

PATENT SPECIFICATION

(11) 1423959

1423959

- (21) Application No. 48214/74 (22) Filed 7 Nov. 1974
 (31) Convention Application No. 453207 (32) Filed 21 March 1974 in
 (33) United States of America (US)
 (44) Complete Specification published 4 Feb. 1976
 (51) INT CL² C23F 13/00
 (52) Index at acceptance
 C7E 13



(54) REGULATED POWER SUPPLY FOR NON-SACRIFICIAL ANODE

(71) We, RHEEM INTERNATIONAL INC., a corporation organised and existing under the laws of the State of Delaware, United States of America, of 767 Fifth Avenue, New York, New York, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to corrosion protection systems of the kind which incorporate a non-sacrificial anode located in an electrically conductive fluid.

In water heaters and other metal tanks susceptible to corrosion it is often desirable to provide an anode in the tank to prevent corrosion. One type of anode which has been used is a sacrificial anode which is consumed in use and must be periodically replaced. Because of the replacement factor non-sacrificial anodes have also been used to inhibit tank corrosion. However, problems with both types of anode arise with various water supplies. For example, in some localities, water containing a relatively high percentage of dissolved solids tends to consume the sacrificial anodes rapidly, requiring frequent replacement of the anode or creating heavy corrosion of the tank when replacement is delayed. In other areas, where the water supply is not chlorinated and/or the sulfate content is high, a sacrificial anode contributes to an odour problem created by hydrogen sulfide which has a smell akin to rotten eggs.

Non-sacrificial anodes made of a non-corrosive metal and supplied with a D.C. current have been used in place of the sacrificial anode to inhibit corrosion. Unfortunately, this type of anode has not met with commercial acceptability because of problems in its operation. These problems generally stem from the fact that proper operation requires constant current and because of the specific environment, it is difficult to maintain a relatively constant current passing through the anode.

Excessively low current levels result in insufficient protection of the water tank, thus permitting unnecessary and undesirable corrosion of the tank and excessively high current levels result in the excessive generation and accumulation of hydrogen gas. This is due to the electrodecomposition of water by the DC current passing through the water to the tank (cathode).

In the past, power has been supplied to the non-sacrificial anode from house current through a stepdown transformer and a conventional rectifier. Unfortunately, the resistance of the anode, cathode (tank), and the water between the two varies almost unpredictably in value, resulting in a varying current being supplied to the anode. Several significant factors affecting this variable resistance are described below.

Water hardness in terms of mineral content and the types of mineral constituents strongly affect the resistivity of the water and thus of the total anode-cathode system. Water resistivity can vary from 100 up to 40,000 ohms per cubic centimeter (ohms-cc) for a corresponding total dissolved solid range from 6500 ppm to 23 ppm (parts per million). In other words, the water resistance in a 30 to 40 gallon household water heater can range from 27 ohms up to and including 1000 ohms as a result of variable water hardness.

Another factor which varies the resistivity of the system is the polarization of the parts exposed during the first few hours of operation. The surface condition of both the anode and the cathode (tank) exposed to the water-electrolyte changes due to decomposition of hydrogen gas on the anode and of hydroxides on the cathode. This decomposition continues to reduce the system conductivity for the first several hours of operation after which an equilibrium is reached. This transient effect can vary the current passed through the anode-cathode system from a constant voltage source by a factor of between a few percent and twenty percent of

the initial current, depending on the water quality.

Also, aging and scaling of the interior of the tank and of the anode surface both reduce conductivity, since the available surface area for conduction (related to conductivity) is continuously and gradually reduced with scaling which takes place over a period of water heater usage. The electrical conductivity of stored water is in some measure related to the temperature of the water. In general, water resistivity decreases when its temperature increases and thus the overall system resistivity will vary unpredictably with the heating and cooling of the water in the tank. Finally, the system resistivity varies with the various sizes of the water tanks and anode and, in fact, with the type of water heater, whether gas or electric.

In the past, the foregoing difficulties resulting from the varying system resistance have often been ignored, resulting in the problems described above. One attempt to solve the problem has been to send an individual to the site of installation to adjust the power supply output in accordance with the system requirements to obtain an optimum current flow level. However, this method requires significant labour cost and is still unacceptable since the system resistivity will vary *after* installation (varying temperature, water type, water temperature, aging).

The present invention is generally related to an improved power supply for use with a non-sacrificial anode. The anode is adapted for placement in a metal tank normally susceptible to corrosion and containing an electrically conductive fluid (for example, water). The anode, cathode and the fluid between the two form an impedance variable with varying conditions of the anode, cathode and fluid. The system according to the invention generally comprises an electrical bridge network connectable across a source of substantially DC voltage. The network includes first, second, third and fourth legs. The anode and cathode and fluid form the first leg of the bridge. A resistor forms the second leg and the bridge includes a semiconductor means having a first terminal connected to the resistor of the second leg. The third and fourth legs are resistors connected in series across the DC voltage source. The semiconductor means also includes a second terminal connected to the anode and a third terminal connected to a substantially constant bias voltage whereby the semiconductor means functions in the bridge network to maintain a substantially constant current to the anode despite the varying impedance from the anode to the cathode.

In one embodiment the improved power supply also includes means for generating a

visual signal in response to current flowing from the DC power source to the bridge network in order to provide a visual indication of the proper functioning of the power supply. In another embodiment, the improved power supply also includes a zener diode connected in the fourth leg of the bridge to the DC voltage source and to the third terminal of the semiconductor means so that the semiconductor means is maintained at a fixed predetermined bias voltage level.

So that the invention will be fully understood several embodiments will now be described by way of example and with reference to the accompanying drawings in which:—

Figure 1 is a front perspective view of a water tank incorporating the anode system according to the invention;

Figure 2 is a block diagram of the power supply of the present invention;

Figure 3 is a schematic diagram of the electrical circuit of this invention forming the power supply;

Figure 4 is a schematic diagram of the power supply of this invention and a rectifier for use therewith;

Figure 5 is a schematic diagram of a second preferred embodiment of the present invention;

Figure 6 is a schematic diagram of a third preferred embodiment of the present invention.

Referring now to Figure 1, there is shown a storage means for storing a volume of fluid. In particular, the storage means is a water heater tank 10 having an anode 12 inserted in the centre of the tank 10. The anode is attached to a lid 14. The tank 10 is normally manufactured of a metal susceptible to corrosion, and the anode 12 is provided to prevent corrosion of the tank 10. In the particular case which this invention is adapted, the anode 12 is a non-sacrificial anode, i.e. one that does not corrode as it protects the tank 10 from corrosion.

Referring now to the block diagram of Figure 2, an AC power source 16 is connected to a rectifier 18 to provide a DC supply to the regulated power supply 20 of this invention. The power supply 20 is in turn connected to the anode 12 and then the tank 10. A convenient AC power source is 120 V 60 cycles.

Referring to Figure 3, the rectifier 18 is connected to the regulated power supply 20. The cathode or tank 10 is connected through the conductive fluid 11 contained therein to the anode 12. The power supply 20 includes an electrical bridge network 22 and a PNP transistor 24. The second leg of the bridge 22 is formed by a resistor 26. The first leg is formed by the anode 12, tank 10 and water 11. Third and fourth legs are formed by resistors 28 and 30 in series across the output

of the supply of DC voltage from the rectifier 18. The first and second legs of the bridge are also in series across the DC output of the rectifier 18. The emitter of transistor 24 is connected to the first leg of the bridge i.e. resistor 26 and the collector of the transistor 24 is connected to the second leg (i.e. the anode 12 of the water tank which is in turn connected through water 11 and tank 10 to ground). The base of transistor 24 is connected to the anode between the third and fourth legs of the bridge. Resistor 26 is selected to have an impedance approximately the same as or slightly less than the resistor 28 so as to bias the PNP transistor 24 into conduction. The transistor 24 is adapted to be operated primarily in the nonsaturated state. Accordingly, with the emitter of transistor 24 held at a voltage in relation to the base of the transistor 24 sufficient to place it normally into the conductive state, the operation of the bridge will be described. In this description the variable resistance of the system provided by the cathode 10, fluid 11 and anode 12 will be described as R_s .

When R_s is decreased (for example, by a higher mineral content in the water), the voltage at the collector of transistor 24 is reduced due to the voltage divider effect of the

circuit. This in turn increases the voltage at the emitter of transistor 24 resulting in a decrease in the conductivity of the emitter collector current through transistor 24. This in turn results in a tendency to reduce the current passed through the system resistance R_s . Accordingly, with decreased resistance of resistor R_s , an overcurrent condition is prevented.

On the other hand very soft water increases system resistance which in turn increases the voltage level at the collector of transistor 24. This likewise tends to decrease the voltage level at the emitter of transistor 24 thus tending to increase the collector current of transistor 24 compensating for the increased system resistance R_s .

In the particular embodiment shown the value of resistors 26, 28 and 30 was selected to be approximately equal to the maximum value of the resistance R_s in a standard system. In particular, resistors 26, 28 and 30 are 1000 ohm resistors utilizing these resistor values and a simulated variable system resistance R_s ranging from 0 to 1000 ohms. The following data were obtained indicating a substantially constant collector current for the range of resistance of the cathode 10, anode 12 and fluid 11.

	Variable Load Resistance R_s	Regulated Collector Voltage	Regulated Collector Current
60	0 ohms	0.2 V	5.0 mA
	100	0.7	"
	200	1.1	"
	300	1.6	"
65	400	2.1	"
	500	2.8	"
	600	3.0	"
	700	3.5	"
	800	3.9	"
70	900	4.4	"
	1000	5.8	" (very soft water)

In the particular embodiment shown in Figure 3, the base current is of course mineral and the total current drain is approximately 10 mA on the 12 V output of the rectifier 18. Thus, the total power drain from the AC power supply 16 is 120 milliwatts or 3 watt hours per day disregarding power losses from the rectifier 18. Power consumption of this magnitude will generally be an insignificant factor in the overall power consumption of the average consumer of electric power.

Variations of the circuits shown may be made. For example, a zener diode (not shown) can be used to replace resistor 28 thus improving current regulation by holding the level of the base of transistor 24 at an absolute constant.

Referring to Figure 4, there is shown a schematic diagram of the bridge circuit 22

and the rectifier 18 of this invention. The AC voltage supply 16 is connected across a stepdown transformer 34 and fed into a halfwave rectifier which includes a diode 36 and an RC circuit (resistor 38 and capacitor 40) for filtration and protection against electrical surges. A fullwave rectifier bridge (not shown) and other more elaborate filtration techniques may, of course, be applied to the rectifier for use with this invention.

As a possible modification to the rectifier, a thyrector diode may be placed across the input of the rectifier 18 to protect the power line transient sensitive semiconductors. Also, a light-emitting diode may be substituted for the diode 36 so that both power rectification and signalling of system operation are accomplished by a single element.

Referring to Figure 5, a light-emitting diode 42 may be added in series between

the rectifier 18 and bridge circuit 22. The light-emitter diode 42 is utilized to function as a means for indicating current flow into the bridge circuit 22 and thus of the continued operation of the regulated power supply of this invention. The light-emitting diode 42 also indicates that (1) the power pack is energized by an adequate external power, (2) that rectifier is properly functioning and conducting current to the bridge circuit and (3) that the current drawn through the overall system is adequate. A variation of this embodiment is shown in Figure 6 where the light-emitting diode 42 is connected to the collector of transistor 24.

WHAT WE CLAIM IS:—

1. A corrosion prevention system wherein a non-sacrificial anode is deployed in an electrically conductive fluid for use in protecting an object which is normally subject to corrosion and normally provides the cathode of the system and wherein the anode, cathode and fluid form an impedance variable with varying conditions of the anode, cathode and fluid, which system comprises an electrical bridge network connectable across a source of DC or rectified AC voltage said bridge having first, second, third and fourth legs, the third and fourth legs of which are connected in series across the voltage source; the anode, cathode and fluid forming the first leg, and including semiconductor means adapted for operation in the non-saturated state, the semiconductor means having a first terminal connected to a resistor forming the second leg, a second terminal connected to the anode and a third terminal connected to a substantially constant bias voltage, the arrangement being such that the semiconductor means functions in the bridge network to maintain a substantially constant current to the anode despite varying impedance from the anode to the cathode.

2. A corrosion prevention system according to Claim 1 wherein the first and second terminals of the semiconductor means are connected in series with the anode.

3. A corrosion prevention system according to Claim 1 or Claim 2, wherein the semiconductor means is a transistor.

4. A corrosion prevention system according to Claim 3 wherein the semiconductor means is a PNP transistor.

5. A corrosion preventing system according to any preceding claim wherein the semiconductor means is a transistor having a base, emitter and collector terminals and wherein the emitter is connected to the resistor forming the second leg, the collector is connected in series with the anode and wherein the base terminal is connected to the anode between the elements of the third and fourth legs of said bridge network.

6. A corrosion prevention system according to any preceding claim in which the second, third and fourth legs of the bridge network are resistors having substantially constant and approximately equal impedances.

7. A corrosion prevention system according to any one of Claims 1 to 5 wherein the third leg of the bridge comprises a zener diode whereby the third terminal of the semiconductor means is maintained at a fixed predetermined bias voltage level.

8. A corrosion prevention system according to any preceding Claim including means for generating a visual signal in response to current flowing from the power source to said bridge network so as to provide a visual indication of the proper functioning of the power supply.

9. The apparatus as set forth in Claim 8 wherein the generating means comprises a light-emitting diode connected in series between the power source and the bridge network.

10. A corrosion prevention system according to any preceding claim including a light-emitting diode connected in series between the semiconductor means and the anode.

11. A corrosion prevention system substantially as herein described with reference to the accompanying drawings.

For the Applicants:
LLOYD WISE, BOULY & HAIG,

Chartered Patent Agents,
Norman House,
105—109 Strand,
London, WC2R 0AE.



the rectifier 18 and bridge circuit 22. The light-emitter diode 42 is utilized to function as a means for indicating current flow into the bridge circuit 22 and thus of the continued operation of the regulated power supply of this invention. The light-emitting diode 42 also indicates that (1) the power pack is energized by an adequate external power, (2) that rectifier is properly functioning and conducting current to the bridge circuit and (3) that the current drawn through the overall system is adequate. A variation of this embodiment is shown in Figure 6 where the light-emitting diode 42 is connected to the collector of transistor 24.

WHAT WE CLAIM IS:—

1. A corrosion prevention system wherein a non-sacrificial anode is deployed in an electrically conductive fluid for use in protecting an object which is normally subject to corrosion and normally provides the cathode of the system and wherein the anode, cathode and fluid form an impedance variable with varying conditions of the anode, cathode and fluid, which system comprises an electrical bridge network connectable across a source of DC or rectified AC voltage said bridge having first, second, third and fourth legs, the third and fourth legs of which are connected in series across the voltage source; the anode, cathode and fluid forming the first leg, and including semiconductor means adapted for operation in the non-saturated state, the semiconductor means having a first terminal connected to a resistor forming the second leg, a second terminal connected to the anode and a third terminal connected to a substantially constant bias voltage, the arrangement being such that the semiconductor means functions in the bridge network to maintain a substantially constant current to the anode despite varying impedance from the anode to the cathode.

2. A corrosion prevention system according to Claim 1 wherein the first and second terminals of the semiconductor means are connected in series with the anode.

3. A corrosion prevention system according to Claim 1 or Claim 2, wherein the semiconductor means is a transistor.

4. A corrosion prevention system according to Claim 3 wherein the semiconductor means is a PNP transistor.

5. A corrosion preventing system according to any preceding claim wherein the semiconductor means is a transistor having a base, emitter and collector terminals and wherein the emitter is connected to the resistor forming the second leg, the collector is connected in series with the anode and wherein the base terminal is connected to the anode between the elements of the third and fourth legs of said bridge network.

6. A corrosion prevention system according to any preceding claim in which the second, third and fourth legs of the bridge network are resistors having substantially constant and approximately equal impedances.

7. A corrosion prevention system according to any one of Claims 1 to 5 wherein the third leg of the bridge comprises a zener diode whereby the third terminal of the semiconductor means is maintained at a fixed predetermined bias voltage level.

8. A corrosion prevention system according to any preceding Claim including means for generating a visual signal in response to current flowing from the power source to said bridge network so as to provide a visual indication of the proper functioning of the power supply.

9. The apparatus as set forth in Claim 8 wherein the generating means comprises a light-emitting diode connected in series between the power source and the bridge network.

10. A corrosion prevention system according to any preceding claim including a light-emitting diode connected in series between the semiconductor means and the anode.

11. A corrosion prevention system substantially as herein described with reference to the accompanying drawings.

For the Applicants:
LLOYD WISE, BOULY & HAIG,

Chartered Patent Agents,
Norman House,
105—109 Strand,
London, WC2R 0AE.