of the tank and which shut off the anode 14. The auxiliary anode 15 is then again in electrical connection with the water inside of the tank. This connection allows the positive charge on the base 46 of the transistor 44 to be bled off to the negative tank 11 to such an extent that the base becomes negative with respect to the emitter and the transistor will again function. Should gas re-accumulate and open the circuit between the trigger electrode 15 and the tank wall, the transistor 44 will again go into a blocking state and shut off the power to the anode 14.

This ability to repeat the performance and turn on and off, when the trigger electrode 15 is covered or uncovered by water, is an important feature of the present

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invention. The presence of the voltage regulator 43 makes it possible only to use a less expensive transistor 44 than would be necessary if such were not used. The diode 42 is the essential part of the rectifying device 34, as the diode 49 could be eliminated if the transistor 44 were of such construction that it could stand high peak voltages. However, to use an inexpensive transistor, the rectifier 49 must be used in a circuit such as illustrated in FIGURE 4. The resistor 41 is here essential in any event to reduce the value of the current flowing to the anode to a predetermined, relatively small, amount that can be tolerated under commercial conditions.

Referring now to the embodiment of my invention illustrated in FIGURE 5 as supplementing the showing of FIGURES 1 and 2, the current limiting device 29a is here a condenser 52 having a capacitance of approximately .2 to .4 microfarad, if the supply voltage is that normally used, say around 110 volts A.C. The rectifying device 34a is here a diode 42a which may be like the diode 42. The voltage regulating device 35a in this embodiment does not have an important function but helps in the control and may be represented by a Zener diode 53, which will serve to limit the applied voltage to a predetermined value.

The control device 37a, in this case consists of a thermistor 54 and a resistor 55. The thermistor 54 when cold will have a resistance of approximately 1 megohm. When the thermistor is heated to approximately 150° C. its resistance will drop to approximately 3000 ohms, thus allowing an effective amount of current to travel to the anode 14 along lead 38. In order to get the thermistor 54 heated to this high temperature, I here connect the resistor 55 thermally to the thermistor 44, and electrically to the auxiliary electrode 15 by lead 39. The passage of a normal current through the resistor 55 will heat the thermistor 54 to a point where it will conduct the necessary amount of current to the anode 14. When the trigger electrode 15 is uncovered, the current to the resistor 55 is open circuited, and cooling of said resistor takes place, allowing the thermistor 54 to also cool and return to its blocking state. Except as specifically disclosed, the present embodiment may correspond with the first embodiment as indicated by the use of corresponding reference characters.

Referring now to the embodiment of my invention illustrated in FIGURE 6 as supplementing the showing of FIGURES 1 and 2, a different method of current control is disclosed. This method is better suited for high current requirement systems and uses, as a voltage regulating device 35b, a stepdown transformer 56 to create current at a low voltage, say from 5 to 10 volts, which is rectified by rectifying device 34b in the form of a diode 42b, which may be like the diode 42. The current may be limited by passing through a current limiting device 29b in the form of a resistor 41b. The control device 37b in this case is a PNP transistor 44b which operates in connection with resistors 47b and 48b to supply current through lead 38 to the anode 14 and through lead 39 to the auxiliary electrode 15, just like the transistor 44 supplies such current in the embodiment of FIGURES 1, 2 and 4. Except as specifically disclosed, the present embodiment may correspond with that of FIGURES 1, 2 and 4.

Referring now to the embodiment of my invention illustrated in FIGURE 7, as supplementing the showing of FIGURES 1 and 2, there is shown a modification 37c of the control device shown at 37, 37a and 37b in FIGURES 4, 5 and 6, respectively. It may be connected to the electrodes 14 and 15 by leads 38c and 39c, respectively, and to the pole 30 of the source of power through the auxiliaries as with any one of the control devices of the previous embodiments. However, if substituted for the control device 37a, a resistor 41c, as well as a diode 42c, in series with its switch 54c is employed as illustrated.

The control device 37c in this instance consists of bi-

metallic switch 54c, consisting of a movable bimetallic contact 57 which, when the temperature is increased above normal to a predetermined extent, say to 150° C., moves to engage a fixed contact 58 and close a circuit through lead 38c. Thus this switch 54c and a resistor of a value comparable with that of the thermistor 54 of FIGURE 5, when heated, may take the place of said thermistor.

In order to get the switch 54c heated to the temperature required to cause it to close, I here employ a resistor 55c connected thermally thereto and electrically to the auxiliary electrode 15 by lead 39c. The passage of a normal current through the resistor 55c will heat the switch 54c to a point where it will close and conduct the necessary amount of current to the anode 14. When the trigger electrode 15 is uncovered, the current to the resistor 55c is open circuited, and cooling of said resistor takes place, allowing the switch 54c to open. Except as specifically disclosed, the present embodiment may correspond with the first embodiment as indicated by the use of corresponding reference characters.

Referring now to the embodiment of my invention illustrated in FIGURE 8, as supplementing the showing of FIGURES 1 and 2, a different method of or wiring for current control is here disclosed. This method uses a step down transformer 56d to provide a voltage, say 5 to 10 volts, as in the method of FIGURE 6, which is rectified by device 34d in the form of a pair of diodes 42d. There is a lead 57 connecting the leads from the diodes 42d on the other side of the secondary winding and grounded by connection to the return lead 33. The unidirectional current output, to the main electrode 14 through lead 38, may be limited by passing from a center tap on the secondary winding of the transformer 56d through a device 29d in the form of a resistor 41d.

The significant thing about the present method is that the energy to operate the transformer 56d is obtained through the auxiliary electrode or trigger anode 15 by connection of said transformer primary winding 58 thereto through lead 39. When the trigger anode is uncovered, the entire transformer is deenergized or open-circuited. This is because the normal circuit for energizing said transformer is through lead 30, primary winding 58, lead 39, trigger anode 15, the water in the tank 11, and the grounded return lead 33. In other words, the transformer primary winding 58 when operating, is always in series with the water in the tank, as contrasted with the form of FIGURE 6.

The secondary winding 59 of the transformer 56d is center-tapped to form a full-wave rectifier device using a single selenium cell rectifier 42d on each side of said center tap. In this case, the only additional piece of apparatus required is the resistor 41d to limit the current, thereby making the system much simpler, more economical and more fool-proof than the other forms. Except when specifically disclosed, the present embodiment may correspond with the FIGURES 1, 2 and 4.

Having now described the invention in detail in accordance with the requirements of the Patent Statutes, those skilled in this art will have no difficulty in making changes and modifications in the individual parts or their relative assembly in order to meet specific requirements or conditions. Such changes and modifications may be made without departing from the scope and spirit of the invention, as set forth in the following claims.

I claim:

1. A hot-water heater having a metal tank with a lining of dielectric material and means to prevent corrosion at imperfections which may exist in said tank lining, said means including a plug screwed into the top of the tank and dual electrodes supported by said plug and extending into the tank, a first one of said electrodes extending close to the bottom of said tank and the second one of said electrodes terminating close to the top of said tank, an insulating coating on said first electrode, said second electrode being superposed on said coating and supported by said first electrode, said coating terminating short of the ends of said first electrode, an insulating sleeve surrounding both electrodes and mounted in the plug, a control device connected to both electrodes, and means in said control device operative to decrease the flow of current through the first electrode upon decrease of level of water in the tank below the level of the second electrode.

2. A hot water heater as defined in claim 1 in which the bottom of the first electrode is distant from the bottom of the tank a distance equal substantially to the radius of the tank.

3. A hot water heater as defined in claim 1 in which the sleeve passes through a nut, said nut being screwed into the plug and there being packing between the lower end of the nut and the plug located about the sleeve to hold the assembly of electrodes, plug and nut in fixed relationship.

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