June 2, 1970 K. BØRDALEN ET AL 3,515,654

METHOD AND APPARATUS FOR REGULATING SUPPLIED CURRENT IN CATHODIC PROTECTION

Filed May 25, 1965

2 Sheets-Sheet 1

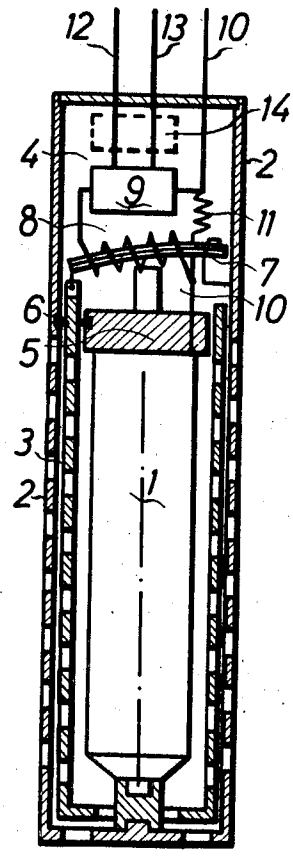


FIG.1

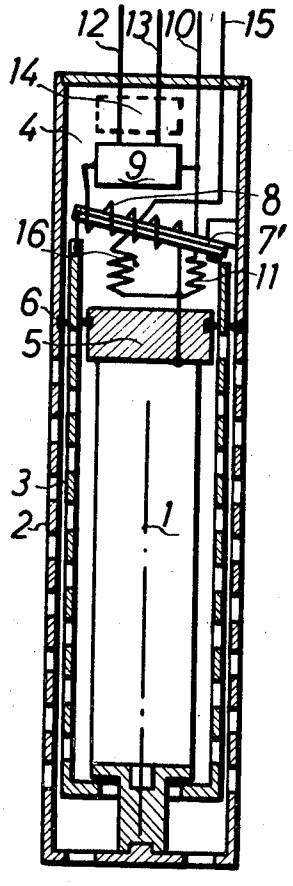


FIG.2

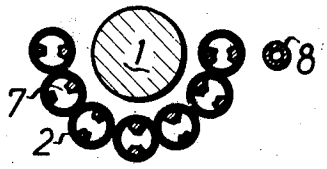
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FIG.3a



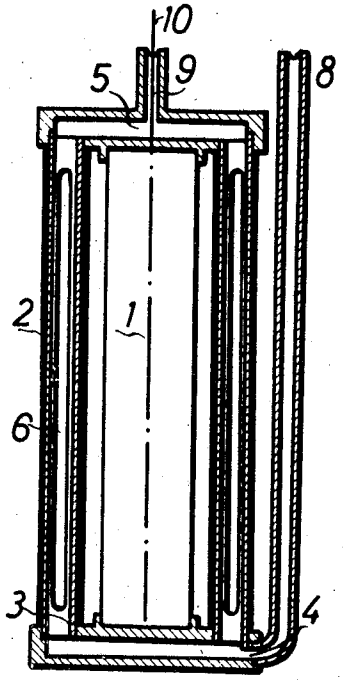
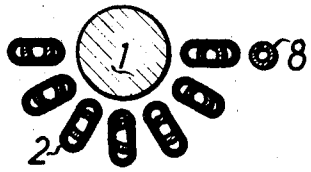


FIG.3

FIG.4a



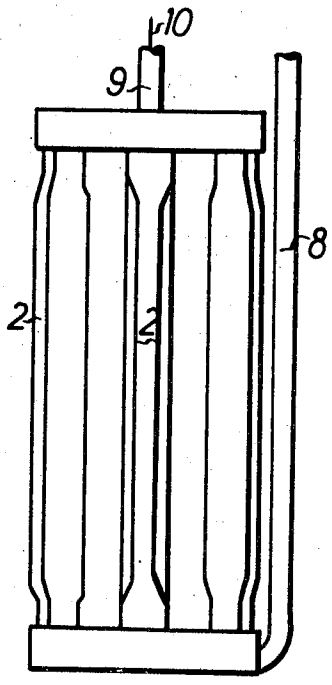


FIG.4

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METHOD AND APPARATUS FOR REGULATING SUPPLIED CURRENT IN CATHODIC PROTECTION

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ABSTRACT OF THE DISCLOSURE

Regulation of cathodic protection of metal constructions in electrolyte solutions where inert anodes are connected to a source of electricity and where such regulation is by mechanical means. The mechanical means varies the permitted flow of electrolyte to and from the anode by perforated screens overlying the anode and adjustable with respect to each other to vary the size of the perforations. Movement of the screens may be effected by bi-metal elements heated by the anode current in turn controlled by a reference electrode in the solution. Such mechanical means may be concentric perforated cylinders, expandable and contractable resilient means operable to close or open passages to said anode or may include means for varying the shapes of individual anodes or varying the position of adjacent anodes with respect to each other.

In cathodic protection of metal constructions in contact with electrolytic solutions, particularly in protection of iron and steel immersed in fresh or salt water, it is a general aim to adjust the supplied current to the immediate requirement.

Galvanic anodes which operate with no external voltage source are, to a certain degree, self-regulating, since the relatively low potential difference between these anodes and technical constructional metals in aqueous solution will, to a great extent, depend on the degree of polarization of the cathode surface. This is particularly the case in the system zinc-iron. By protecting steel with zinc anodes there is no risk of drastic over-protection. By using magnesium anodes the risk is considerably greater. Even so in systems with a greater number of galvanic anodes it is usual to dispense with every external regulation of the protective current, since the anodes are permanently connected directly to the cathode with the least possible ohmic resistance in the connection.

The case is very different in systems utilizing an external voltage source and inert or soluble anodes. One of the main advantages of this method is that it is possible to operate with substantially greater voltage differences than in a purely galvanic system and thereby to cover substantially greater cathode areas from the individual anode point. In such systems it is particularly necessary to be able to regulate the protective current, manually or automatically, in accordance with the degree of polarization of the cathode surface.

Such a system is simple enough if there is only one anode in the system or several anodes which may all be regulated collectively. On the other hand, however, technical difficulties arise if an individual regulation of the supplied current for a plurality of anodes fed in parallel from the same voltage source is desired. The choice lies between using a transformer-rectifier unit or a high-effect variable resistance in each anode circuit. In large systems with current requirements of hundreds or thousands of amperes, none of these possibilities are particularly attractive, since in both cases the equipment is expensive,

heavy and bulky. In systems of greater dimensions the cost of the individual current conduits to the individual anode units may be prohibitive. On the other hand it is often inconvenient to have rectifiers and other electrical equipment distributed around the system.

The invention comprises a method of cathodic protection of metal constructions in electrolyte solutions by means of an external voltage source, particularly in parallel feeding of a plurality of anodes from the same voltage source, and it is substantially characterized in that the current from the individual anode or anode group is regulated entirely or partly by a varying mechanical screening of the anode's (anodes') electro-chemically active surface and/or by a variation, produced in a similar manner, of the effective electrolyte-cross section available to the anode current in close proximity to the anode. The invention further relates to a construction hereinafter described.

The principle of the method is illustrated in the following examples:

In cathodic protection of metal in contact with an electrolyte solution by means of an external voltage source, the anode will in most cases be substantially less extensive than the cathode surface it is to protect. This means that the current lines from the anode on the whole will diverge markedly, and a substantial portion of the effective elecrtolyte resistance in the circuit will be found adjacent the anode. This fraction may easily be increased, most simply by reducing the effective surface of the anode. This may be achieved, for instance, by covering a cylindrical anode, to a greater or lesser extent, with a tightly fitting sleeve or casing. Another possibility is to construct the anode of two or more elements connected in parallel, the mutual spacing and/or orientation of which may be changed. If, for instance, the anode consists of two equal sized, thin plates, it is obvious that the effective surface of the anode can be halved if the plates cover each other. If the outwardly-facing sides and edges of the plates are covered with an insulating coating, the effective surface of the anode may be brought down to zero if so desired. However, before this complete covering of the anode's surface takes place, the reduction in the anode's current supply is caused by a decrease of the effective electrolyte cross sectiton available to the current from a constant anode area. A corresponding effect can, for that matter, be achieved even if the anode is in one piece, but deformable. It may have the form of an elastic bellows, a helical wire or simply a curved sheet.

All anode materials are not, however, suitable for components which are to be repeatedly deformed. It is an advantage moreover to maintain anodic current density as low as conditions permit, in consideration of the specific anode loss, which usually increases with the current density. In many cases it is preferable, therefore, to allow the actual anode material to constitute a rigid construction and to maintain the active anode surface unchanged, while the current regulation is effected by means of a varying restriction of the effective electrolyte cross section around the anode, e.g. by mobile screens which do not fit tightly against the anode surface. The screening system may, for instance, consist of two perforated cylindrical sleeves which are mounted coaxially with the anode. The location and size of the openings in the sleeves should be so selected that a moderate displacement of one cylinder causes a substantial change in the free opening through the walls of both cylinders, and it should preferably be possible to reduce this opening to approximately zero, in order that the anode may practically speaking be put out of action by means of the screening system.

A complete utilization of such a regulation possibility is achieved only if the regulation is made automatic, con-

trolled by the potential difference between the cathode surface and a reference electrode having a suitable location in the system. This can be done by means of conventional regulating technique. In this case it may be convenient to use a part of the anode current to move the screen. A very simple constructiton for the automatic regulation of the anode current in accordance with the invention, is shown in the accompanying drawing.

In the drawings:

FIG. 1 is a vertical section of an anode assembly in accordance with the invention.

FIG. 2 is a view similar to FIG. 1 of a slightly modified form of the invention.

FIG. 3 is a similar view of an assembly employing expandable flow control means.

FIG. 3*a* is a partial horizontal cross section thereof.

FIG. 4 is an elevation of an assembly employing a different form of expandable means, and

FIG. 4*a* is a partial horizontal cross section thereof.

The anode **1** is surrounded by a system of two perforated sleeves **2**, **3** of electrically insulating material. The upper portion of the sleeve **2** comprises a closed chamber **4** being at the bottom separated from the electrolyte by the plate **5** and gasket **6** which form a guide for the upper end of the inner sleeve **3**. The sleeve **3** may be displaced vertically by the bimetal spring **7** when this is heated by a heat coil **8** which is fed by a part of the anode current via the control element **9**. In the main current conduit **10** a small resistance **11** is inserted in order to allow a branching of the anode current. The control element **9**, which may be a transistor, is governed by the potential difference between the cathode surface and a suitable reference electrode connected with the control element **9** by the conduits **12** and **13**, if necessary through the amplifier **14**. The regulation unit, comprising elements **2**, **3**, **7**, **8**, **9**, **11** and **14**, together with the reference electrode connected at **13**, are arranged so that the current through **8** increases rapidly when the potential difference supplied at **12** and **13** passes a value which corresponds to a polarization of the cathode surface sufficient for protection.

FIG. 1 indicates that the screening system gives maximum opening when the coil **8** is without current. However in many practical cases it is desirable, quite to the contrary, that the anode is entirely screened from its surroundings when it is not in use. A construction which meets this requirement is shown in FIG. 2. In this case it is assumed that the bimetal spring **7'** in cold condition maintains the screen **3** in a position in relation to the screen **2** wherein the one screen completely covers the holes in the other, while the maximum opening through the screens corresponds to a specified temperature increase on the spring **7'**. Provided that there is a good fit between the screens **2** and **3**, it is not possible to render the anode operational merely by supplying voltage through the conduit **10**. The anode must in this case be started by an auxiliary circuit, by temporarily connecting it to the cathode or to the negative pole of the voltage source, by the conduit **15** via the resistance **16**. The connection may be effected by means of a press button which must be depressed for a certain period of time until the spring **7'** is heated sufficiently by the coil **8**, whereafter the anode will be self-regulating, and the connection through **15** may be broken. An ordinary switch may be used instead of a press button, (outside the anode) in series with a switch operated by the bimetal spring **7'**, so that the connectiton through **15** is automatically broken as soon as the spring **7'** is heated.

It is obvious that the bimetal spring **7'** must in all cases have a certain heat dissipation for proper functioning. This entails no problem in an anode construction which is totally immersed in water or in an aqueous solution of normal temperature. If necessary, a cooling element may be disposed around the coil **8** having direct thermal contact with the liquid outside of the anode. If

an anode is to be used in heated liquid it may be practical to cool both the spring **7** or **7'** and other regulating elements in the chamber **4** by means of an air flow supplied externally.

FIGS. 1 and 2 represent only examples of possible embodiments of the screening system. In actual fact, the construction may be even more simple if the screening movement is effected by rotation of the sleeve **3** about the axis of the anode, instead of by translation. This will save space both in the lower and upper end of the construction, and the screening movement may still be actuated by a bimetal spring. However, other mobile elements e.g. servomotors may also be used.

In a conventional design of the anode body itself, the screening system may complicate the transport of anode products away from the anode surface. This may have unfortunate consequences. With consumable anodes (e.g. comprising zinc, iron, or aluminum), there is a possibility that anode products developed may be deposited in or within the screening system. Inert anodes may correspondingly cause collection of gas within the screens. To this must be added that the ohmic heat generation in the electrolyte may be considerable in the relatively narrow liquid channels through which the current must pass, if the anode current is to be reduced extensively while maintaining both the applied voltage and active anode area. For instance a current density of 2 A./square inch in calm sea water will heat the liquid from sea temperature to the boiling point in the course of a few minutes. These effects which can disturb the function and control of the anode, are eliminated by means of a "hollow anode" design according to Norwegian Pat. No. 92,165 where the anode products are transported by a flow of liquid into a cavity in the anode and from there are drawn out of the system. Anodes of this type are particularly suitable for current control according to the present method, but the method may also be adapted for conventional anode types. The current control may be effected by varying the exposed anode surface by means of a tightly fitting screen (or a screen which is filled with gas from the anode), while the remainder of the anode surface is freely exposed. Or the gas generation and the change in the density of the liquid with temperature must be utilized to produce a constant circulation of liquid through the screening system via suitable channels.

There exist many possibilities for the embodiment of the anode's screening system, and the constructions described above represent only examples of the embodiments which in addition to the advantageous regulation also give good protection of the actual anode against mechanical damage.

Another embodiment which can give even better mechanical protection of the actual anode, and which is less sensitive to disturbances by foreign bodies in the liquid, utilizes elastic hollow bodies whose volume, or form may be changed pneumatically or hydraulically. An example of such a construction is shown in diagram in FIG. 3. Here the anode **1** is surrounded by a plurality of straight, parallel, thick-walled rubber tubes **2** which are stretched over pipes **3** which connect the cavities **4** and **5** in the top and bottom pieces of the anode construction. The tubes **2** are rigidly supported at both ends by, and clamped between, the ends of the pipes **3**, these being provided, over the greater part of their length, with slots **6** which leave only two ribs **7** of each pipe. Assuming that there is moderate pressure in the surrounding liquid, the tubes **2** by their own elasticity tend to give a complete screening of the anode. If the cavities are evacuated through the pipes **8** or **9** the tubes **2** will be flattened by the pressure in the electrolyte and will open the way for the anode current. The regulation of the pressure in the cavities **3**, **4**, and **5** and thereby the variation of the electrolyte cross section between the tubes can for instance be effected by the regulation of the opening in a valve

(not shown) in the pipe 9 which allows air into the cavities while the pipe 8 remains under vacuum. For the adjustment of said valve, a similar arrangement as that described above for the adjustment of the screen 3 in FIG. 1 and FIG. 2 may be used.

Instead of operating with reduced pressure in the tubes 2 in order to open the screening system, it is possible to operate in the opposite way, as shown on FIG. 4 where the cross section of the pipes is so selected that they must be subjected to internally increased pressure in order to give complete screening of the anode, while with atmospheric internal pressure they are compressed by the liquid head, and thereby give maximum opening for the current. Another possibility is to subject the cavities to liquid pressure from an adjustable water column.

In order to obtain the maximum electrolyte cross section on complete opening of the screening system, rubber tubes having a special profile (for instance with rectangular or V-shaped cross section) may be used to advantage. Quite different embodiments of the hollow bodies may also be used, e.g. double walled rubber bellows mounted coaxially with the anode.

What is claimed is:

1. A method for regulating the cathodic protection of metal constructions in electrolyte solutions by means of an external voltage source which comprises, mounting an inert, non-consumable anode having an electro-chemically acting surface in the electrolyte solution, applying a voltage to said anode, partially shielding said electro-chemically acting surface of such anode from said electrolyte by enclosing said anode with shielding means at a position close to said anode and mechanically varying the area of said shielding to regulate the anode current effecting said protection.

2. The method as in claim 1 in which a plurality of anodes mounted in parallel are fed from the same voltage source and said variable shielding is effected by varying the relative position of adjacent anodes with respect to each other.

3. The method as in claim 1 wherein the variation in shielding is carried out by moving one perforated screen with respect to an overlying perforated screen to vary the cross sectional area of the passages through said perforations.

4. The method as in claim 1 wherein the variation in shielding is carried out by surrounding said anode with expandable and contractable members and varying the passages between said members by expansion and contraction thereof.

5. The method as in claim 1 including disposing reference electrodes in said electrolyte solution and varying the area of said shielding in response to the potential difference between the cathode of the system and one of said reference electrodes.

6. Anode assembly construction for variably controlling the area for passage of electrolyte to an anode which comprises, an anode member, a pair of overlying screen members formed with perforations therethrough mounted adjacent said anode, said screen members being formed with openings therein with one of said screen members being formed to uncover the openings in the other of said screen members to a varying extent and means for moving said one of said screen members with respect to the other thereof to uncover the openings in the other of said screen members to a varying extent so that the electrolyte cross section accessible for flow of the current between the surface of said anode and the exterior of said anode assembly can be varied substantially between closed and fully open position.

7. Anode assembly construction in accordance with claim 6 including bi-metal spring means for effecting the movement of said one of said screen members with respect to the other, a source for supplying current to the anode and regulating elements for regulating the flow of such current, means for heating said bi-metal spring means comprising a resistance element for diverting a portion of the current supplied to the anode through said regulating elements for heating said spring means, a reference electrode formed to be positioned in said electrolyte and in a reference electrode circuit for establishment of a potential difference between the same and the cathode system, and means for actuating said regulating elements by said reference electrode circuit.

8. Anode assembly construction for the controlled cathodic protection of metal constructions in electrolyte solutions which comprises, an anode member, means surrounding said anode member for changing the electrolyte cross-section accessible to the surface of said anode from the exterior of said anode assembly, said surrounding means including hollow elastic means mounted around and adjacent to said anode and means for expanding and contracting said elastic means to close or open the passage of said electrolyte to or from said anode.

9. A method for regulating the cathodic protection of metal constructions in electrolyte solutions by means of an external voltage source, which comprises mounting an inert, non-consumable anode of deformable material having an electro-chemically acting surface in the electrolyte solution, applying a voltage to said anode, partially shielding said electro-chemically acting surface of such anode from said electrolyte at a position close to said anode and mechanically varying the area of said shielding by deforming the material of the anode for restricting the effective electrolyte cross section near the anode to regulate the anode current effecting said protection.

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U.S. Cl. X.R.

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