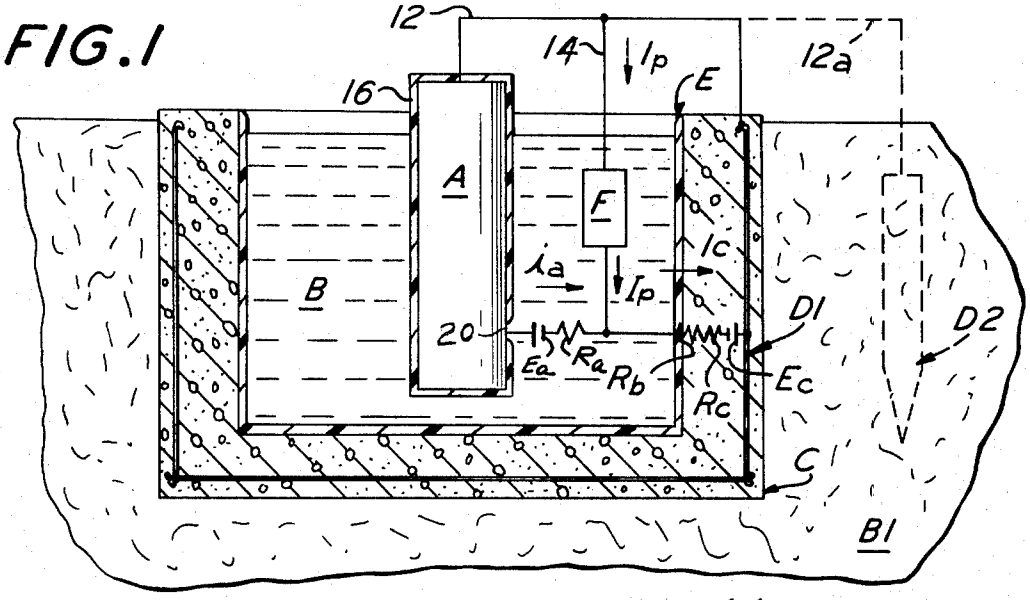
April 3, 1973 L. P. SUDRABIN ET AL 3,725,225

CATHODIC PROTECTION METHOD

Filed March 30, 1971 3 Sheets-Sheet 1

FIG. 1



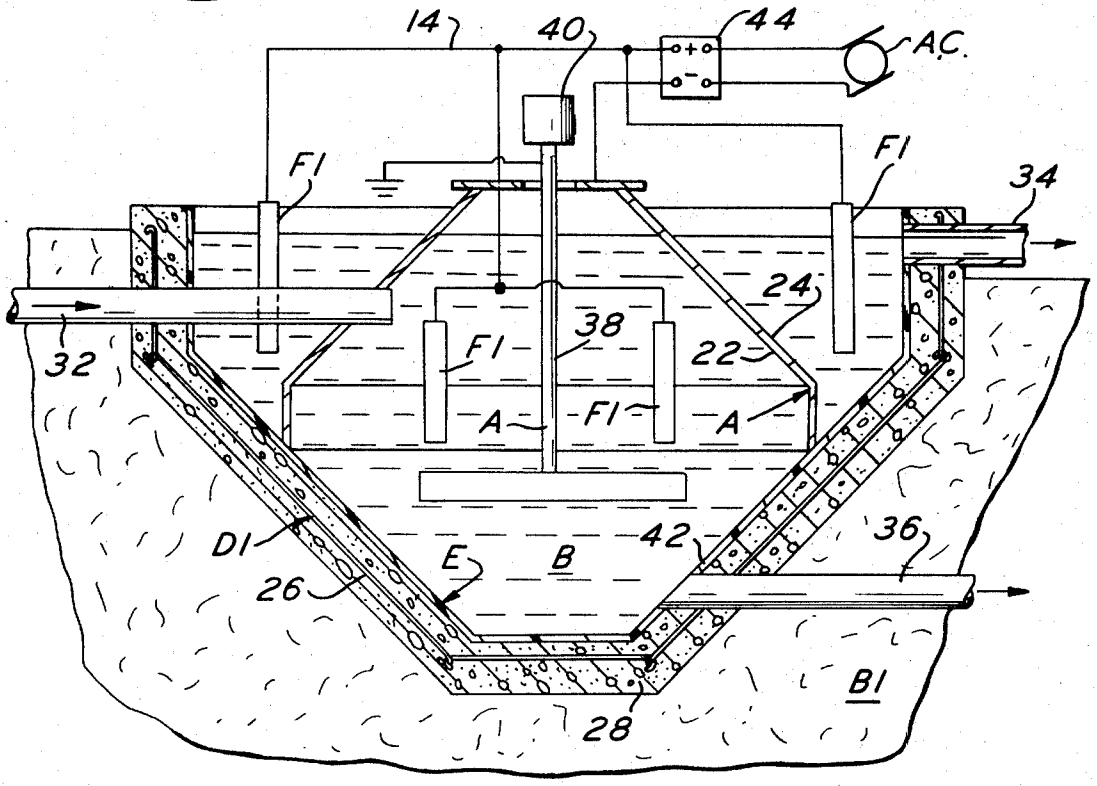




FIG. 2

INVENTORS
LEON P. SUDRABIN
PAUL KAISER
BY
Stanley Bilker
ATTORNEY

FIG. 3

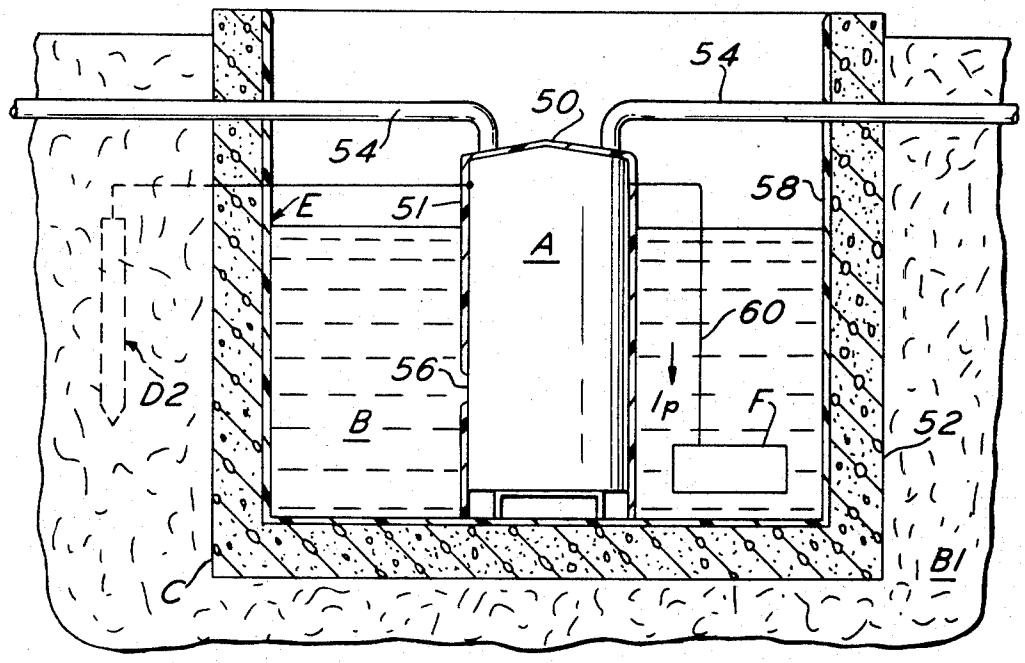
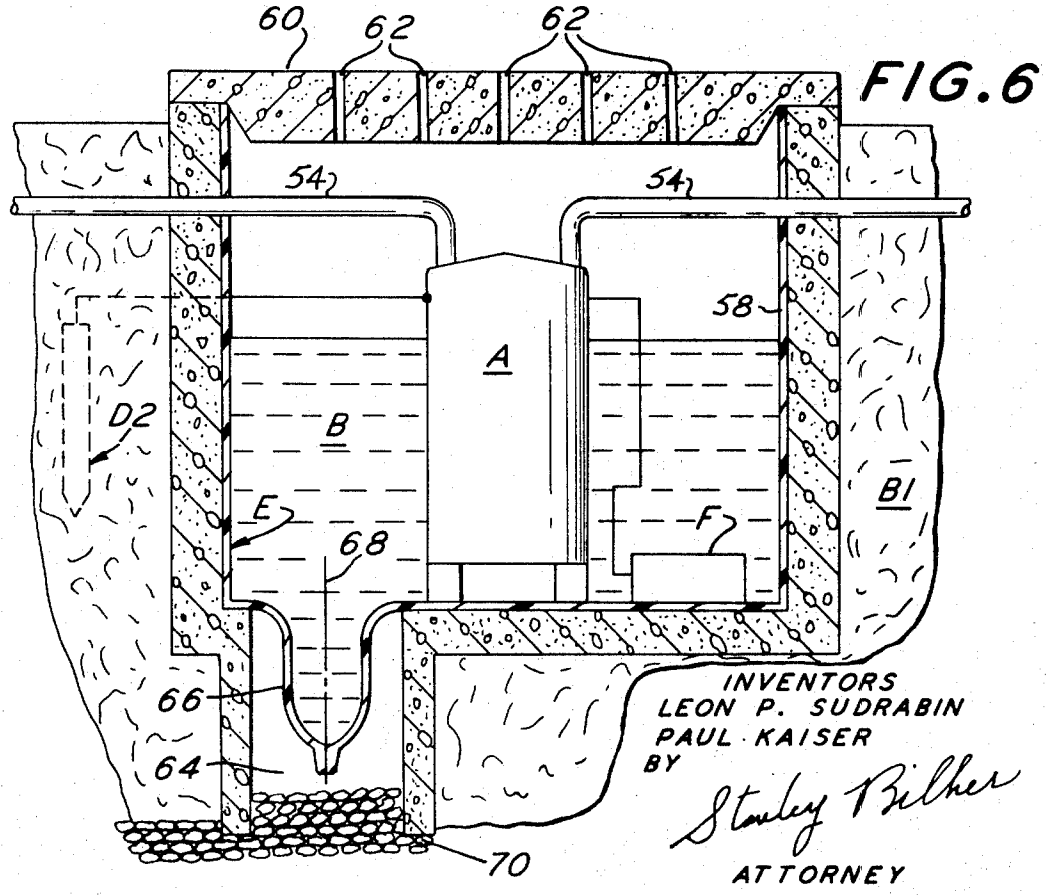



FIG. 6



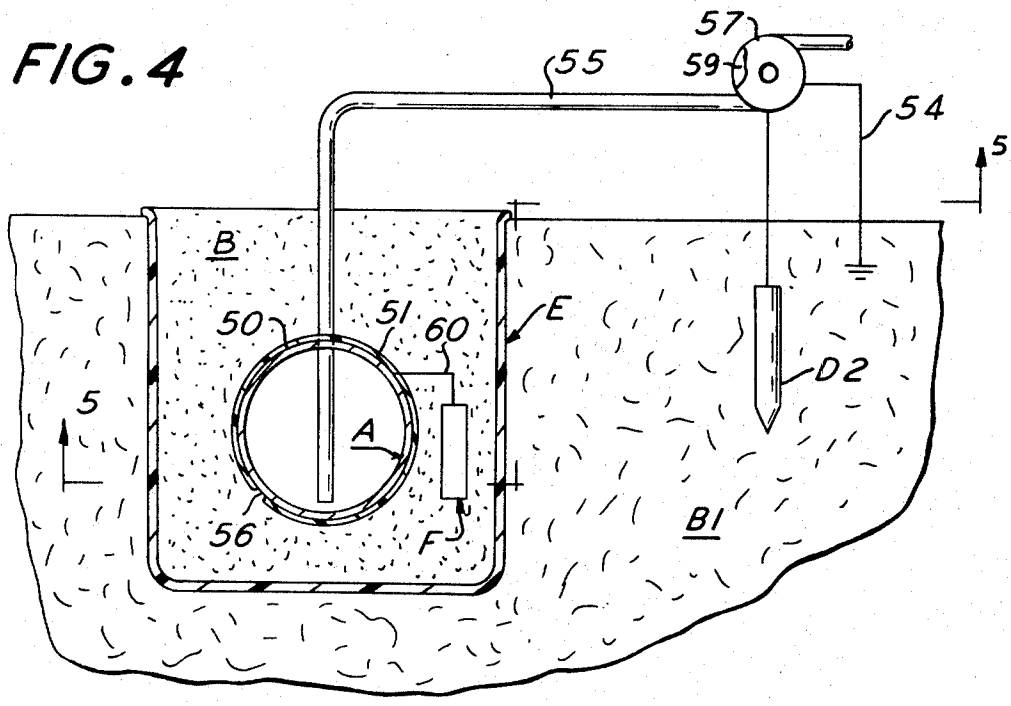

INVENTORS
LEON P. SUDRABIN
PAUL KAISER
BY
Stanley Bilker
ATTORNEY

April 3, 1973 L. P. SUDRABIN ET AL 3,725,225

CATHODIC PROTECTION METHOD

Filed March 30, 1971 3 Sheets-Sheet 3

FIG. 4



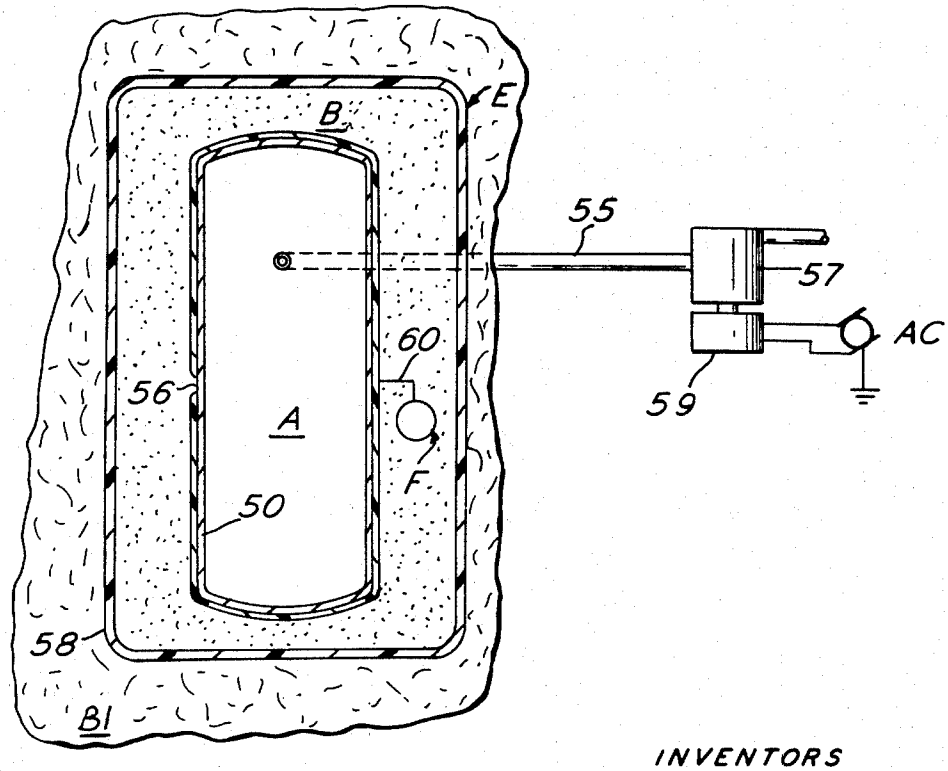




FIG. 5

INVENTORS
LEON P. SUDRABIN
PAUL KAISER
BY
Stanley Bilker
ATTORNEY

United States Patent Office

3,725,225

Patented Apr. 3, 1973



3,725,225

# CATHODIC PROTECTION METHOD

Leon P. Sudrabin, Berkeley Heights, and Paul Kaiser, Union, N.J., assignors to Pennwalt Corporation, Philadelphia, Pa.

Filed Mar. 30, 1971, Ser. No. 129,496
Int. Cl. C23f 13/00
U.S. Cl. 204—147 10 Claims

## ABSTRACT OF THE DISCLOSURE

Cathodic protection system for metal structures at least partially immersed in a corroding electrolyte and being connected to a second metal structure by a continuous conductive path. An electrically resistant diaphragm is interposed in the electrolyte between the two structures. Cathodic protection current is then applied to the first metal structure by an anode disposed within the electrolyte between the first metal structure and the diaphragm.

This invention relates to methods for controlling corrosion and applying cathodic protection to selected metal surfaces which are bonded metallically to foreign metallic structures exposed to water and other electrolytes. Specifically, these procedures involve the application of protective current flow from one or more anodes in the water, or other electrolyte, to prevent or retard corrosion on the selected metal surfaces. Such metal surfaces, corroding electrolyte and cathodic protection system, are separated from the foreign metal structures in the adjoining electrolyte by means of an electrically resistive diaphragm, or barrier.

Amongst examples of metal structures for which the present invention has special advantage in reducing corrosion and reducing the amount of cathodic protection current required are water and waste treatment facilities, such as clarifiers, flocculators, steel troughs of rapid sand filters, underground residental distribution transformer tanks, fuel storage tanks and hydraulic elevator cylinders, as well as buried pipe lines.

Today, it is recognized that the flow of corrosion current on a metal surface is the result of potential differences caused by local nonuniformities on the metal surface, such as differences in oxygen concentrations in the contacting electrolyte. In the metal structures mentioned above, a second corrosion mechanism also exists in which corrosion current flow through the electrolyte results from the potential difference between one metal, such as steel coupled metallically to dissimilar metals, such as the copper grounding systems or reinforcing steel in concrete. Copper in soils or water and reinforcing steel in concrete are 0.3 to 0.6 volt cathodic with respect to steel in soil or water.

Cathodic protection consists of the superposition of protective current from an auxiliary anode upon the corroding metal surface in amounts sufficient to result in zero net current flow out of any point on the metal surface. In the case of steel in soils or water, the fully protective condition has been achieved when the steel surface has been polarized to a potential of −0.85 volt, or more negative, measured against a copper sulphate reference electrode.

In any corrosion system when no external current is applied, the equivalent electrical circuit of corroding cell may be expressed by Kirchhoff's law, as follows:

$$i_L=i_a=i_c \tag{1}$$

where

$i_a$=anode current
$i_c$=cathode current, and

$$-E_a+E_c+i_LR_a+i_LR_c=O$$



where

$E_a$=anode potential
$E_c$=cathode potential
$R_a$=anode (or electrolyte path) resistance
$R_c$=cathode (or electrolyte path) resistance
$i_L$=corrosion current flow

or

$$i_L=\frac{E_a-E_c}{R_a+R_c}$$

Thus, the corrosion current flow, $i_L$, is determined by (a) the difference in the potential between the first metal structure and the second metal structure (or between the first metal structure and the ground electrode), and (b) the resistance of the electrolytic path. In the corrosion system to which the present invention is applicable, the first metal structure is in contact with a corroding electrolyte. and a metallic lead or bond provides a closed conductive path to the second metal structure, such as steel reinforcing bars embedded in a concrete vessel or basin, or to a copper grounding bar in a second electrolyte, such as soil. It is assumed in Equation 3 that the resistance of the bond or lead between the first structure and the second and/or the ground electrode is negligible.

It is common practice to apply highly resistive (electrically insulative) coatings, such as vinyl, epoxy, chlorinated rubber paints, asphalt, or coal tar mastics, to the surfaces of the first metal structure which is in contact with the corrosive electrolyte. These coatings inevitably develop flows which then expose small areas of the structure's metal to the corrosive electrolyte. The corrosion attack rate at the coating flow is much greater than the average corrosion rate on an overall bare surface. This increased rate of attack has been found to be attributable to the small ratio of anode area of the first metal structure which is exposed in relation to the extensive cathode areas of the second metal structure or of the ground electrodes. The rapid penetration of the structure at the flaw and accelerated deterioration of the coating by undercutting at the flaw is commonly observed on structures, such as painted steel troughs in rapid sand filters, which are found to have a closed conductive path (electronic closure circuit) to the reinforcing steel in the concrete of the filter basin.

It is therefore an object of this invention to provide an improved cathodic protection system for metal structures which are at least partially immersed or in contact with a corroding electrolyte when such structures are in addition connected by a closed continuous conductive path with a second metal structure or with a grounding bar.

Another object of this invention is to reduce the corrosion current for metal structures in contact with a corrosive electrolyte and directly connected to another metal member by an electronic closure circuit.

Yet still a further object of this invention is to lessen the cathodic protection requirements to control corrosion on metal structures in contact with a corroding electrolyte.

Other objects of this invention are to provide an improved device of the character described which is easily and economically produced, sturdy in construction, and both highly efficient and effective in operation.

With the above and related objects in view, this invention consists of the details of construction and combination of parts as will be more fully understood from the following detailed description when read in conjunction with the accompanying drawings in which:

FIG. 1 is an electrical schematic representation of a cathodic protection system embodying this invention.

FIG. 2 is a diagrammatic side sectional view of the

cathodic protection system of the instant invention as applied to a water clarifier.

FIG. 3 is a diagrammatic view of the cathodic protection system of the instant invention as applied to an underground distribution transformer tank.

FIG. 4 is a side sectional view of the cathodic protection system applied to an underground storage tank.

FIG. 5 is a sectional view taken along lines 5—5 of FIG. 4.

FIG. 6 is a side elevational view, and partly in section, of another modification of the instant invention.

Referring now in greater detail to the drawings in which similar reference characters refer to similar parts, there is shown in FIG. 1 a cathodic protection system for a metal structure, generally designated as A, which is immersed partially in a corrosive electrolyte, generally designated as B, for example water contained within a tank or other basin-like vessel, generally designated as C. The metal structure A is directly connected to a second metal structure, such as reinforcing bars D1 contained within the concrete basin C by way of connections which normally exist, such as straps 12. The metal structure A may also be connected by way of a continuous conductive path, such as lead wires 12*a* to copper grounding bars D2 which are sunk into a second electrolyte B1, such as soil. It is to be noted that concrete itself constitutes an electrolyte. An electrically resistive or insulative diaphragm E is positioned in the corroding electrolyte B or secured to the surface of the substrate basin C such that an insulative layer is interposed in the electrolytic corrosion current path between the metal structure A and the foreign metal structures D1 or D2. The diaphragm E may be any organic coating, such as vinyl, epoxy, chlorinated rubber, asphalt or coal for enamel, or a non-conductive rubber or plastic sheet, such as polyethylene. The position of the insulative diaphragm in relation to the metal structure A is determined by the operational requirements of the equipment to which it is applied. However, sufficient space must be provided between the metal structure A and the diaphragm E to install a cathodic protection anode current source F. The overall resistance across the diaphragm E between the electrolyte B to structure D1 or between electrolyte B1 and electrode D2 should preferably exceed 10 ohms per 1000 square feet of diaphragm area.

The anode F may be of the galvanic or sacrificial anode type in which its material may be inherently more anodic or active than the metal structure A and/or the second metal member D1 or D2. The anode F may be fabricated of magnesium, aluminum, zinc or cadmium, for example, and is coupled to the structure A by way of leads 12 and 14.

The anode F may also be of the impressed current type, for example, one in which A.C. power is converted to direct current by way of rectifiers, the current then being applied to the system from non-sacrificial anodes, such as high silicon cast iron, platinum, platinum coated titanium, columbium or tantalum substrates, and graphite, or sacrificial anodes, such as iron and aluminum. Furthermore, the impressed current systems may be automatically regulated to maintain a preselected potential on structure A or maintain a constant current flow.

The structure A may be coated with a protective paint 16 or be uncoated, the area 20 being designated to indicate where a flaw has occurred or where a corrosion pit has developed.

Application of Kirchhoffs laws demonstrates the reduction in corrosion current flow and the more efficient use of the cathodic protection current obtained by use of the resistive diaphragm E.

In the absence of cathodic protection, the corrosion current flow is:

(4)
$$i_L=\frac{E_a-E_c}{R_a+R_b+R_c}$$

where $R_b$=diaphragm resistance.

When cathodic protection current ($I_p$) is applied from anode F in the corroding electrolyte B, the current is divided into components to the metal structure A and the metal structures D1 or D2, in accordance with the Law of Shunts.

(5)
$$I_p=i_c-i_a$$

and

(6)
$$i_a=\frac{E_a-E_c}{R_a+R_b+R_c}-\frac{R_b+R_c}{R_a+R_b+R_c}\,I_p=i_L-\frac{R_b+R_c}{R_a+R_b+R_c}\,I_p$$

or

(7)
$$i_c=\frac{E_a-E_c}{R_a+R_b+R_c}+\frac{R_a}{R_a+R_b+R_c}\,I_p=i_L+\frac{R_a+R_b+R_c}{R_a}\,I_p$$

Study of Equations 6 and 7 show that the portion of protective current ($I_p$) flowing to the structure A opposing the current flow $i_a$ is increased by the resistance ($R_b$) of the diaphragm E. In the corrosion system shown, corrosion ceases on structure A when $i_a=0$.

The reduction in corrosion current ($i_L$) and the protective current ($I_p$) required to control the corrosion current can approach 100-fold, depending upon the corrosion system dealt with.

The following examples illustrate the application of the invention:

EXAMPLE 1

The adaption of the invention to water, sewage or industrial waste clarification equipment is illustrated in FIG. 2. The metallic structure A, structural steel inverted cone 22, ordinarily coated with paint 24, is immersed within the corrosive electrolyte B within reinforced concrete basin C.

The submerged structural members 22 are generally found in metallic contact with the second structure D1 via reinforcing steel 26 in concrete 28 at anchor bolts 30 and/or in contact with inlet pipe 32, outlet pipe 34 or sludge drain 36. The submerged structural members 22 are also metallically coupled to the power system copper grounding D2 through the mixing propeller shaft 38 and the electric drive motor 40 and through the metallic piping 32, 34 and 36. The copper grounding is in soil electrolyte B1.

The method of the invention is accomplished by lining the surface 28 of the concrete basin C in contact with electrolyte B with a diaphragm E consisting of 3/32" thick asphaltmastic 42. Cathodic protection current is applied from high silicon cast iron anodes F1, immersed and appropriately positioned within the electrolyte B contained in the concrete basin 28. A.C. power is converted to direct current by a selenium rectifier 44 and applied to the anodes F1 through insulated lead wires 14. The current ($I_p$) is returned from the structural members through lead wire 12 to the negative terminal of rectifier 44.

A specific example of the application of this invention was to a steel chain belt and rake blade assembly within a rectangular, reinforce concrete settling basin (18' x 60' and 10' deep). A 20-ampere, 40-volt output capacity rectifier was used to apply protective current from 58—1" diameter by 9" long high silicon cast iron anodes arranged within the settling basin to distribute the protective current to the submerged chain belt and rake blades. The concrete basin had been coated with an asphaltmastic diaphragm. It was found that protective potentials were obtained on the submerged steel members with only 2.5 amperes of applied current. The 20-ampere capacity rectifier cathodic protection system was designed for an unlined concrete basin; thus, protection of the steel structural members was attained with about 12.5% of the current ordinarily required for an unlined, reinforced concrete basin.

EXAMPLE 2

An example of the application of this invention for an underground residential transformer tank is shown in FIG. 3. The corrosion ordinarily experienced previously resulted in accelerated attack at coating flaws on the metal structure A constituting a steel transformer tank **50** which contacted the electrolyte B, such as corrosive soil or water, accumulating within the concrete vault **52**. A bare copper neutral wire **54** or a copper grounding rod D2 sunk into electrolyte soil B1, is metallically coupled to transformer tank A, through pipes **55** and acts to accelerate attack at flaws **56** in the coating **51**.

A resistive lining **58** (diaphragm E) within the concrete vault C impedes the flow of corrosion current in the dissimilar metal system. Galvanic anodes F, such as zinc, coupled to the tank **50** through lead wire **60** are immersed in the corrosive electrolyte B within the lining **58** provide most efficient cathodic protection.

Another variation of the instant invention is illustrated by the direct burial of a fuel storage tank or underground residential transformer tank, as shown in FIGS. 4 and 5. The construction procedure is as follows: The tank **50** is connected to the electrolyte B1 by way of external piping **55** and pump **59** which are themselves coupled to ground by way of sunken rods D1 and/or copper leads **54** running to electric motor **59**.

The excavation, within which the coated tank A is to be buried, is lined with a diaphragm E, such as .020" thick polyethylene sheet **58** to separate the external soil B1 from the soil backfill B surrounding the tank **50**. The sheet joints should be sealed to minimize openings for electrical leakage.

The tank **50** should be buried in sand backfill B with a minimum of 1 foot space between the tank **50** and the resistive diaphragm E to allow the distribution of protective current to the coating flaws **56** on the tank by way of galvanic anodes F buried in the same B and coupled to the tank A by lead wire **60**.

An advantage to the invention is that metallic isolation of the tank A from the grounding system D1 is not required to minimize corrosion activity or lessen the cathodic protection requirements. It is to be observed that the embodiments set forth in Example 2 are applicable to buried pipelines.

EXAMPLE 3

A still further variation of the present invention includes means for drainage of accumulated water, corroding electrolyte B from a cathodically protected (URD) underground residential transformer vault C, as shown in FIG. 6. It is important to minimize the electrolytic conductive path through any aperture in the resistive diaphragm E that must be provided for corrosive electrolyte B drainage.

Large capacity (URD) transformers (10 kva. capacity, or greater) release considerable heat. In order to prevent excessive temperatures to develop, a vault cover **60** with openings **62** are required for ventilation. Rainwater entering through openings **62** will accumulate and fill vault C unless removed.

In this embodiment of the invention, the accumulated water B in vault C is drained into well **64** through a flexible rubber or plastic tube **66**. Tube **66** consists of a round upper section sealed onto the resistive diaphragm E about an opening therein and a lower section molded so that the tube surfaces normally contact each other along plane **68**. An accumulation of water B to the level of for example 6" of water head is sufficient to force the surfaces **68** of contacting tube **66** apart, allowing the corrosive electrolyte B to drain into well **64** and crushed rock **70** contained therein. When the water level drops below



the prescribed level the tube surfaces **68** along the plane of contact close against each other thereby sealing the electrolytic conductance path between corrosive electrolyte B and external electrolyte B1.

Tube **66** functions as a check valve when the ground water level rises above the lower tip of tube **66** or exceeds the level of the corrosive electrolyte B in vault C thereby preventing entry of ground water. At the same time, the available drainage aperture is sealed against electrolytic current flow.

Although this invention has been described in considerable detail, such description is intended as being illustrative rather than limiting since the invention may be variously embodied, and the scope of the invention is to be determined as claimed.

What is claimed is:

**1.** A method for cathodically protecting a metal structure immersed at least partially in a corroding electrolyte and being connected with a second metal member contained within an electrolyte by a continuous conductive path comprising the steps of:

interposing an electrically insulative substantially impermeable diaphragm in the corroding electrolyte in spaced-apart disposition between the metal structure and the second metal member and in a manner adapted to separate said metal structure from said metal member, and

applying cathodic protection current to the metal structure by way of at least one anode disposed within the corroding electrolyte in spaced-apart disposition between the metal structure and the electrically insulative diaphragm.

**2.** The method of claim **1** wherein said metal structure and corroding electrolyte is confined within a discrete vessel.

**3.** The method of claim **1** wherein said metal structure is coated.

**4.** The method of claim **1** wherein said metal structure is bare.

**5.** The method of claim **1** wherein the anode is sacrificial.

**6.** The method of claim **1** wherein rectified D.C. current is applied to said anode.

**7.** The method of claim **1** wherein the metal structure and the second metal member are like metals.

**8.** The method of claim **1** wherein the metal structure is cathodic with respect to the second metal member prior to application of cathodic protection current.

**9.** The method of claim **1** wherein the metal structure is anodic with respect to the second metal member prior to the application of cathodic protection current.

**10.** The method of claim **1** wherein accumulated water within the electrically insulative diaphragm is drained through an electrically insulative flexible tube.


**References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 1,866,065 | 7/1932 | Stuart | 204—266 |
| 2,762,767 | 9/1956 | Mosher et al. | 204—196 |
| 2,890,157 | 6/1959 | Raetzsch | 204—196 |
| 2,941,935 | 6/1960 | Miller et al. | 204—197 |
| 3,475,304 | 10/1969 | Currey | 204—147 |
| 3,477,930 | 11/1969 | Crites | 204—196 |
| 3,563,878 | 2/1971 | Grotheer | 204—256 |
| 3,578,982 | 5/1971 | Nelson | 204—196 |



TA-HSUNG TUNG, Primary Examiner

U.S. Cl. X.R.

204—148, 196, 197, DIG. 7