

Dec. 12, 1961

L. F. VIXLER

3,012,958

VITREOUS LINED WATER TANKS WITH SACRIFICIAL ANODES

Filed April 17, 1958

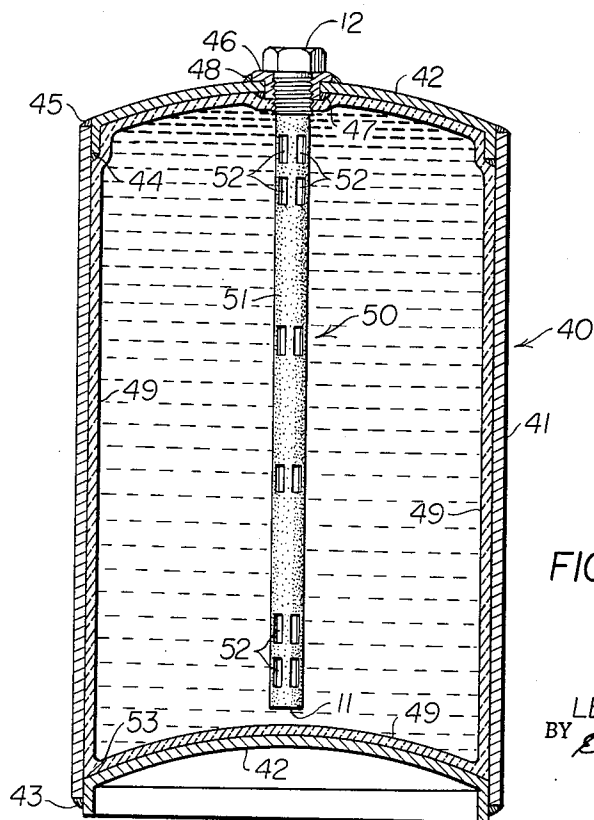
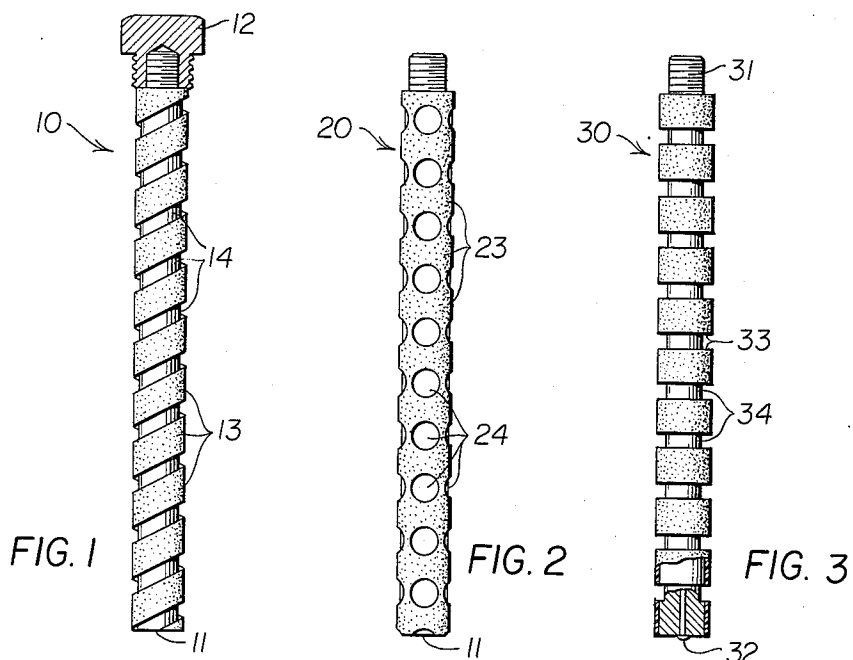


FIG. 4

INVENTOR.

LESLIE F VIXLER
BY *Ely, Kearns & Gordon*
ATTORNEYS

1

3,012,958

VITREOUS LINED WATER TANKS WITH SACRIFICIAL ANODES

Leslie F. Vixler, Rocky River, Ohio, assignor to The
Patrol Valve Co., Cleveland, Ohio, a corporation of Ohio

Filed Apr. 17, 1958, Ser. No. 729,159
12 Claims. (Cl. 204-197)

This invention relates to hot water heater and storage tanks in which a so-called "sacrificial anode" is employed to protect the interior surfaces of the tank from corrosion, and particularly to such tank-anode assemblies in which the tank has an interior vitreous lining substantially covering the interior metal surface of the tank.

The objects of the invention are to improve the life and current efficiency of sacrificial anodes for hot water heater and storage tanks having vitreous interior linings; to thereby prolong the life of such tanks; and to provide sacrificial anodes for vitreous lined tanks which provide an improved distribution of the galvanic current so as to better protect the areas of the tank which are most vulnerable to corrosion.

The objects of the invention, how they are achieved, and the problems for which the invention provides ready solutions will be more fully understood by first considering the mode of operation of sacrificial anodes, as heretofore understood in the art, and by explaining the discovery of certain unexpected phenomena on which the invention is based.

"Galvanic corrosion" is the term used to designate the corrosion that occurs when an electrically conductive material is in electrical contact with a different electrically conductive material in a corrosive environment, e.g., when the two materials are immersed in an electrolyte, such as water containing dissolved salts to enhance its conductivity. An electric current will flow through a closed circuit from the more "cathodic" or less "anodic" of the two materials to the other and then through the water back to the more cathodic material. The electrical energy is created by electrolytic action at the expense of the more anodic material, which is slowly consumed thereby. Thus, when a magnesium anode is placed in a steel water heater storage tank and is electrically connected thereto by a solid connection, a current will flow from the tank through its solid electrical connection with the anode and from the anode through the water back to the tank. As a result, the magnesium anode is slowly consumed in the process of generation of this current, but the tank is protected thereby from being itself consumed by electrolytic corrosion.

When a metal body is simply immersed in water and is not otherwise electrically connected to another conductor in contact with the water, a similar kind of electrolytic corrosion of the metal body occurs due to variations in the composition of the immersed metal body. Two portions of the metal body of slightly different composition are in solid electrical contact and are also connected through the water. The electrical energy so generated is created at the expense of the more anodic of the two portions of the metal body. Thus, corrosion of the metal body also occurs in this manner. Such corrosion is termed "local cell corrosion" and varies in amount with the purity and uniformity of composition of the metal body. The greater the purity and uniformity of composition, the lesser is the amount of local cell corrosion.

Along with local cell corrosion, any metal body immersed in water is subject to chemical corrosion to some degree which varies with the particular metal. This kind of corrosion is negligible for the more inert metals, but is most pronounced for the more chemically active metals.

2

Like local cell corrosion, chemical corrosion consumes the metal independently of any electrical contact with another metal body.

Both local cell corrosion and chemical corrosion may be classed as "normal corrosion." Normal corrosion of a sacrificial anode serves no protective function for a water tank in which it is mounted, since it involves no flow of electrical current between the anode and the tank. The term "galvanic corrosion," as applied to the corrosion of a sacrificial anode, is commonly used to refer only to the protective or useful type of electrolytic anode corrosion first described above, although, strictly considered, local cell corrosion could just as aptly be embraced by the same term.

From the above, it will be understood that the total corrosion (C_T) to which a sacrificial anode is subjected is equal to the galvanic corrosion (C_G), as the term is used in this art, plus the normal corrosion (C_N), the latter comprising both local cell and chemical corrosion. The relationship may be expressed thus—

$$C_T = C_G + C_N$$

Since only the galvanic corrosion is useful, the current efficiency (E_C) of a sacrificial anode, expressed in percent, may be calculated as follows:

$$E_C = \frac{C_G}{C_T} \times 100 = \frac{C_G}{C_G + C_N} \times 100$$

The normal current efficiency of the commercial magnesium metal used most widely as a sacrificial anode material is generally less than 50%, due largely to local cell corrosion of the anode.

Obviously, the more that local cell plus chemical corrosion (C_N) can be suppressed, the greater is the current efficiency of the anode. However, current efficiency is not the only consideration, for the galvanic current must be great enough to protect the tank and yet not so great as to consume the anode at an excessive rate. In the latter case, the current efficiency (E_C) of the anode may be close to 100% if C_N is low, but the protective efficiency of the anode may be poor if the galvanic current generated is greatly in excess of that which is necessary to protect the tank from local cell corrosion.

The foregoing considerations require that two additional factors be considered in the design of a sacrificial anode to give optimum protection for a prolonged period of time at a minimum anode cost. The first of these additional considerations involves the size and shape of the anode. The second involves the effect of sheathing the anode to permit only selected portions of its surface to be exposed to the water and subjected to corrosion. Although the sheathing of sacrificial anodes in the water heater and storage tank industry is not common, the sheathing of sacrificial anodes in other fields has been practiced and some technical data has been published on the effects thereof.

The anode current in any tank-anode assembly is concentrated in regions between anode and cathode areas where the resistance (length) of the water path is a minimum. Hence, the shape of the anode is preferably selected to provide a fairly uniform spacing between the anode and the tank wall, with regions of minimum spacing being in the vicinity of joints or welds in the tank wall where tank corrosion tends to be most pronounced. In large tanks, a plurality of anodes may be used for achieving this result while still providing the required current density per square foot of exposed interior tank surface to protect the tank. For ordinary galvanized steel water heater tanks, this current density is preferably in the range of about 1.0 to 2.0 milliamperes per square foot of interior tank surface to be protected. Since the size of the anode, i.e., total mass of metal available to

be consumed, is largely determinative of the effective life of the anode, its size must be sufficient so that it will have a reasonably long life and not require too frequent replacement. These related factors affecting anode life and efficiency have dictated that anodes for cylindrical tanks generally be elongated cylindrical rods somewhat shorter than the tank and be mounted in the tank to extend axially thereof. A single anode would, of course, extend along the axis of the tank, and if a plurality of anodes is used, they would be more or less uniformly distributed about the axis of the tank. In all cases, the diameter of the anode or anodes is selected to provide the desired mass of anode metal.

Depending upon the electrical conductivity of the water in the tank, a given anode-tank arrangement may provide a greater galvanic current than needed to give optimum tank protection. This results in an excessive and wasteful rate of anode corrosion, despite the fact, as pointed out above, that the anode current efficiency (E_c) may be reasonably good. When, for example, an anode of a magnesium alloy is used in a galvanized steel tank having no protective lining, it has long been known that the galvanic current induced will vary almost in direct proportion to the exposed surface area of the anode. To illustrate this by a specific case, where the galvanic current in a galvanized steel tank was 21 ma. using a magnesium alloy anode having 40 square inches of surface area, doubling the anode surface area produced a galvanic current of 36 ma., and further increases in anode area produced still further increases in galvanic current in about the same proportion. Thus, the galvanic current per unit area of anode surface remains fairly constant with changes in anode surface area, and the total galvanic current may be varied by increasing or decreasing the anode surface area.

Because of the above, in some industries where sacrificial anodes are used, it has been the practice to make an anode or plurality of anodes of sufficient size to give satisfactory anode life, but which will produce an excessively high galvanic current if the current is not otherwise controlled. The current is then reduced to the desired range by sheathing the anode so as to cover a substantial portion thereof and thereby reduce its effective exposed area. This reduces the normal corrosion and the galvanic corrosion in about the same proportion and has little effect on anode current efficiency. However, it does prolong the life of the anode while providing sufficient galvanic current for protection of the tank.

The sheath for a sacrificial anode may be made of a metal that is less anodic than the metal of the body of the anode, e.g., an aluminum sheath for a magnesium alloy anode; or the sheath may be a non-metallic plastic material or the like which is electrically non-conductive and, hence, may also be considered to be less anodic than the metal of the body of the anode, as explained further hereinafter. The sheath may be suitably bonded to the surface of the anode so as to preclude the entrance of water therebetween and leave portions of the body of the anode exposed for galvanic action. However, as a practical matter, the sheath need not be bonded to the body of the anode, and a closely fitting sleeve of the sheath material appears to function as well, even though a small clearance space exists between the sheath and the body of the anode in which a thin film of water may be formed on immersion of the anode.

Because the use of a sacrificial anode does not prevent chemical corrosion of the metal of the tank, it is not a "cure-all" for the corrosion problem. Therefore, in order to reduce chemical corrosion of steel tanks, as well as electrolytic corrosion, it has also been common practice to line the tanks with a vitreous protective coating, such as a conventional, glasslike, vitreous enamel. However, it has been virtually impossible to make perfect vitreous linings in the first instance, and additional lining imperfections commonly appear due to vibration, sud-

den shocks, non-uniform thermal expansion of the tank and its lining, etc. Cracks, abrasions, pinholes, and the like in the tank linings obviously expose the metal of the tank to the three types of corrosion explained above. Accordingly, even in vitreous lined tanks, sacrificial anodes have been used to prevent electrolytic corrosion of the metal of the tank where it is exposed.

When ordinary anodes are used in vitreous lined steel tanks, the galvanic current and galvanic corrosion of the anode are much smaller than when an anode is used in the same tank having no lining or having a galvanized interior surface (e.g., 2 ma. in a vitreous lined tank compared to 36 ma. in the same tank with a galvanized interior under otherwise identical conditions). Apparently because of the reduction in the galvanic current between the anode and the tank, normal corrosion of the anode is proportionately greater in a lined tank than in an unlined tank. As a result, the current efficiency of the anode is very low, probably around 10% or less in most cases. This means that the anode life is short, considering the small galvanic current produced. Nevertheless, sheathed anodes have not heretofore been used in vitreous lined tanks, to the best of my knowledge. Since sheathing of the anode in an unlined tank effects little change in its current efficiency, it has apparently been assumed that the same would be true in a lined tank and that the low galvanic current in a lined tank would only be further reduced by sheathing the anode, at the expense of tank protection and with little change in anode current efficiency.

Upon testing the effect of changes in anode surface area in a lined tank, I discovered that an increase in anode surface area produced no increase in the galvanic current, contrary to published data on anode behavior in unlined tanks. Accordingly, I then tested the effect of a reduction in anode surface area, produced by sheathing the anode to protect selected portions of the anode surface from exposure to the water in the tank. These latter tests revealed that reduction of the exposed anode area by as much as 95% caused no reduction in the galvanic current and, therefore, no loss of tank protection. Since this necessarily caused a twenty-fold increase in galvanic current density at the exposed surface of the anode and a 95% reduction in the surface area exposed to normal corrosion, the result was a tremendous increase in anode current efficiency and, therefore, a correspondingly great increase in anode life without the expected loss of tank protection. These results obtained by sheathing the anode in a tank having a vitreous lining were entirely different from the results obtained by sheathing the anode in an unlined tank and were wholly unexpected from published technical data.

In an unlined tank, the galvanic current is controlled by the exposed anode surface area, and the current is said to be under "anodic control." The present invention is based upon the discovery that, in a lined tank, the surface area of the anode, at least within practical limits of anode sizes, is not a significant factor. This suggests, as an explanation of my discovery that, in a lined tank having a relatively very small exposed metal cathode area, the current is under "cathodic control," i.e., is governed by changes in exposed metal cathode area, rather than changes in exposed anode area.

Since the exposed metal cathode area in a lined tank is very small as determined by the imperfections in the lining, and will vary only slightly as cracks, scratches, pinholes, and coating porosity may be increased with age, the exposed surface of an anode of practical dimensions may be varied greatly without affecting the total galvanic current or the amount of galvanic corrosion. By using an anode having a surface area many times the small exposed cathode surface area, and by shielding the anode until its exposed surface area approaches that of the cathode, the normal corrosion of the anode may be reduced so that it becomes a small factor in the rate of

5

anode consumption. Thus, the anode current efficiency can be raised to well above the normal 50% for unlined tanks, while also providing enough mass of anode metal in an anode of conventional dimensions to greatly increase the anode life. This increase in anode life may be of the order of 5 or 6 times or more, depending upon design details.

Based upon the discovery described above, the objects of the present invention are achieved by using a sheathed anode in a tank having a vitreous lining. The sheath may be made of a metallic or non-metallic material, or a combination thereof. When a metallic material constitutes all or a part of the sheath, it should be a metal or metal alloy that is more noble, i.e., less anodic than the metal of the body of the anode or cathodic with respect thereto, so that electrolytic or galvanic action will preferentially occur between the metal of the tank, on the one hand, and the metal of the body of the anode rather than the metal of the sheath, on the other hand.

When a non-metallic material constitutes all or a part of the sheath, the same comparative terminology is not so generally recognized as being applicable. However, using the expression "anodic" to indicate the property by which a material will give up electrons to an electrolyte in a voltaic cell, the degree to which a material may be anodic is as useful for classifying non-metallic as metallic materials for the purposes of the present invention. Non-metallic substances generally may be classified as being less anodic than metals when the expression "anodic" is used in that sense, and non-metallic materials in general may be used so long as they are substantially unreactive or insoluble in water and are capable of forming water-resistant coatings on the metal of the body of an anode. Examples of suitable non-metallic sheath materials are the many water-insoluble, highly inert plastics or synthetic resins such as the polystyrenes and other vinyl copolymers, epoxy resins, silicone resins, etc., including thermoplastic as well as thermosetting resins so long as they do not soften unduly in hot water. Certain resins, such as the phenolics and the urea resins, are objectionable because they impart an undesirable taste to water. Otherwise, they too are satisfactory.

The various suitable sheath materials may be applied by dipping, spraying, molding, wrapping, or otherwise encasing the anode, according to the nature of the sheath materials, so as to provide a protective sheath over those portions of the surface of the body of the anode which are to be protected from attack by chemical and galvanic action upon prolonged exposure to hot water. The purpose of an anode sheath is merely to limit the surface area over which corrosion can occur to the unsheathed area or areas. Accordingly, as regards the particular sheath materials and processes for applying them that are mentioned herein by way of illustration, the invention is not limited to such details. Any sheathing material that is sufficiently resistant to hot water temperatures and to chemical attack, and that may be bonded to or closely applied about the body of the anode may be applied by any suitable process, provided only that the sheathing material is less anodic than the metal of the body of the anode.

The body of the anode is most suitably a magnesium alloy consisting essentially of about 4% to 9% aluminum, about 1% to 3% zinc, with the total amount of aluminum and zinc not exceeding 10%, and the balance substantially all magnesium. The alloy should be substantially free from iron, nickel, and copper, which elements should be kept as low as possible. The alloy which I presently prefer consists essentially of about 6% aluminum, about 3% zinc, and the balance substantially all magnesium.

In order to illustrate several representative anode sheath patterns which may be employed in accordance with the invention, and also how the distribution of sheathed and unsheathed areas may be usefully varied to

6

improve the effectiveness of the anode for its intended purpose, as well as various other details of anode construction, several forms of sheathed anodes and an illustrative tank-anode assembly are shown in the accompanying drawing. In the drawing—

FIGURE 1 is an elevational view of a simple, generally cylindrical anode having a fitting (shown in vertical section) secured to its upper end for mounting the anode in a tank and having a sheath covering selected portions of the surface of the anode in one suitable pattern;

FIG. 2 is an elevational view of a similar anode having a sheath applied thereto in a different pattern;

FIG. 3 is an elevational view of a modified form of anode having a sheath applied thereto in still another different pattern, a portion of the anode being broken away to show its interior construction; and

FIG. 4 is a vertical sectional view of a water heater storage tank having a cylindrical anode mounted therein and a sheath applied to the anode in still another different pattern selected to provide maximum protection for the portions of the interior of the tank which are most vulnerable to corrosion (water inlet and outlet connections to the tank being omitted for simplicity).

In all figures of the drawing, surface stippling is used on certain anode areas to indicate more clearly that these are surfaces of a sheathing material and differ in composition from adjacent unstippled areas. As indicated above, the sheathing materials may be organic materials, such as plastics and synthetic or natural resins, or they may be inorganic, such as metals and ceramic or vitreous glazes, or they may be mixtures of such materials if desired. Where the thickness of the sheathing materials is shown, it is somewhat exaggerated for clarity.

Referring to FIG. 1, the anode 10 may consist of a cylindrical rod 11 of a metal, such as magnesium, that is anodic with respect to a metal such as steel, of which a tank may be constructed. A fitting 12, suitably made of brass, may be internally threaded to receive a threaded end portion of the rod 11 of reduced diameter. The fitting may also be externally threaded so that it may be screwed into a tapped opening in the top of a metal tank, the upper portion of the fitting being suitably shaped for turning with a wrench. A sheath material 13 is helically wound around the anode from adjacent the fitting 12 to the lower end of the anode, leaving a continuous, uncovered, helical area 14 between successive turns of the sheath material. Thus, on all sides of the anode, spaced areas of the surface of the rod 11 are exposed between intervening sheathed areas, the sheath protecting the sheathed areas of the rod from contact with water in the tank. This arrangement of sheathing on the anode is particularly suited for use where the sheathing material is a preformed tape of, for example, woven glass fibers impregnated and coated with a polyester resin. The tape may be bonded to the rod 11 with a thermosetting, water resistant adhesive, and the spacing of successive turns of the tape may be varied as desired to expose a selected percentage of the total area of the rod 11. Suitably, the exposed area 14 of the rod 11 may be as little as 5% of its total area.

Referring to FIG. 2, an anode 20 may comprise the same cylindrical rod 11 as in FIG. 1, but with a suitable plastic or metal coating 23 covering the rod except for spaced circular areas 24 distributed longitudinally and circumferentially over the rod. The sheath coating may be applied over the entire area of the rod 11 and the exposed areas 24 thereafter formed by cutting or scraping away the coating. Alternatively, the areas to remain exposed may first be temporarily masked with a loosely adherent material and the sheath coating then applied by dipping or spraying, followed by removal of the loosely adhering material to expose the areas 24. As still another alternative, the sheath may be a cylindrical tube of aluminum or the like with openings preformed therein to provide the uncovered surface areas 24 when the

anode body is inserted with a close friction fit into the cylindrical sheath.

In FIG. 3, a modified form of anode 30 is shown which comprises a rod 31 of suitable metal, such as magnesium, having a core wire 32 running axially therethrough from end to end thereof. The rod 31 may be shaped to provide axially spaced cylindrical portions 33 of large diameter connected by axially spaced cylindrical portions 34 of smaller diameter. In this instance the sheath material may be applied only to the cylindrical surfaces of the spaced portions 33 of large diameter, leaving the end areas of these portions of large diameter and the cylindrical surfaces of the portions 34 of small diameter uncoated and exposed. Any of the sheathing materials heretofore mentioned may be selectively applied to the cylindrical surfaces of the rod portions 33 of large diameter. In the case of liquid coating materials that are solidifiable to a solid condition, they may conveniently be rolled onto the surfaces to be coated and then set to their solid state. Alternatively, the coating or sheathing may be applied by wrapping a suitable sheet material around the portions to be sheathed and bonding the sheet material thereto with a water resistant adhesive.

The type of anode illustrated in FIG. 3 may be formed in one integral piece, as by casting, or it may consist of a series of alternate large and small diameter cylinders threaded over the core wire and secured thereto by suitable fastening means at each end of the core wire (not shown). The core wire 32 should be of a metal or other material of adequate strength for supporting the weight of the anode, and the material of the core wire should be cathodic to the surrounding cylindrical members which constitute the consumable anode material. The purpose of the core wire 32 is to support the lower portions of the surrounding body of the anode in the event that corrosion of intermediate portions 33 of small diameter should work its way completely through the consumable anode material. It may also be desirable to use such a core wire through the center of the other forms of anodes shown and described herein in order to prevent a lower portion of the anode from breaking off from the remainder if corrosion should be concentrated so as to cause necking down of an intermediate portion.

Referring now to FIG. 4, a water heater storage tank 40 may comprise a cylindrical steel shell 41 closed at its opposite ends by upwardly dished steel end walls 42. As shown, the end walls have flanged rims telescoped within the cylindrical shell 41 and circumferentially welded thereto as indicated at 43, 44, and 45. The upper dished end wall 42 may have a suitably internally threaded fitting 46 mounted in an aperture in the center thereof and welded thereto at 47 and 48 for receiving a fitting 12 (also illustrated in FIG. 1) for mounting an anode. In accordance with the invention, the completely fabricated tank is then lined with a layer 49 of a vitreous enamel or equivalent material.

An anode 50 may be mounted in the fitting 12 in the assembly of FIG. 4 in the same manner as shown in FIG. 1, the anode 50 again being a cylindrical metal rod 11 of magnesium or the like coated over most of its surface with a suitable sheath material 51. In this instance, unsheathed areas of the anode 50 are shown as generally rectangular areas 52 which are distributed non-uniformly over the surface of the metal rod 11. The exposed areas 52 are widely spaced over the surface of the central portion of the anode and more closely spaced adjacent both the upper and lower ends thereof. The purpose of this is to provide relatively short electrical paths through the water in the tank, from a greater concentration of exposed areas 52 to the interior welds 44 and 47 and to the unwelded internal joint 53 where lining imperfections are most likely to occur and where corrosion would normally tend to be concentrated. The short electrical paths to these vital regions of the interior surface of the tank provide a minimum of resistance to the flow of galvanic cur-

rent to these vital regions, and the greater concentration of exposed areas 52 of the rod 11 tend to concentrate the galvanic current at the vital regions of the tank surface and thereby provide more effective protection where it is most needed. In a similar manner, other exposed areas 52 may be concentrated close to any other vital interior surface areas of the tank, such as the points at which water inlet and outlet connections (not shown) may be made.

While the particular form of anode illustrated in FIG. 4 has the advantages pointed out above, the anodes of FIGS. 1, 2, and 3 are intended to be similarly mounted in a tank and may be substituted in the tank of FIG. 4 for the anode 50 shown therein.

From the foregoing explanation of the discovery on which the present invention is based and the manner of applying it in practice, and from the illustrative embodiments of the invention illustrated in the drawing, it will be apparent that I have provided a simple and effective way in which to prolong the life of anodes used in vitreous lined tanks without reducing their effectiveness for their intended purpose. It will also be apparent that, in prolonging the life of the anode, no additional anode metal is required, and the tank may be more fully protected for longer periods of time without the necessity for replacing anodes or danger from operating the tank after the anodes therein have been consumed to the point where they are no longer effective.

While the invention has been illustrated with reference to various specific materials and design details, it will be recognized by those skilled in the art that the invention is not limited to such details and that many equivalents thereof may be employed while utilizing the essential features and principles of the invention. Accordingly, the invention is intended to include all such equivalents.

Having described my invention, I claim:

1. A metal water storage tank, a vitreous lining for the tank, a metal anode mounted in the tank, the metal of the anode being anodic with respect to the metal of the tank, and an aluminum sheath covering a substantial portion of the surface of the anode and distributed thereover so as to leave uncovered surface areas, the metal of the anode being more anodic than the aluminum of the sheath.
2. A metal water storage tank, a vitreous lining for the tank, a metal anode mounted in the tank, the metal of the anode being anodic with respect to the metal of the tank, and an aluminum sheath covering a major portion of the surface of the anode and distributed thereover so as to leave uncovered surface areas thereof with intervening covered surface areas, the metal of the anode being more anodic than the aluminum of the sheath.
3. A metal water storage tank, a vitreous lining for the tank, a magnesium alloy anode mounted in the tank, the metal of the tank being cathodic with respect to the magnesium alloy, and an aluminum sheath for the anode, the sheath partially, but not entirely, covering the surface of the anode.
4. A metal water storage tank and sheathed anode assembly according to claim 3, in which said magnesium alloy is one consisting essentially of 4% to 9% aluminum, 1% to 4% zinc, and the balance substantially all magnesium, the total amount of aluminum and zinc not exceeding 10%, and said alloy being substantially free from iron, nickel, and copper.
5. A steel water storage tank, a vitreous lining for the tank, a magnesium alloy anode mounted in the tank, and an aluminum sheath for the anode, the sheath partially, but not entirely, covering the surface of the anode, said magnesium alloy consisting essentially of about 6% aluminum, about 3% zinc, and the balance substantially all magnesium and being substantially free from iron, nickel, and copper.
6. A metal water storage tank, a vitreous lining for the tank, a metal anode mounted in the tank, an aluminum

9

sheath for said anode, the sheath partially, but not entirely, covering the surface of the anode, the metal of the tank being principally iron and the metal of the anode being anodic with respect to the metal of the tank and more anodic than the aluminum of the sheath, a solid electrical connection between the metal of the anode and the metal of the tank, and water in the tank constituting an electrolyte between the anode and the vitreous lined metal tank walls.

7. A metal water storage tank, a vitreous lining for the tank, a metal anode mounted in the tank, and an aluminum sheath covering a substantial portion of the surface of the anode and distributed thereover so as to leave uncovered surface areas with intervening covered surface areas, the metal of the tank being principally iron and the metal of the anode being anodic with respect to the metal of the tank and more anodic than the aluminum of the sheath, the anode being in the form of an elongated bar having a core wire extending longitudinally therethrough and in electrical contact therewith substantially from end to end thereof, and said core wire being of a material that is less anodic than the surrounding body of the anode.

8. A metal water storage tank, a vitreous lining for the tank, a metal anode mounted on a wall of the tank and electrically connected thereto by a solid connection, and an aluminum sheath covering a major portion of the surface of the anode and distributed thereover so as to leave uncovered surface areas thereof with intervening covered surface areas, the metal of the tank being principally iron and the metal of the anode being anodic with respect to the metal of the tank and more anodic than the aluminum of the sheath.

9. A metal water storage tank, a vitreous lining for the tank, a metal anode mounted on a wall of the tank and electrically connected thereto by a solid connection, and an aluminum sheath covering a major portion of the surface of the anode and distributed thereover so as to leave uncovered surface areas thereof with intervening covered surface areas, the metal of the tank being principally iron and the metal of the anode being anodic with respect to the metal of the tank and more anodic than the aluminum of the sheath, the anode being in the form of an elongated bar having a core wire extending longitudinally therethrough and in electrical contact therewith substantially from end to end thereof, and said core wire being of a material that is less anodic than the surrounding body of the anode.

10. A metal water storage tank, a vitreous lining for

10

the tank, a metal anode mounted in the tank, the metal of the anode being anodic with respect to the metal of the tank, and a metal sheath covering a substantial portion of the surface of the anode and distributed thereover so as to leave uncovered surface areas with intervening covered surface areas, the metal of the anode being a magnesium alloy, the metal of the tank being principally iron, and the metal of the sheath being principally aluminum.

11. A metal water storage tank, a vitreous lining for the tank, a metal anode mounted on a wall of the tank and electrically connected thereto by a solid connection, the anode being of a metal that is anodic with respect to the tank, and a metal sheath covering a substantial portion of the surface of the anode and distributed thereover so as to leave uncovered surface areas and intervening covered surface areas, the metal of the anode being a magnesium alloy, the metal of the tank being principally iron, and the metal of the sheath being principally aluminum.

12. A metal water storage tank, a vitreous lining for the tank, a metal anode mounted on a wall of the tank and electrically connected thereto by a solid connection, and an aluminum sheath covering a major portion of the surface of the anode and distributed thereover so as to leave uncovered surface areas thereof and intervening covered surface areas, the metal of the tank being principally iron and the metal of the anode being anodic with respect to the metal of the tank and more anodic than the aluminum of the sheath and the uncovered areas being distributed in greater concentration over portions of the anode adjacent critical areas of the interior surface of the tank where corrosion of the tank metal would normally tend to be concentrated than over portions of the anode more remote from such critical areas of the interior surface of the tank.

References Cited in the file of this patent

UNITED STATES PATENTS

915,846	Friedham	Mar. 23, 1909
2,709,679	Andrus	May 31, 1955
2,721,172	Higgins	Oct. 18, 1955
2,752,308	Andrus	June 26, 1956
2,808,373	Andrus	Oct. 1, 1957
2,855,358	Douglas	Oct. 7, 1958
2,882,213	Douglas	Apr. 14, 1959

OTHER REFERENCES

Corrosion in Action, The International Nickel Co., 1955, pp. 1-31, Corrosion, vol. 4, No. 7, July 1948, pp. 358 to 370.