Oct. 18, 1966 N. L. CONGER 3,280,020

ANODIC POLARIZATION SYSTEM

Filed Oct. 1, 1962 3 Sheets-Sheet 1

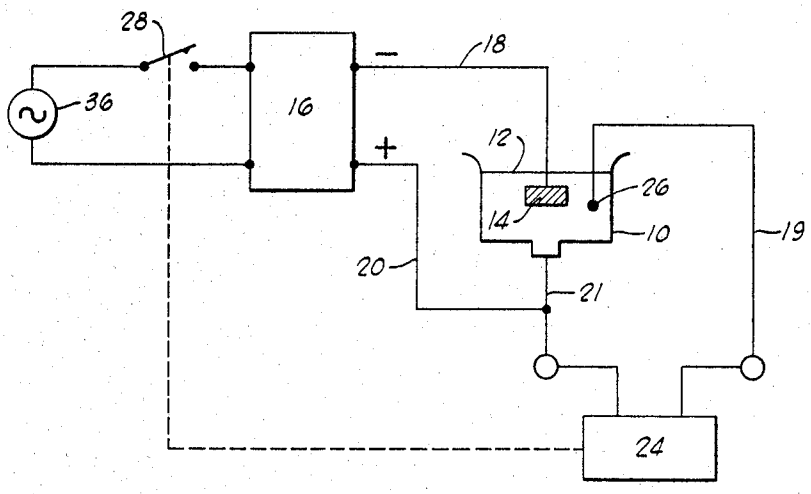


Fig. 1

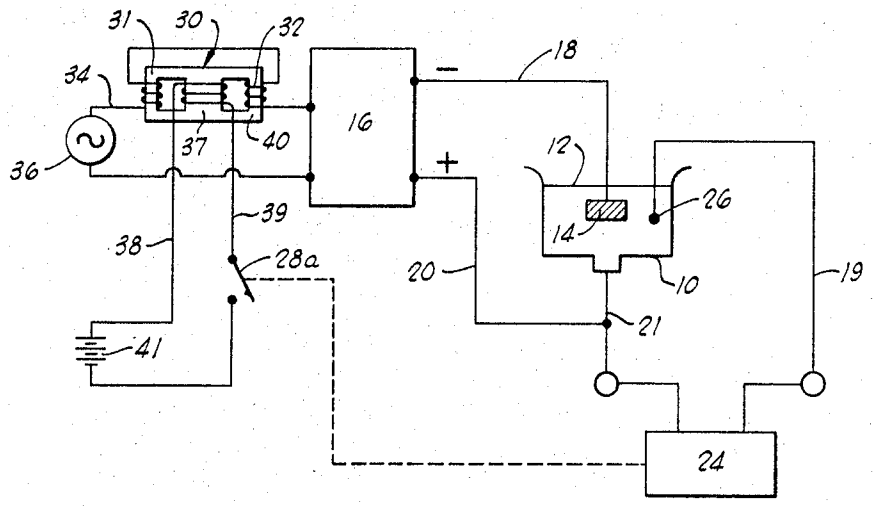


Fig. 2

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ANODIC POLARIZATION SYSTEM

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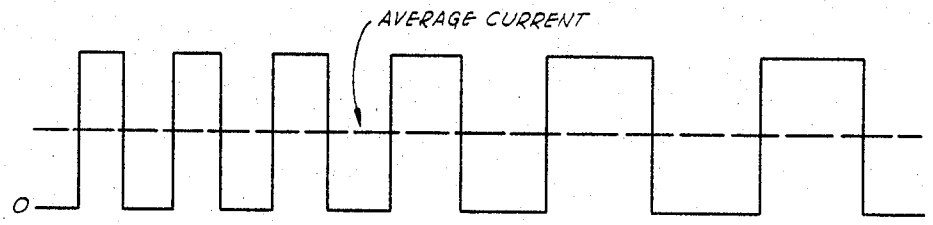


FIG. 1A

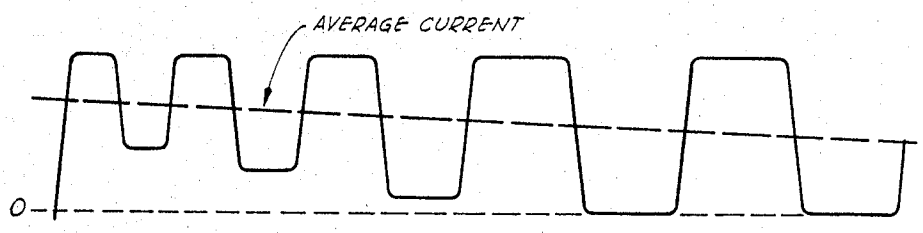


FIG. 2A

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ANODIC POLARIZATION SYSTEM

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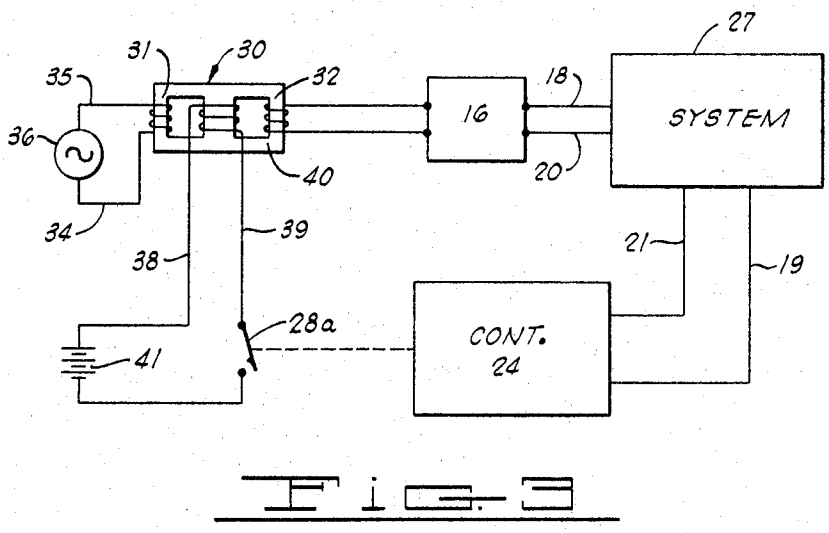


Fig. 3

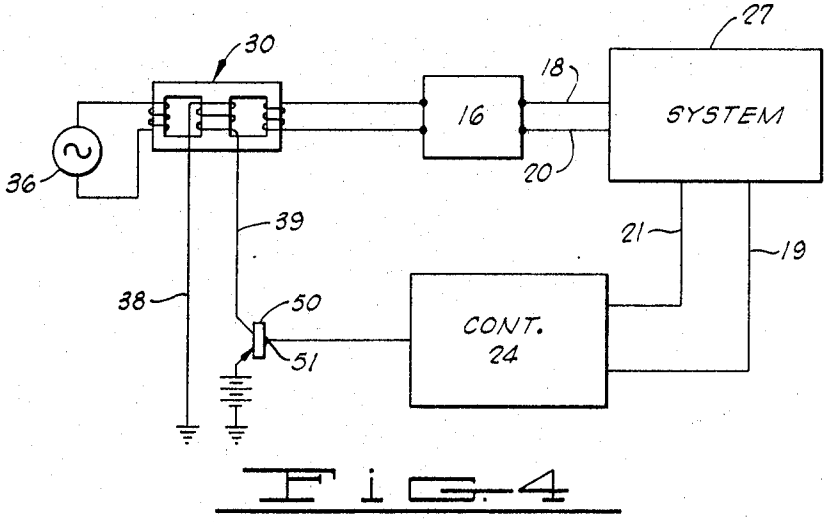


Fig. 4

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ANODIC POLARIZATION SYSTEM

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5 Claims. (Cl. 204—196)

This is a continuation-in-part of applicant's co-pending application, Serial No. 858,094, filed December 8, 1959, now abandoned, and entitled "Saturable Reactor Switch for an Anodic Polarization System."

This invention relates to an improved apparatus for the anodic protection of metals against corrosion.

The present invention is an improvement in the apparatus disclosed and claimed in co-pending application, Serial No. 1,136, filed January 7, 1960, now U.S. Patent No. 3,208,925, and entitled "Anodic Protection Against Corrosion," which co-pending application is assigned to the same assignee. Application, Serial No. 1,136, discloses a novel system which provides a periodic application of a control current to a vessel in such a manner that the corrosive effects of a caustic or other corrosive solution contained in the vessel will be substantially eliminated. This prior system utilizes an "on" and "off" type of controller operating a switch in the control current circuit for interrupting the anodic polarization current each time the corrosion of the vessel reaches a predetermined minimum, that is, each time the vessel reaches a predetermined degree of passivity. Each time the corrosion of the vessel increases to a predetermined maximum, the switch is closed and anodic polarization current is again passed through the corrosive solution to re-establish the passivity of the vessel. This prior system is highly useful in minimizing corrosion in a storage tank or other vessel where there is little change in the corrosive solution or in the storage conditions, and particularly in systems where the required anodic current is low, such as 20 to 25 amps at 15 to 25 volts. However, under changing conditions, such as when the vessel is a process vesssel and the corrosive solution is frequently changed, the corrosion rate changes rapidly. Under these conditions, the "on" and "off" controller provides a rapid making and breaking of the switch in the anodic current circuit, and the switch is worn out and rendered ineffective in short order.

An important object of this invention is to effectively control corrosion of a vessel containing a corrosive solution, even though frequent changes occur in the corrosive solution or in the storage conditions.

Another object of this invention is to rapidly passivate a vessel containing a corrosive solution at any time the passivity is partially destroyed, without damage to the anodic protection system.

A further object of this invention is to provide a system for protecting a vessel against corrosion by means of an anodic current wherein high currents can be passed from the vessel through a corrosive solution contained in the vessel during the times that passivation is being established.

A further object of this invention is to delay the opening and closing of the anodic current circuit of an anodic protection system to provide rapid passivation of a vessel being controlled by the system each time passivation of the vessel is interrupted.

A still further object of this invention is to provide an anodic protection system which is simple in construction, has a long service life and which requires a minimum of repair.

The present invention contemplates a novel system for anodically passivating a vessel containing an electrolytic corrosive solution wherein the vessel is subject to frequent changes in corrosion rate, which system features a saturable core reactor having its A.C. winding interposed in the anodic current circuit and having its control winding controlled by a suitable switch means connected in series with a D.C. source having a much smaller power output than the power supplied through the anodic control circuit. The switch means is operated by a simple "on" and "off" controller which monitors the corrosion rate of the vessel to close and open the switch means in response to predetermined maximum and minimum corrosion rates. With this arrangement, the anodic current is not interrupted until after the vessel has become passivated, even though the controller rapidly opens and closes the switch means in the D.C. control circuit in response to rapid changes in the potential measured or monitored by the controller. In this connection, it may be pointed out that the controller operates rapidly during the time that a high anodic current is being utilized, even though the vessel has not been passivated. The present system is particularly useful in systems requiring high anodic currents, such as 70 amps at 25 volts.

Other objects and advantages of the invention will be evident from the following detailed description, when read in conjunction with the accompanying drawings which illustrate the invention.

In the drawings:

FIGURE 1 is a schematic illustration of a previous anodic protection system, such as is disclosed in application, Serial No. 1,136, mentioned above.

FIGURE 1A is a schematic illustration of the anodic current provided by the system shown in FIG. 1 during a time in which the vessel is being passivated.

FIGURE 2 is a schematic illustration of the present anodic protection system.

FIGURE 2A is a schematic illustration of the anodic current provided by the system shown in FIG. 2 when the vessel is being passivated.

FIGURE 3 is a schematic illustration of another embodiment of the present invention.

FIGURE 4 is a schematic illustration of still another embodiment of the present system.

Referring to the drawing in detail, and particularly FIG. 1, reference character **10** designates a vessel, such as a tank, containing an electrolytic corrosive solution **12** and which is to be protected against the corrosive action of the solution **12**. The vessel **10** is constructed of metal normally mild or stainless steel in view of the required service. The solution **12** may be, for example, sulfuric, phosphoric, or nitric acid.

An inert electrode **14** is suspended or otherwise supported in the solution **12** and is connected to the negative terminal of a rectifier **16** by a conductor **18**. The electrode **14** may be any material which is inert to the solution **12** and resists changes in potential as current is passed therethrough, that is, a material which preferably does not polarize. Preferable electrode materials are platinum or carbon. The positive output terminal of the rectifier **16** is connected by a conductor **20** to the

vessel 10. It will thus be seen that the vessel 10 functions as an anode and the electrode 14 functions as a cathode.

A reference electrode 26 is placed in electrical communication with the solution 12, as by being suspended in the solution 12. The reference electrode 26 is made of a material which is located in the E.M.F. table at a lower or more noble position than the material of the vessel 10, and may be, for example, a calomel electrode when the vessel 10 is stainless steel. An "on" and "off" controller 24 is connected across the vessel 10 and the reference electrode 26 conductors 21 and 19 to monitor the potential between the vessel 10 and electrode 26, for purposes to be described. The input impedance of the controller 24 should be at least ten times as great as the internal impedance of the reference electrode 26 in order to prevent an erroneous indication of the vessel potential, since the controller 24 draws current from the reference electrode 26. In an anodic protection system, the reference electrode has a high internal impedance, and in order for the controller 24 to accurately measure the potential between the vessel 10 and the reference electrode 26, the controller 24 must have a correspondingly high input impedance, preferably ten to one hundred times the internal impedance of the reference electrode 26. The controller 24 is mechanically connected to a switch 28 interposed in the power supply circuit extending from an A.C. power supply 36 to the input of the rectifier 16.

As is known in the art, the rate of corrosion of the type being considered varies with the potential of the vessel being corroded, and the corrosion may be prevented, or at least minimized, by anodic polarization. The potential of the vessel is determined with respect to the reference electrode 26. When the vessel is made the anode of an electrochemical cell, as shown in FIG. 1, the potential of the vessel shifts in a more noble direction. When this shift is of sufficent magnitude, the corrosion stops and it is said that the vessel has become passive.

In operation of the system shown in FIG. 1, the controller 24 monitors the potential between the vessel 10 and reference electrode 26 to open and close the switch 28. The switch 28 is closed when the corrosion rate of the vessel 10 reaches a predetermined maximum (as indicated by the potential between the vessel 10 and electrode 26) to establish the anodic current from the power supply 36 and rectifier 16. The flow of the anodic current from the vessel 10 to the electrode 14 pacifies the vessel 10 and minimizes the corrosion rate. When the corrosion rate reaches a predetermined minimum (as determined by the potential between the vessel 10 and the electrode 26), the controller 24 opens the switch 28 and interrupts the anodic current. The passivity of the vessel 10 gradually decreases until the corrosion rate again reaches the predetermined maximum; whereupon the anodic current is again turned on to maintain the passivity of the vessel 10 between predetermined maximum and minimum levels.

As previously indicated, the controlled 24, in combination with the switch 28, works very effectively when the vessel 10 has once been pacified and when the solution 12 and other storage conditions do not vary to any appreciable degree. However, if the passivity of the vessel 10 is interrupted (as by a change in the solution 12), the potential between the vessel 10 and reference electrode 26 varies rapidly while passivity is again being established. As a result, the controller 24 rapidly opens and closes the switch 28 to apply and interrupt the anodic current. Under these conditions, the anodic current will appear as illustrated in FIG. 1A.

As shown in FIG. 1A, the anodic current is in the form of a square wave varying from zero to a predetermined level (such as 70 amps) depending upon the power output of the A.C. power supply 36. When passivity is being established, as illustrated by the left-hand portion of the wave shape in FIG. 1A, the anodic current varies rapidly by the rapid opening and closing of the switch 28. For example, the switch 28 may be opened and closed ten times per second. As passivity is established, which may require several hours (as long as five or six hours with a mild steel vessel containing 90 percent sulfuric acid), the anodic current is turned on and off at a decreasing frequency. The rapid opening and closing of the switch 28 during the establishment of passivity quickly wears out the switch and eventually renders the system ineffective to prevent corrosion of the vessel 10.

In accordance with the present invention, and as shown in FIG. 2, the anodic current is controlled directly by a saturable core reactor 30 controlling the A.C. supplied to the rectifier 16, rather than the use of a mechanical switch as described above. The reactor 30 has a core 40 on which are wound a pair of A.C. windings 31 and 32. The windings 31 and 32 are connected in series with one another and in series with the A.C. power supply 36 and one input of the rectifier 16 by a conductor 34. A mechanical switch 28*a* is interposed in the conductor 39 and is connected to the controller 24 for operation in the same manner as the switch 28 previously described in connection with FIG. 1. The remaining portion of the system shown in FIG. 2 is the same as that shown in FIG. 1.

In operation of the system shown in FIG. 2, the controller 24 closes the switch 28*a* when the potential between the vessel 10 and the reference electrode 26 reaches a predetermined maximum, indicating a predetermined maximum rate of corrosion. Closure of the switch 28*a* causes current to flow from the D.C. power supply 41 through the control winding 37 of the reactor 30 to saturate the core 40; whereupon the A.C. from the power supply 36 flows through the conductor 34 and the A.C. windings 31 and 32 pass the anodic current from the vessel 10 to the electrode 14. When the predetermined degree of passivity is established, as indicated by the potential between the vessel 10 and the reference electrode 26, the controller 24 opens the switch 28*a* and interrupts the D.C. supplied to the control winding 37 of the reactor 30; whereupon the A.C. power supply is isolated from the rectifier 16 and the anodic current is turned off.

As previously indicated, the system shown in FIG. 2 is particularly useful when passivity of the vessel 10 is frequently interrupted, such as by a change in the solution 12. Under these circumstances, and as described above, the controller 24 operates rapidly until passivity of the vessel is established. The anodic current produced by the system shown in FIG. 2 is illustrated in FIG. 2A as it occurs during the establishment of passivity. As will be observed, the anodic current increases rapidly when the switch 28*a* is first closed, but not instantaneously as shown in FIG. 1A. The inherent time delay required to saturate the core 40 upon imposition of the D.C. from the power supply 41 provides a short time delay in the buildup of the anodic current. Likewise, an inherent time delay is required in the unsaturation of the core 40 upon opening of the switch 28*a*. As a result, the anodic current will fluctuate between a predetermined maximum and a predetermined minimum which is above zero upon rapid opening and closure of the switch 28*a*, as when passivity is being established for the vessel 10. As passivity of the vessel is established, the anodic current more nearly approaches a square wave, with the troughs of the wave being at zero.

It will thus be seen that the fluctuation of the anodic current above zero (provided by the system shown in FIG. 2) will provide a higher average amplitude for the anodic current during the initial phases of the establishment of passivity to more quickly pacify the vessel, compared with the use of a mechanical switch in the anodic current network as shown in FIG. 1. Furthermore, the saturable reactor 30 has no moving parts to become worn or cause arcing. Thus, the system shown in FIG. 2 is particularly

useful for preventing corrosion of the vessel **10** when the vessel is subjected to varying storage conditions, such as frequent changing of the solution **12**. Each time passivity of the vessel **10** is interrupted, it will be quickly re-established to minimize the overall corrosion of the vessel.

The embodiment shown in FIG. 3 is the same as that shown in FIG. 2 except that the A.C. winding **31** of the saturable reactor **30** is connected directly across conductors **34** and **35**, and the A.C. winding **32** is connected directly to the input of the rectifier **16**. In this embodiment, when switch **28***a* is closed, the core **40** will likewise saturate, however, since the energy from winding **31** must be transferred to winding **32** through core **40**, as core **40** is saturated, little energy will be transferred thereto. When switch **28***a* is opened, core **40** provides an effective transfer medium for energy between the windings **31** and **32**. It is to be understood that windings **31** and **32** must have sufficient impedance so they will not be damaged by the voltage from the power supply **36** when core **40** is saturated.

The embodiment shown in FIG. 4 is also the same as that shown in FIG. 2, with the exception of the switch interposed in the conductor **39** extending from the D.C. power supply **41** to the control winding **37** of the reactor. In the embodiment shown in FIG. 4, the switching means comprises a transistor **50** having its emitter and collector in series with the conductor **39** and having its base **51** connected to the controller **24**. It will be understood that the controller **24** must develop suitable bias for the base **51** of the transistor **50**, such that the transistor will be driven between saturation and cut off to provide a switching action. It is, of course, understood by those skilled in the art that operating conditions for transistor **50** other than those previously stated may be employed if the efficiency of transistor **50** may be sacrificed.

From the foregoing, it will be apparent that the present invention provides a novel anodic protection system which is particularly useful for controlling the corrosion of a vessel or the like which is subject to frequent changes in corrosion rate. Each time passivity of the vessel is interrupted, a high anodic current is utilized to quickly re-establish passivity in a minimum of time and with a minimum of corrosion of the vessel. The only mechanical switching element which may be utilized in this system is utilized to control a negligible D.C. current rather than the higher anodic current which is actually imposed to control corrosion. It will also be apparent that the present system is simple in construction, may be economically manufactured and will have a long and trouble-free service life.

Changes may be made in the combination and arrangement of parts or elements as heretofore set forth in the specification and shown in the drawings, it being understood that changes may be made in the embodiments disclosed without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed is:

1. A system for anodically passivating a vessel containing an electrolytic corrosive solution and subject to frequent changes in corrosion rate, comprising:

an electrode immersed in the solution;

a rectifier having its negative output terminal connected to the electrode and its positive output terminal connected to the vessel to make the electrode a cathode and the vessel an anode;

an A.C. source;

a saturable core reactor having an A.C. winding connected in series with the A.C. source and the rectifier and having a control winding;

a reference electrode electrically communicating with the solution;

an "on" and "off" type controller connected across the vessel and the reference electrode to monitor the potential between the reference electrode and the vessel, said controller having an input impedance substantially greater than the internal impedance of the reference electrode;

a D.C. source connected in series with the control winding of the reactor; and

switch means operably connected to the controller and interposed in the connection of the D.C. source to the control winding of the reactor to alternately energize and de-energize the reactor in response to low and high potentials between the reference electrode and the vessel.

2. A system as defined in claim **1** wherein the switch means comprises a switch mechanically connected and operated by the controller.

3. A system as defined in claim **1** wherein the switch means comprises a transistor having its emitter and collector in series with the D.C. source and the control winding of the reactor and having its base electrically connected to and operated by the controller.

4. A system for anodically passivating a vessel containing an electrolytic corrosive solution and subject to frequent changes in corrosion rate, comprising:

an electrode immersed in the solution;

a rectifier having its negative output terminal connected to the electrode and its positive output terminal connected to the vessel to make the electrode a cathode and the vessel an anode;

an A.C. source;

a saturable core reactor having a pair of A.C. windings connected in series with each other and with the A.C. source and the rectifier, said reactor also having a control winding;

a reference electrode electrically communicating with the solution;

an "on" and "off" type controller connected across the vessel and the reference electrode to monitor the potential between the reference electrode and the vessel, said controller having an input impedance substantially greater than the internal impedance of the reference electrode;

a D.C. source connected in series with the control winding of the reactor; and

switch means operably connected to the controller and interposed in the connection of the D.C. source to the control winding of the reactor to alternately energize and de-energize the reactor in response to low and high potentials between the reference electrode and the vessel.

5. A system for anodically passivating a vessel containing an electrolytic corrosive solution and subject to frequent changes in corrosion rate, comprising:

an electrode immersed in the solution;

a rectifier having its negative output terminal connected to the electrode and its positive output terminal connected to the vessel to make the electrode a cathode and the vessel an anode;

an A.C. source;

a saturable core reactor having a pair of A.C. windings, one of said windings connected in series with the A.C. source and the other connected in series with the rectifier, said reactor also having a control winding;

a reference electrode electrically communicating with the solution;

an "on" and "off" type controller connected across the vessel and the reference electrode to monitor the potential between the reference electrode and the vessel, said controller having an input impedance substantially greater than the internal impedance of the reference electrode;

a D.C. source connected in series with the control winding of the reactor; and

switch means operably connected to the controller and interposed in the connection of the D.C. source to

the control winding of the reactor to alternately energize and de-energize the reactor in response to low and high potentials between the reference electrode and the vessel.

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