Sept. 12, 1972 L. P. SUDRABIN ET AL 3,691,040

ELECTRICAL SHIELD FOR CATHODIC PROTECTION SYSTEMS

Filed April 8, 1970 2 Sheets-Sheet 1

FIG. 1

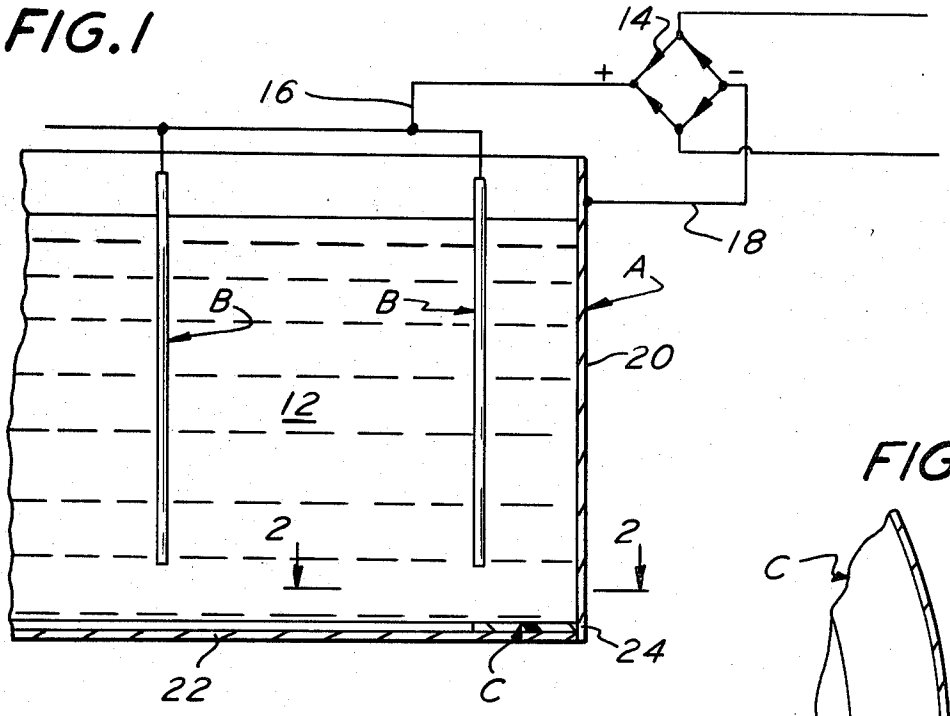
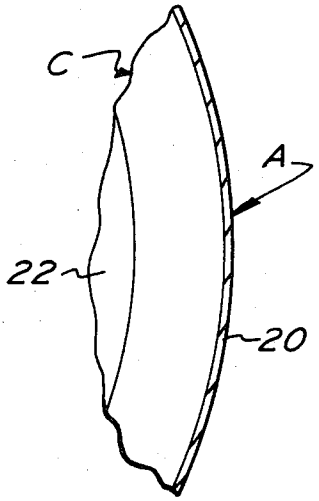


FIG. 2



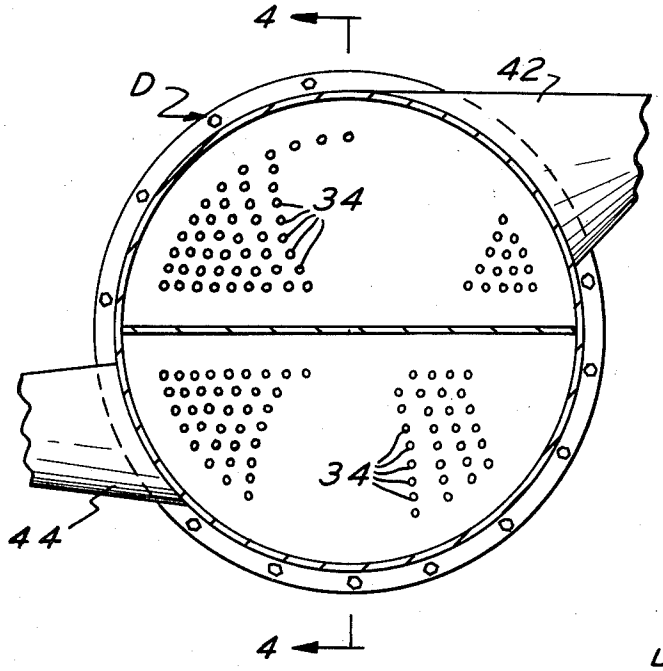


FIG. 3

INVENTORS
LEON P. SUDRABIN
HARRY NEUGOLD, JR.
BY Stanley Bilker
ATTORNEY

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ELECTRICAL SHIELD FOR CATHODIC PROTECTION SYSTEMS

Filed April 8, 1970 2 Sheets-Sheet 2

FIG. 4

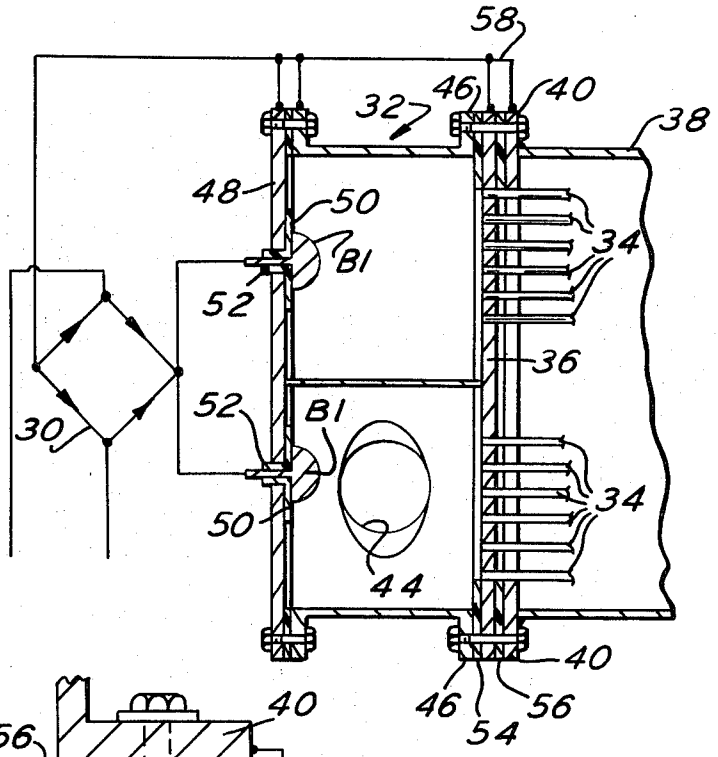
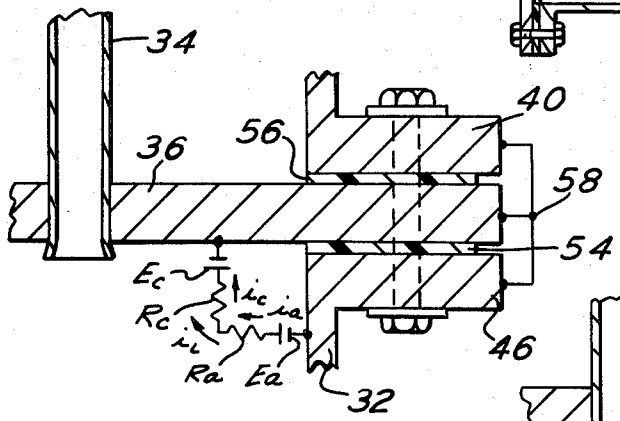


FIG. 5



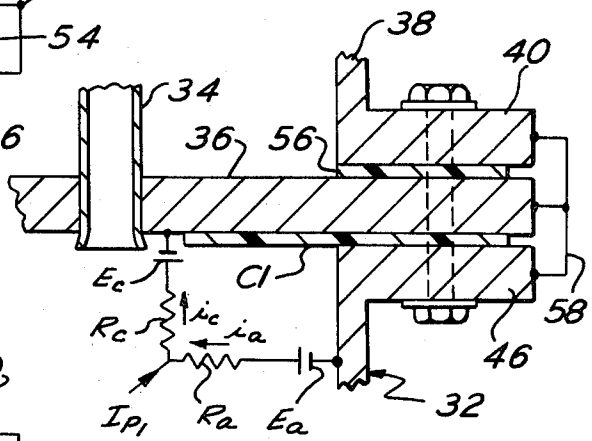


FIG. 6

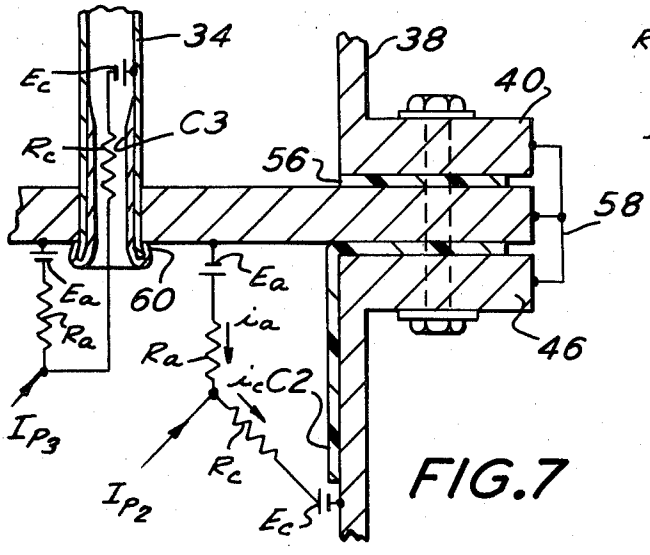


FIG. 7

INVENTORS
LEON P. SUDRABIN
HARRY NEUGOLD, JR.
BY Stanley Bilker
ATTORNEY

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ELECTRICAL SHIELD FOR CATHODIC PROTECTION SYSTEMS

Leon P. Sudrabin, Berkeley Heights, and Harry Neugold, Jr., Livingston, N.J., assignors to Pennwalt Corporation, Philadelphia, Pa.

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Int. Cl. C23f 13/00
U.S. Cl. 204—147 10 Claims

ABSTRACT OF THE DISCLOSURE

A cathodic protection system for improvement of cathodic protection current distribution at the junction of intersecting metallic structures which hold electrolyte. Electrically insulative shields are extended from at least one of the intersecting surfaces at the junction in spaced disposition from the anode. Where the intersecting surfaces are dissimilar metals, the electrical shield is applied to the surface of the less noble metal.

This invention relates to corrosion prevention systems and methods, and more particularly relates to cathodic protection of metal structures immersed in an electrolyte. It involves the use of an impressed D.C. current upon the metal from one or more anodes submerged in the electrolyte, such as water, in order to prevent or reduce corrosion of the metal surfaces. In accordance with the present invention, the submerged anodes are spaced from the surfaces of such vessels as water storage tanks and reservoirs, heat exchanger or condenser cooling boxes, and similar structures confining electrolytes, the essence of this invention being the promotion of efficient distribution of the protective current over the surfaces of the vessels.

It is well known in the art to protect the interior of metal tanks and the like from galvanic corrosion by making the structure electrically cathodic to the surrounding medium by causing current to flow from one or more submerged anodes to the structure. Corrosion is inhibited providing the current density on every point of the metallic tank structure exceeds a minimum require to polarize the metal surface to the protective potential which depends upon the metal or metals, the liquid medium, and the configuration of the vessel. For example, it has been found that considerably more protective current must be applied to the upper parts of a cylindrical wall than is actually required in order to obtain the minimum polarization potential for protecting the metal at or adjacent the junction of the plane and cylindrical sections. Dissimilar metals of water box and tube sheets in heat exchangers accentuate the corrosion attack on the less noble metal at the junctions of the dissimilar metals. Therefore considerably more protective current must be applied to other water box surfaces to achieve minimum polarization potentials of the less noble metal at the junctions.

Cathodic protection is optimum when a current is superimposed upon the corrosion system with the correct polarity and value to provide a net zero of current at the locally anodic corroding areas, the effect being as though the current projected to the particular area exactly opposes the local corrosion current tending to flow down such area. Prior practices to distribute more effectively the protective current into the zone of the metal surfaces include either positioning the anodes such that they are immediately adjacent the junction of the surfaces or coating the entire surfaces of the vessel in contact with the electrolyte. However, such prior practice has been impractical because of the paucity of reliable anode materials, difficulty in mechanical constructions, and the extremely high

cost of electrical insulation for such impressed current systems. The use of insulating sheets between the anode and cathode structures merely eliminates high current density on the adjacent cathode but does not influence the distribution of current at the intersection of the cathode surfaces. The other alternative of coating the entire electrolyte contact surfaces also has inherent disadvantages in that suitable coatings are costly and require continuing maintenance. Coating and recoating the entire submerged surfaces necessitates appreciable down time. Finally such complete coating may interfere with the heat transfer characteristics of heat exchangers.

It is therefore an object of this invention to provide a cathodic protection system with a selected anode arrangement, either impressed or galvanic type, which will achieve minimum protective potential at the intersection of metallic surfaces with minimal total protective current.

Another object of this invention is to provide an impressed current or galvanic-anode cathodic current protection system which employs an electrically resistant barrier applied to a portion of one of the two intersecting surfaces.

Yet another object of this invention is to provide a cathodic protection system in which corrosion intensity on the less noble metal at the junction of two intersecting surfaces will be minimized in the event of interruption of protective current.

Still another object of this invention is to provide a cathodic protection system utilizing an electrically resistant barrier which does into interfere significantly with heat transfer.

Yet still another object of this invention is to provide a cathodic protection system in which minimum coating is required.

A further object of this invention is to provide a cathodic protection system requiring lower protective current and hence decreases the deposition of calcareous salts so likely to cause blockage at the entrance of heat transfer tubes.

Other objects of this invention are to provide an improved device and method of the character described that is easily and economically produced, which is 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 a perspective view and partly broken away of a cathodic protection system embodying this invention as applied to a water tank.

FIG. 2 is a sectional view taken along lines 2—2 of FIG. 1.

FIG. 3 is an end sectional view of a heat exchanger having a conventional cathodic protection system.

FIG. 4 is a sectional view taken along lines 4—4 of FIG. 3.

FIG. 5 is an enlarged sectional view of the heat exchanger illustrating the electrical equivalent circuit of corrosion for a tube sheet mounted in a conventional manner.

FIG. 6 is an enlarged sectional view similar to FIG. 5 but with the barrier insulation extended over a portion of the tube sheet in accordance with the present invention and illustrating the electrical equivalent corrosion circuit.

FIG. 7 is an enlarged sectional view similar to FIGS. 5 and 6 but with the barrier insulative shield extended over a portion of the interior of the water box and over a portion of the tube interior.

In any corrosion system, the equivalent electrical circuit of corroding cell may be expressed by Kirchoff's law, as follows:

(1) $$-E_a+E_c+i_LR_a+i_LR_c=0$$

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

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

when no external current is applied to the system

(2) $$i_L=i_a=i_c$$

where

i_a=anode current
i_c=cathode current

However, when cathodic protection current I_p, is applied, I_p divides into components independent of E_a and E_c: Applying law of Shunts

(3) $$i_a=\frac{E_a-E_c}{R_a+R_c}-\frac{R_cI_p}{R_a+R_c}$$

when corrosion current ceases ($i_a=0$).

Therefore,

(4) $$I_p=\frac{E_a-E_c}{R_c}$$

Accordingly, the amount of protective curent I_p, required to limit the anode corrosion current i_a to zero, is diminished by increasing the cathode resistance R_c.

Referring now in greater detail to the drawings in which similar reference characters refer to similar parts, there is shown a metal tank or reservoir, generally designated as A, which contains a body of electrolyte **12**, such as drinking water, and a plurality of anodes B oriented in appropriate spaced disposition with each other and with the tank.

A conventional impressed current rectifier **14** in the form of a full wave bridge, for example, converts power from an A.C. supply source to apply D.C. voltage by way of external leads **16** to the anodes B. Current flow through the water from the anodes B is directed upon the surfaces of the steel tank A to constitute a cathodic protection system in which the positive terminal of the rectifier is coupled to the anodes while the negative terminal through lead **18** is connected to the tank.

As illustrated, the tank A is of cylindrical configuration which includes a cylindrical side wall **20** and a flat bottom **22** welded in sealed disposition with respect to each other. The anodes B are vertically suspended and positioned with respect to each other in accordance with the principles set forth in U.S. Pat. No. 3,425,921.

However, in accordance with the present invention an electrically insulating barrier or shield C extends from the intersection **24** of the cylindrical-flat wall in annular disposition over a portion of the bottom **22**. The barrier C must be resistant to the electrolyte **12** and demonstrate good adhesion to the metal surface. Vinyl or epoxy coatings applied to the steel bottom **22** or polyvinyl chloride, polyethylene, micarta and/or neoprene rubber sheets adhered to the bottom have all been found to be suitable barriers. It has been determined that the annular shield C which proceeds annularly inward along the bottom **22** from the cylindrical wall **20** markedly increases the cathodic protective effect at the lower surfaces of the cylindrical wall **20** adjacent the junction **24**.

The electrically insulative annular shield C becomes more effective in directing the protective current to the lowermost areas of the cylindrical wall as the annular distance of the barrier increases. For example, an annular barrier C which extends a distance from the intersection **24** one-half the distance to the nearest vertically suspended anode B increases the protective effect at the intersection **24** more than five fold.

The following are examples of laboratory test procedures on cathodic protection utilizing the electrical insulative barrier of this invention:

EXAMPLE 1

A plastic tank 12 inches long by 4 inches wide by 7 inches high was filled to a depth of 6½ inches with Belleville, N.J. tap water whose resistivity was 12,000 ohm centimeters. A single anode of 0.1 diameter platinized titanium wire was suspended in the tank of water such that the lower end of the anode was 2 inches from the tank bottom and the axis of the wire was spaced 3 inches from the end wall. A steel plate 4 inches by 8 inches long and ⅛ inch thick was coupled against the interior of the 4 by 7 inch end wall so that the lower end of the plate extends toward the bottom. A second steel plate 4 inches wide by 8 inches long by ⅛ inch thick was laid on the tank bottom so that one end of the plate could be adjustably positioned from the end wall plate of the tank. The two plates were electrically tied together. The spacing between the floor plate and the tank end wall represented the width of the electrically insulative barrier or shield. An I_p current of approximately 6 milliamperes was impressed by connecting a D.C. voltage across the anode and the steel plates, the applied voltage being approximately 3 to 4 volts from a voltage regulated rectified source. A calomel reference electrode with a capillary tip was positioned exactly 0.5 centimeter from the side wall of the vertical plate immediately adjacent the lower end thereof. The potential of the end wall plate to the reference electrode was measured first with no I_p applied and again with I_p momentarily applied. The difference in potential represents the IR drop through the 0.5 cm. of electrolyte between the end wall plate and the reference electrode capillary resulting from the application of I_p. The IR drop measurements were repeated with the reference electrode positioned at heights of 0, 1, 2, 3, 4, 5 and 6 inches. This sries of tests were conducted with the bottom plate abutting the end wall plate and again with the bottom plate placed 1, 2, and 3 inches away from the end wall plate. The table below sets forth the IR drops in millivolts at the various levels using various electrical shield widths: The IR drops vary in direct proportion to the current density reaching the end wall plate surfaces closest to the reference electrode position.

	Millivolts			
Electrical barrier width, inches	0	1	2	3
Vertical level, inches:				
0	4	25	36	50
1	62	62	85	80
2	125	125	152	136
3	164	190	180	150
4	250	225	205	150
5	260	272	210	200
6	262	286	200	205

As is evident from the foregoing data, the current distribution upon the lower end of the sidewall at a 1 inch insulative barrier (25 mv.) is approximately six times greater than a metal interface at the junction (4 mv.). With a 2 inch electrically insulative barrier the voltage drop of 36 mv. is nine times greater than a metal-to-metal junction and with a 3 inch shield approximately twelve times as efficient.

EXAMPLE 2

Utilizing the same test procedures as in Example 1, the test was repeated with the axis of the wire anode again spaced 3 inches from the vertical metal plate side wall, but with the lower end of the anode spaced one inch from the floor plate of the tank.

The millivolt drops as a measure of the barrier action and at the various levels in the tank were as follows:

	Millivolts			
Electrical barrier width, inches	0	1	2	3
Vertical level, inches:				
0	3	22	54	58
1	40	48	80	100
2	60	58	120	154
3	90	70	150	166
4	130	115	185	185
5	190	150	230	232
6	200	205	218	238

Again, it is apparent that at the junction the current distribution using a one inch barrier (22 mv.) improved seven times over the cathodic system with no barrier at all. Using a two inch barrier, the I_p distribution was 18 times as efficient than with no barrier and almost twenty times superior with a three inch barrier.

Referring now to FIGS. 3 and 4, there is shown a heat exchanger, generally designated as D, in which anodes B1 are employed to apply cathodic protection in a conventional manner. A rectifier 30 is used to apply current from the anodes B1 to the surfaces of steel water box 32 as well as to the surfaces of the heat exchanger elements. The heat exchanger is generally conventional and includes a plurality of tubes 34 which are mounted upon a bronze tube sheet 36 and enclosed within cylindrical shell 38 having heat transfer medium circulating therein. The shell 38 is welded to a flange 40. The water box 32 includes an inlet volute 42 and an outlet volute 44. The water box shell 32 is welded to a flange 46. End plate 48 is bolted to the water box 32, the anodes B1 being electrically insulated from the plate 48 by means of gasket sheet 50 and grommets 52. The water box flange 46 is bolted to the tank flange 40 with the bronze tube sheet 36 therebetween and insulated therefrom by gaskets 54 and 56, used to seal the flange faces. A strap 58 electrically ties the water box 32, the tube sheet 36 and the tank together, the water box 32 and the tube sheet 36 being in contact with a common electrolyte.

In FIG. 5, the sealing gasket is shown extending just to the internal edge of the water box 32 such that the junction of the steel water box with the more noble bronze tube sheet 36 provides a short path through the electrolyte for the corrosion current i_L to flow. As a result of such direct exposure the electrolytic cathode resistance R_C is necessarily minimal.

In FIG. 6, an electrically resistant barrier or shield C1 has been incorporated upon the surface of the bronze tube sheet 36 so that the shortest possible corrosion current flow line i_L from the water box 32 to the tube sheet 36 has been lengthened. As taught by Equation 4, the lengthened electrolytic path increases the cathode resistance R_C and reduces the amount of protective current I_{p1}, required to reduce i_a to zero.

In FIG. 7, an aluminum tube sheet 36*a* is tied to the more noble steel water box 32 by metal strap 58. In this case, the electrically resistive barier C2 extends over the surface of the more noble water box 32. Again, by extending the length of the shortest possible corrosion current line, there is a concomitant decrease in the amount of protective current I_{p2} needed to limit the anode current i_a to zero.

As might be evident from the use of an aluminum tube sheet with stainless steel tubes 34*a*, extensive corrosion attack ordinarily occurs in the aluminum sheet adjacent the junctions with the tubes. Non-conductive ferrules C3 are set into the inlet and outlet ends of the stainless steel tubes 34*a* in order to diminish the local action current i_L and the protective current I_{p3} required to stop anode current flow. The ferrule C3 should extend at least three diameters into the stainless steel tubes 34*a* and include a rolled over end portion 60 which completely covers the outside of each stainless steel tube to its intersection with the aluminum tube sheet 36*a*. Resistive and adherent coatings applied over the inlet and outlet tube ends extending at least 3 tube diameters may be used as an alternative to the ferrules.

As is apparent from the foregoing description, the instant invention relies upon the use of an extended surface electrically insulative barrier or shield which is disposed at the junction of intersecting plane surfaces in a system already incorporating cathode protection current. The insulating shields are spaced from the anodes themselves in order to improve the current distribution over the structure being protected. Where the junctions are comprised of dissimilar metals, the electrically insulative barrier is extended over the surface of the more noble metal.

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 cathodic protection system for metallic structures having intersecting metal surfaces immersed in an electrolyte comprising: at least one anode immersed in the electrolyte in spaced disposition from the junction of the metallic surfaces, conducting means for electrically connecting said structures together so that a continuous electrical path extends from one surface to the other, means for applying a D.C. voltage across each said anode and the metal surfaces, and an electrically insulative shield on just one of the surfaces and extending only partially thereon from the said junction to a poistion in spaced relationship with respect to each of said anodes whereby protective current distribution at intersections is improved with minimal use of insulative coatings.

2. The cathodic protection system of claim 1 wherein said intersecting surfaces constitute dissimilar metals and said electrically insulative shield is on the surface of the the more noble metal.

3. The invention of claim 2 wherein said metallic structures comprise respective walls of a water box, tube sheet and tubes in a heat exchanger, said tube sheet forming a first intersecting junction with said water box and said tubes forming a second set of intersecting junctions with said tube sheet.

4. The invention of claim 3 wherein insulative ferrules are incorporated within the tubes and cover the ends thereof to a position immediately adjacent the peripheral intersection thereof with the tube sheet.

5. The cathodic protection system of claim 1 wherein the electrically insulative shield comprises a coating.

6. The invention of claim 1 wherein said intersecting surfaces constitute side walls of a water tank, the electrolyte being water.

7. A method for the cathodic protection of metallic structures having intersecting surfaces immersed in an electrolyte comprising the steps of applying an electrically insulative coating to just one of the surfaces and only partly thereon from the junction of the intersecting surfaces to a position extending away from the junction, suspending electrodes in the electrolyte in spaced disposition from the electrically insulative coating, and imposing a D.C. voltage across said electrodes and the metal surfaces while electrically connecting the metallic structures so that there is a continuous conductive path extending from one surface to the other.

8. The method of claim 7 wherein the intersecting surfaces constitute dissimilar metals, and the electrically insulative coating is applied to the more noble metal.

9. The method of claim 7 wherein the metal structures comprise a series of tubes mounted within tube sheets of a heat exchanger and wherein the coating is applied to the terminus of the tubes from the intersection with the tube sheets to a distance within the tubes substantially three times the diameter thereof.

10. The method of claim 7 wherein the coating is applied as an annulus adjacent the intersection.

References Cited

UNITED STATES PATENTS

629,092	7/1899	Ross	204—197
901,809	10/1908	Harris et al.	204—197
2,329,961	9/1943	Walker	204—196
2,698,291	12/1954	Andrus	204—196
2,752,308	6/1956	Andrus	204—197
2,941,935	6/1960	Miller et al.	204—196
3,037,925	6/1962	Boncher et al.	204—196
3,477,930	11/1969	Crites	204—147
3,515,654	6/1970	Bordalen et al.	204—196

TA-HSUNG TUNG, Primary Examiner

U.S. Cl. X.R.

204—196