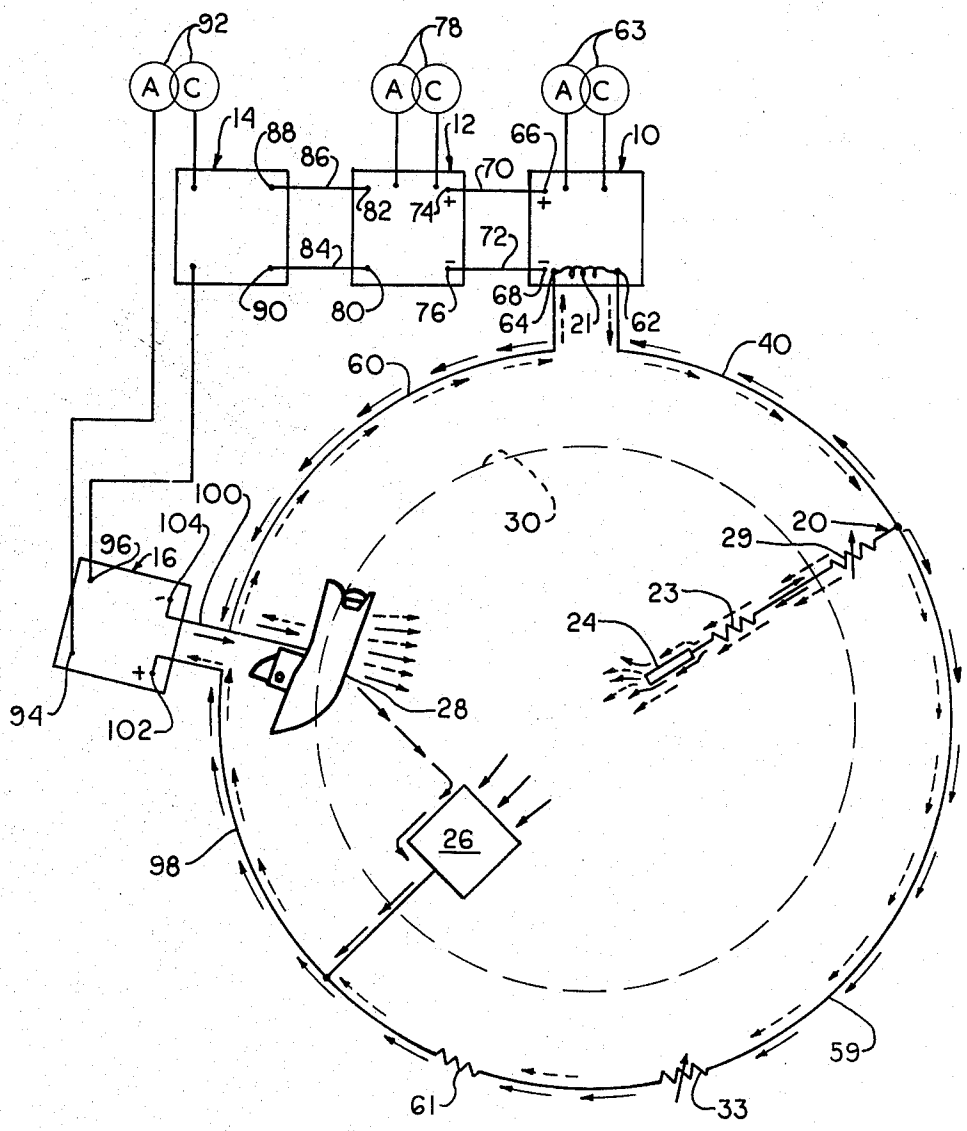
Dec. 6, 1960 R. C. SABINS 2,963,413

ELECTROLYTIC SYSTEM

Filed Jan. 12, 1959



INVENTOR.
ROLLAND C. SABINS
BY Pulvider, Mattingly & Huntley
ATTORNEYS.

United States Patent Office 2,963,413 Patented Dec. 6, 1960

2,963,413

ELECTROLYTIC SYSTEM

Rolland C. Sabins, 522 Catalina Blvd., San Diego 6, Calif.

Filed Jan. 12, 1959, Ser. No. 786,365

9 Claims. (Cl. 204—196)

The present invention relates generally to a control system and method and more particularly to a control system and method for automatically providing cathodic protection for various types of structures, such as vessels or the like which normally float or are immersed in water or some solution which acts as an electrolyte.

As is well known, such systems include an extraneous source of D.C. current impressed upon the cathodic structure to elevate the potential thereof to above the dissolution potential. The current requirement to provide satisfactory protection is dependent upon many factors, as for example, the speed of movement of the hull through the water, the temperature of the water, the ionic contents of the water through which the hull is moving, etc. Such structures, such as the hull of a ship, are often subjected to shock and vibrations, such as would be produced by gunfire aboard navy ships. The difficulty of control is also enhanced by the fact that the system must operate over long periods of time, must operate over a wide range of impressed current; it must respond to very small control currents, and must provide magnification of a very high order.

Each of the systems of the foregoing type includes the cathodic structure to be protected, an anode or anode array, both of which are subjected to an electrolyte and connected with one another by an external source of D.C. current for impressing a current on the cathodic structure. Such systems may take various forms, and for the purpose of illustrating one form of the system, I have chosen a ship or ship's hull as the cathodic structure, and the water in which it floats or is immersed as the electrolyte. The ship or ship's hull will be referred to herein as the "cathode" and the anode or anode array, hereinbefore mentioned, as the "ship's anode." The present invention contemplates a monitoring system for controlling the value of D.C. current impressed upon a cathode. This monitoring system includes a closed circuit which connects a "reference" or "drive" anode, also immersed in the electrolyte (water), with the cathode; this reference or drive anode is formed of material which is higher in the electrochemical series than the cathode; the monitoring circuit also includes a solid state conductor which connects the reference anode with the positive side of the source of D.C. current. Thus a complete loop is formed of solid state material, as will be more clearly set forth hereinafter.

The monitoring system includes a current responsive device between the reference anode and the ship or cathode, and this current responsive device is responsive to the potential difference between the reference anode and the cathode, and, in response to such difference causes a variation in the value of D.C. current impressed upon the cathode. The solid state conductor between the reference anode and the positive side of the source of D.C. current includes resistance and is used to modulate the value of current flowing in the aforementioned current responsive device, for the purposes as will appear more fully hereinafter.

The aforementioned resistance device is in the form of a variable resistance for the purpose of increasing or decreasing, at will, the effect of the aforementioned current responsive device, whereby the valve of the D.C. current, impressed upon the cathode, can be controlled.

Furthermore, the invention contemplates a monitoring system which, in the event of failure, causes the impressed D.C. current to be rendered ineffective.

Further objects and advantages will be apparent from the following description, reference being had to the accompanying drawing wherein a preferred embodiment of the invention is illustrated.

The drawing is a circuit diagram showing one form of the invention.

The instant application is a continuation-in-part of my co-pending application Serial No. 781,624, filed on December 19, 1958. That application included, in the monitoring system, three electrodes, all of which were formed of substantially inert material and included an extraneous source of D.C. current which cooperated with the three electrodes. The instant application distinguishes from said co-pending application primarily in that only one anode is employed in the monitoring system, and this anode is formed of far less expensive material which is higher in the electrochemical series than the cathode to be protected and comprises magnesium or one of the magnesium alloys which is higher in the chemical series such as an alloy of magnesium and zinc, or magnesium and aluminum, or magnesium, zinc and aluminum.

Referring more in detail to the drawing, my control system comprises, generally, impressed power supply means through a power rectifier **16**, the output of which is controlled by a current responsive device in the form of a coil **21** of a monitoring system or reference circuit **20**. The value of current passing through the coil **21** may be sufficient to more directly control the output of the power rectifier **16**, if so desired, however in the preferred embodiment, I prefer to utilize the coil **21** as part of a signal amplifier **10** which in turn is connected through a control reactor **12** and power reactor **14** to the power rectifier **16**.

The reference circuit **20** includes the reference or drive anode **24**, resistances **23** and **29**, conductor **40**, terminal **62** of amplifier **10**, coil **21**, terminal **64**, conductor **60**, the structure shown as a ship's hull **28** and the electrolyte **30**. The anode **24** is formed of material which is higher in the electrochemical series than the cathode **28** and, for example, if steel or iron is the cathode, then the anode **24** may be formed of magnesium or a magnesium alloy such as an alloy of magnesium and zinc or an alloy of magnesium and aluminum, or an alloy of magnesium, zinc and aluminum. The monitoring or reference circuit **20** also includes the conductor **59**, connected with the conductor **40**, a variable resistance **33**, a resistance **61** and a conductor **98** connected to the positive terminal **102** of the power rectifier **16**. The negative terminal **104** of rectifier **16** is connected by conductor **100** to the conductor **60** and is therefore connected to the cathode **28**.

The impressed current supply means is connected between an anode array or assembly **26** (hereinafter referred to as the ship's anode) and the cathode **28** to be protected. The ship's anode **26** and the cathode **28** are shown submerged or immersed in the electrolyte **30** which, for example, can be sea water. As previously stated, for illustrative purposes, I have chosen the hull of a ship as the structure or object to be protected; and the ship's anode **26** can be of any suitable type such as that disclosed in my co-pending application entitled Electrolytic System, Serial Number 715,440, filed February 14, 1958, and preferably formed of a substantially inert anodic material.

In the operation of the system, reference to current

flow is intended to mean the direction of electron flow, and reference to electron flow in the electrolyte is intended to mean the direction of electron migration within the ion exchange phenomena.

Assuming that the reference or drive anode **24** and the cathode **28** are at the same level of potential, there will be a negligible current flow from the anode **24**, through the resistances **23** and **29**, conductor **40**, coil **21**, conductor **60** to the cathode **28**. Under these conditions, we will assume that the level of the potential for hull **28** is at the proper level to afford cathodic protection. However, now assuming that the potential level of the hull **28** falls below that desired, it will be apparent that its potential with respect to the anode **24**, would change, causing an increase of flow of current through the coil **21** of amplifier **10**. This increased current provides the signal which initiates or actuates the automatic impressed current supply. It will be understood that the value of resistance **23** and **29** are such that sufficient amperage can be developed whereby coil **21** can function to control the power rectifier **16** directly through the power reactor **14**, however, I prefer to materially prolong the life of the anode **24** and in so doing I provide the amplifier **10** and the control reactor **12** in addition to the power reactor **14** and power rectifier **16**. By employing these extra instruments and by suitably selecting the value of the resistances **23** and **29**, I can employ a relatively small anode which will last for a period of years before disintegrating.

This amplifier **10** is responsive only to saturation current in the forward direction. It is important to note, therefore, that the electrical potential of reference circuit **20** can be established at a level which, if it exists on the hull **28** also, will be sufficient to provide cathodic protection to the hull **28**, and that the monitoring system will increase the output of the impressed current supply means at any time that this established level of potential falls.

With respect to the impressed current system, which is effective to raise the potential of the cathode **28** through the utilization of the reference current flowing through the monitoring means at amplifier **10**, it will be seen that the amplifier **10** is supplied with power from a source of A.C. current **63**. This A.C. input is controlled by impedance as a result of the A.C. windings on the reactor cores. The controlled A.C. is rectified and supplies the D.C. output. The D.C. current in coil **21** controls the saturation of the cores, resulting in control of the D.C. output which is fed from a pair of D.C. output terminals **66** and **68** through a pair of conductors **70** and **72** to a pair of D.C. input terminals **74** and **76** of the amplifier or control reactor **12**. In the present embodiment, at full output the incoming signal will fully saturate at 20 micro-amperes, in which case the amplifier **10** of the present system puts out a signal in excess of 300 micro-amperes. It is important to note that signal amplifier **10** is of that type which saturates only in a forward direction, that is, from terminal **62** to terminal **64**. Current flowing in the opposite direction will thus be ineffective to saturate the core of amplifier **10** and, accordingly, no signal input will be made to amplifier **10** by reason of any such reverse flow. This is important, as will be seen, because if the potential of cathode **28** should for some reason be greater than the potential of anode **24**, and if a reverse flow of current through amplifier **10** would saturate the D.C. input core thereof, which as stated is not the case, the impressed current supply means would be actuated and tend to raise the potential of cathode **28** to a still greater level. The reverse flow would then increase, and the system would be uncontrolled. For this reason amplifier **10** is made to saturate or be actuated only by a flow of current in the forward direction from terminal **62** to terminal **64**.

Control reactor **12**, which is provided with power from a suitable 110 volt A.C. source **78**, then amplified the input signal in excess of 300 milli-amperes which is fed through a pair of output terminals **80** and **82**, and through a pair of conductors **84** and **86** to the D.C. input terminals **88** and **90** of power reactor **14**. Reactor **14**, which is connected to a suitable 110 volt A.C. power source **92**, further amplifies the signal, and this signal is fed to the A.C. input terminals **94** and **96** of power rectifier **16**. The A.C. input is then rectified to a D.C. output which is connected to ship's anode **26** and cathode **28** by a pair of conductors **98** and **100** which in turn are connected, respectively, to the positive and negative output terminals **102** and **104** of rectifier **16**.

From the foregoing it will be seen that amplifier **10**, reactor **12**, reactor **14**, and rectifier **16** are in effect various stages of an amplification system for accepting a small D.C. input signal and amplifying it to a rather large D.C. output signal. The D.C. output signal comprises the impressed current for raising the electrical potential of cathode **28** to provide the necessary cathodic protection therefor.

Thus, assuming as before that cathode **28** is below the necessary potential to provide cathodic protection, the small input signal from reference circuit **20** of the monitoring means will be amplified through the amplification system just described, and the D.C. output of rectifier **16** will impress an electron flow through conductor **100** to cathode **28**, and thence through the electrolytic or water path to anode array **26** to complete the impressed electrochemical circuit.

As the control signal continues to flow through the reference circuit **20**, the impressed current supply will be applied through the conductor **100** until such time as the potential of cathode **28** reaches a level corresponding substantially with the potential of the anode **24**. At this time, since there is substantially no potential difference between the anode **24** and cathode **28**, there will be a diminished flow of current through conductor **40** until a balance is achieved between the impressed current supply means for ship's anode **26** and the reference circuit **20**. The leveling of the potentials of the anode **24** and cathode **28** brings the system into balance.

Although it was assumed that the potential of cathode **28** dropped an appreciable extent to initiate the above operation, it will be apparent that no appreciable drop will normally occur because the system tends to maintain a continuous balance between the impressed current system and the reference circuit **20**. That is, any slight unbalance between the potentials of the anode **24** and cathode **28** will be immediately corrected by the actuation of the impressed current system through the flowing of the control potential difference through the reference circuit **20**. Likewise, as soon as the impressed current means has brought the potential of cathode **28** to its proper level, the potential between **24** and **28** comes into balance and only the required current flow occurs through the reference circuit **20** to maintain the structure's preset polarization level.

The reference potential in reference circuit **20** is, as previously stated, that potential at which satisfactory cathodic protection is provided to cathode **28** when cathode **28** is also near that potential. The potential of reference circuit **20** may be established independently by utilizing the well known reference electrode or half cell (not shown). Such a reference electrode can be of any suitable type such as the silver-silver chloride reference electrode which has a potential in the electrolyte **30** which differs from the potential of the cathode **28** when it is submerged in the electrolyte. The reference electrode can be utilized in combination with any suitable micro-voltmeter or sensitive recording instrument to determine the achieved polarization level of the structure.

The level of the current flow necessary to cathodically protect the cathode **28** may be determined by adjusting the variable resistance **29** until the independently connected reference electrode indicates that the potential of

cathode 28 is satisfactory to provide cathodic protection. Once this resistance is determined, the polarization reference electrode and meter could be disconnected, but for practical purposes it is usually left installed to afford a constant reading or recording of the potential of cathode 28.

The coil 21 has a resistance value of 1500 ohms and the resistances of 23 and 29 are respectively 500 ohms and 50 ohms. These resistances in effect control the current flowing from the anode 24 to the cathode 28 but cannot control the potential difference between the anode 24 and the cathode 28, resulting in no exact control of the potential level of the cathode 28. I have discovered that the potential of the cathode 28 can be controlled by a solid state conductor 59 including the series arranged resistances 33 and 61. In the example given, the resistance 33 is of the variable type and has a value of 20,000 ohms, while resistance 61 has a value of 1000 ohms.

It will be noted that the anode 24, being higher in the electrochemical series than the cathode 28, delivers electrons through the metallic circuit to the lower negative electrode as well as to the electrolyte. It will also be noted that during the period of suspension, due to the fact that the cathode 28 is at the desired polarization level, the cathode 28 will continue to emit an emission of electrons to the electrolyte, which emission represents the principal electrical load of the entire system. The automatic control system is devised to feed an amount of current to the cathode 28 to exactly balance the amount of this electron emission which takes place at the desired polarization level. The emission rate of this electron emission from the surface of the cathode 28 is governed by the environment and varies with velocity, temperature, ionic content of the sea water temperature, conditions of paint coatings, etc.

As an illustration of the use of the present invention, it is well known that it is desirable to maintain the hulls of ships somewhere between 850 and 1000 millivolts depending on the size of the ship, it being well known that a large ship need not and should not have as high potential as a smaller ship. Let it be assumed that, for example, it is desirable to maintain the hull at a potential of approximately 1000 millivolts; then for desired control, such potential should be maintained within a tolerance of 20 millivolts. To accomplish this, there should be available approximately 1040 millivolts in the reference circuit. The alloy of anode 24 has a potential level of approximately 1490 millivolts; the coil 21 has a resistance value of 1500 ohms; and the values of resistances 23 and 29 are 500 ohms and 50 ohms respectively. These resistances 21, 23 and 29 decrease the voltage impressed on coil 21 but do not affect the potential difference between the anode 24 and cathode 28. I employ the solid state conductor for maintaining a closer and approximately stable differential between the anode 24 and cathode 28, and this differential can be regulated and controlled by varying the value of the resistance in said conductor 59. It is believed that the system functions as follows. (Let it be understood that when the term "suction" is employed, I am referring to the positive side of D.C. current, and when the term "pressure" is employed, I am referring to the negative side of the D.C. current.) Should there by an increase in potential difference between the reference anode 24 and the cathode 28 of such value as to cause coil 21 to bring the rectifier 16 into operation, then the suction will be started to withdraw electrons from the reference anode through the solid state conductor 59 and conductor 98. Obviously, if the potential between the ship cell 26—28 should continue to increase, requiring a higher amperage to be impressed on the ship cell by the rectifier 16, the suction effect will be increased from reference anode 24 through conductors 59 and 98 to thereby increasingly detract electrons from anode 24 and thereby lessen the available electrons from said anode 24, resulting in controlling the electron flow through coil 21; this in effect compensates for the tendency of increased flow of electrons from anode 24, through coil 21, to the cathode 28. Should the potential level of the ship's hull 28 be increased, of course the potential difference between ship's anode 26 and the hull 28 would be decreased; this in effect would lessen the suction effect on reference anode 24 through conductors 59 and 98 commensurate with the decrease in the potential difference between reference anode 24 and the cathode 28. By suitably adjusting the value of resistance 33 in conductor 59, the potential level of the cathode (ship's hull) can be maintained within the tolerance of 20 millivolts, regardless of the changes in conditions to which the ship's hull is subjected.

Another advantage of this positively closed loop electrical circuit (i.e. the electrical circuit of solid components including the power rectifier 16, conductor 98, ship's anode 26, conductor 59 including resistances 61 and 33, anode 24 and resistances 23 and 29, conductor 40, coil 21, and conductors 60 and 100) lies in the conservation of electrical energy during that period of raising, materially, the potential level of the cathode from, for example, its normal static potential to that necessary to prevent dissolution in the electrolyte. It will be understood that time is a factor in increasing the polarization of steel; for example, on large ships, two days may be necessary to bring the hull from its static to its desired potential level. Too, ample power must be available at all times, at the rectifier 16, to raise the potential of the hull 28 from its static level to that level desired. During the period that the hull is being raised from its normal static low polarization level to that level desired, there normally would be a tendency to impress current on the hull at a rate higher than true polarization can take effect, resulting in material loss of electrical energy, however, by the employment of the closed loop circuit, the value of the impressed current is regulated automatically by the balancing effect of modulating the electron flow, part through the reference circuit 20 and part through the conductor 59, all as previously described. Wherever practical, the raising of the potential level can be hastened by increasing the resistance in variable resistance 33 to thereby lessen the flow of electrons through conductors 59, resulting in making more electrons available in energizing coil 21 of the reference circuit 20.

Should the monitoring electrode be withdrawn from the electrolyte and unintentionally not restored to the electrolyte, the galvanic relationship between the anode 24 and the cathode 28 is interrupted and consequently coil 21 will be rendered ineffective. When coil 21 is ineffective, the reactor 16 will be rendered ineffective. Thus should the reference circuit be interrupted for any reason whatsoever, the system "fails safe" in that no extraneous current is impressed on the cathode.

By way of example, the values of the signal amplifier 10, control rectifier 12, power reactor 14 and power rectifier 16 may be, as is specifically set forth in my aforementioned co-pending application, and my co-pending application Serial Number 739,104, filed June 2, 1958. It has been found that a system having the above components has ample capacity to provide complete cathodic protection for a ship 300 feet in length with a steel hull, and having approximately 12,000 to 13,000 square feet of wetted surface.

From the foregoing it will be seen that I have provided a control system requiring no moving parts, that is, i.e., no mechanical relays, contact points, servo mechanism, motorized variacs or other moving parts which are apt to be rendered ineffective or give false results in case of severe shock such as that caused by gunfire, and which require extensive and continuous maintenance. A precise control is obtained which has substantially instantaneous response and which closely follows the demand of the system. Such performance coupled with

the lack of maintenance is particularly important in systems of the type which are often installed in large ships which may not return to their home ports for long periods of times. It is well understood by those in the art that a breakdown in the system, while the ship is out of port, could permit severe damage to occur to the hull of the ship before the system could be placed in operation.

It is also apparent, from the foregoing, that I have provided a system in which the polarization level, once established, can be maintained substantially constant. Also great saving of electrical energy is effected by the present system during that period of time when a ship is brought from its normal static polarization level to a polarization level in which dissolution of the steel is prevented.

Also it is apparent that I have provided a system which fails safe in the event of failure for any reason whatsoever of the reference circuit. In failing safe, there will be no flow of current from the reactor **16** to the ship's hull. In this manner, paint stripping and other damage to the structure, due to over-polarization, is prevented.

It is also apparent that in addition to being useful for cathodic protection of the hulls of ships, barges or other floating vessels, or submarines, my system can be used for cathodically protecting other structures such as underwater foundations, pipe lines, storage reservoirs and the like.

While the form of embodiment herein shown and described constitutes a preferred form, it is to be understood that other forms may be adopted falling within the scope of the claims that follow.

I claim:

1. In combination, a cathode; an anode, said cathode and anode being immersed in an electrolyte; a source of direct current having the negative side thereof connected to the cathode and having the positive side thereof connected to the anode to raise the potential of the cathode; a monitoring system comprising an anode formed of material which is higher in the electro-chemical series than the cathode and immersed in the electrolyte, a conductor connecting the monitoring anode and cathode, a current responsive device in said conductor and responsive to the flow of current in the conductor for causing varying of the value of current flow from said source of current to the cathode, a metallic conductor constantly connecting the monitoring anode with the first mentioned anode and with the positive side of said source of current, and a resistance in said last mentioned conductor disposed between said anodes.

2. A system as defined in claim 1, characterized in that the monitoring anode is formed basically of magnesium.

3. A system as defined in claim 1, characterized in that the resistance in the last mentioned conductor is of higher value than the resistance offered by the first mentioned conductor and said current responsive device therein.

4. A system as defined in claim 1, characterized in that the last mentioned resistance is variable.

5. A system as defined in claim 1, characterized in that the monitoring anode is a magnesium alloy higher in the electrochemical series than said cathode.

6. A system as defined in claim 1, characterized in that the monitoring anode is a magnesium alloy including zinc.

7. A system as defined in claim 1, characterized in that the monitoring anode is a magnesium alloy including aluminum.

8. A system as defined in claim 1, characterized in that the monitoring anode is a magnesium alloy including aluminum and zinc.

9. A system as defined in claim 1, characterized in that the resistance in the last mentioned conductor is of higher value than the resistance offered by the first mentioned conductor and said current responsive device therein.

References Cited in the file of this patent

UNITED STATES PATENTS

476,914	Bernard	June 14, 1892
2,221,997	Polin	Nov. 19, 1940
2,752,308	Andrus	June 26, 1956
2,759,887	Miles	Aug. 21, 1956

FOREIGN PATENTS

669,675	Great Britain	Apr. 9, 1952