Nov. 30, 1948. G. L. YOUNG 2,454,956

SYSTEM FOR CORROSION PROTECTION

Filed June 21, 1944

Fig. 1.

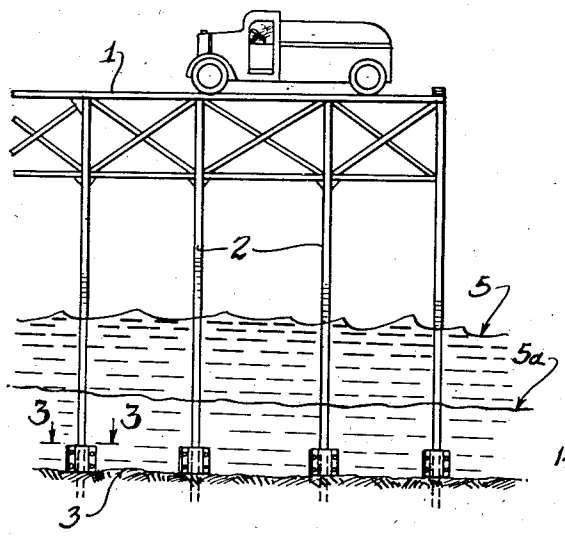


Fig. 2.

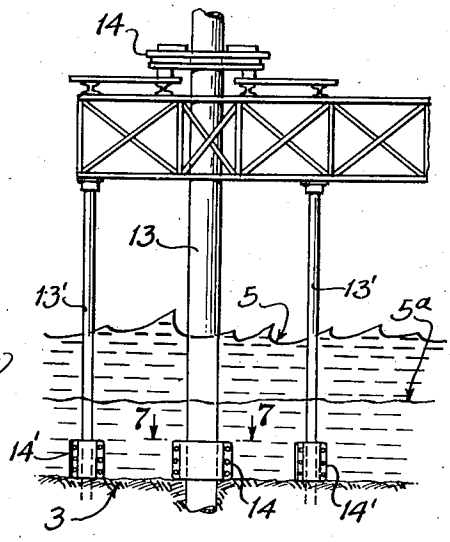


Fig. 3.

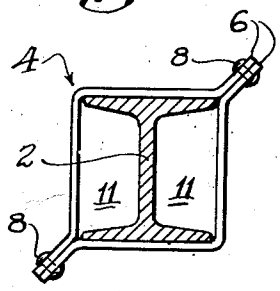


Fig. 4.

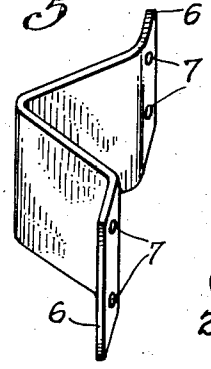


Fig. 7.

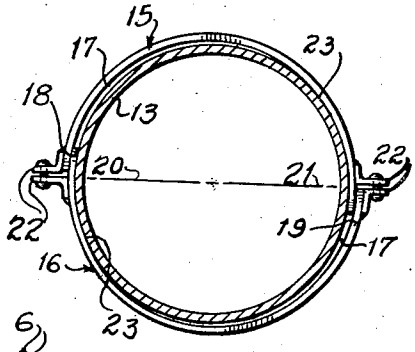


Fig. 5.

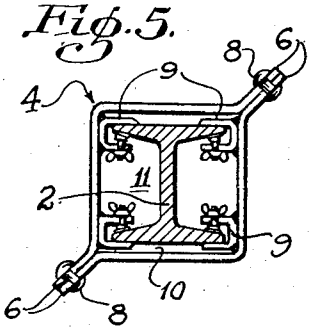
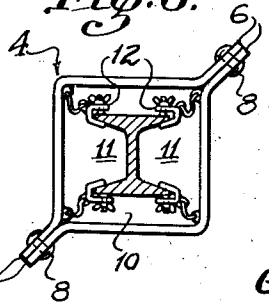


Fig. 6.



INVENTOR.
GARTH L. YOUNG
BY Philip Lukow
ATTORNEY.

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SYSTEM FOR CORROSION PROTECTION

Garth L. Young, Los Angeles, Calif., assignor to Signal Oil and Gas Company, Los Angeles, Calif., a corporation of Delaware

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7 Claims. (Cl. 204—197)

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This invention relates to the protection of metallic structures against corrosion.

The protection of metals, particularly iron and steel, against corrosion when in contact with earth or water is one of the most important problems facing designers of structures. Such problems arise in many such structures where steel structural shapes are employed as piles or supporting beams driven into or placed on the ground. Such problems are also present in a most difficult form in the construction of pipe lines. They are present in aggravated form when such structural shapes are used as supporting piles in marine constructions, as in piers or marine foundations.

Where the metal shapes are in contact with the earth, both chemical and electrochemical corrosion occurs. It arises from the chemically active nature of the soil or mud, and also from the conductive nature of the soil or mud. Where the structural shapes are employed as steel piles for the support of marine structures, such as bridges, piers, etc., there is the additional complicating factor of electrochemical corrosion by sea water, or other waters in which they are positioned.

In general two methods have been employed to inhibit corrosion of such structures. One is to coat the structure with some coating, such as a paint or asphalt composition, and the other is to employ cathodic protection. It is impractical to coat the shape so as to protect the portion of the metal in contact with the earth except in such cases as in pipe line protection. Certainly this is impractical in the case of beams employed as piles which are driven into the earth. As far as is known no satisfactory coating for such purpose has been developed.

The use of protective coatings for structural shapes submerged in water is also unsatisfactory. No coating yet developed is to my knowledge sufficiently permanent to give adequate protection. The most useful one is a tar or asphalt composition. However, this material scales and exfoliates and the surface becomes exposed. Obviously, in neither case may the coating be readily renewed.

Cathodic protection is, of course, useful but requires expensive installations and large and continued power consumption. Additionally, whereas I have discovered the corrosion is concentrated near or at the points of large stresses in contract with the corrosive environment, cathodic protection requires the charging of the whole metal structure.

As a result of these difficulties, the use of metal shapes in marine foundations, as, for instance, steel piles for piers, has found but a limited and restricted use. It is generally recognized that if the problem of corrosion could be solved, the use

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of structural shapes for this purpose would be widespread and largely replace wooden or concrete piles, since the other inherent advantages of steel makes this material of superior value but for the corrosion difficulty.

My invention arises from my observations upon the character of corrosion occurring in steel structures when in contact with a corrosive medium, and particularly when employed in structures submerged in water. While these observations pertain particularly to the action of metal marine structures such as pier foundations, they are believed to be of general character. The system of corrosion protection which I have devised is therefore applicable to other environments where similar forces occur. The system is applicable to metallic structures, such as iron structures, for example and not by way of limitation, steel piles, immersed in rivers, lakes, or in ground waters, such as underground or surface waters which are corrosive.

I have observed that the corrosion of a metal shape when submerged in water, such as a steel I-beam or H-beam under load, is far greater than when the beam is not loaded. I have also observed that a beam so loaded corrodes most in the region of maximum stress. Thus, for instance, an H-beam driven into the sea bottom and forming the foundation of a pier has its maximum stress in the submerged portion near the sea bottom. Such a structure is a restrained beam fixed at one end and loaded and guided at the other. In the case of piers and bridges, the maximum stress is at a section near the bottom.

There is a concentration of corrosion to within a few feet of the sea bottom. The corrosion becomes aggravated near the sea bottom and appears to be concentrated at what appears to be in the region of maximum fiber stress developed by the bending forces on the beam. Since this is the point of maximum stresses in the loaded beam forming the pier foundation, I believe it is reasonable to credit this corrosibility to the presence of the maximum stresses at this point. The surface of the metal at the corroded area is under the greatest stress resulting from the periodic and variable bending forces exerted by the imposed loads, such as the loads resulting from wave and wind action and from loads on the pier. This is in accordance with observations made by others, that stresses increase the corrosibility of iron and steel, and that such a stressed metal, when in electrical contact with unstressed iron or steel, is anodic to the unstressed metal.

I have, however, made the surprising and unexpected discovery that the metal stressed under an imposed load may be protected against corrosion by an unstresed member in electrical contact with the stressed member. I have evolved a

system wherein the stressed metal may be made cathodic or at least neutral or so feebly anodic with respect to the unstressed metal, without interposition of electrical charges from extraneous power source, as to practically inhibit the corrosion of the stressed member.

I have discovered that the corrosion of the said stressed member may be substantially diminished and, in fact, inhibited and the stressed metal made cathodic to the said unstressed member or neutral or feebly anodic to the unstressed member, which is thus made more anodic and more corrosible by taking advantage of the following expedients which, according to my observations, will materially reduce corrosion. I have, in fact, found it possible to protect steel piling for piers so as to prevent corrosion of the piles.

I encase the member which is or may be stressed by an imposed load, particularly at the submerged region of its highest stresses, with an envelope so as to insure a quiescent cell of water adjacent the exposed stressed area.

I may, and preferably do, employ a metallic member of the same or similar composition as the loaded member for said envelope. Thus, when employing a steel member I may employ a steel envelope which may be constructed of the same or similar composition.

I obtain a further advantage by electrically connecting the said member which is stressed or may be stressed by an imposed load to a metallic member also exposed to the sea or other water in which said stressed member is immersed in close proximity to the stressed area, which metallic member is relatively less loaded than the stressed member and therefore less stressed, and preferably which is not loaded or stressed.

I obtain a further advantage by employing the unstressed member as the encasing envelope so that one side of the unstressed member is exposed to the water in the relatively quiescent cell and the other side is exposed to the free movement of the water of the sea or other water in which said stressed member is positioned.

My invention will be better understood by reference to the accompanying description taken together with the drawings, in which

Fig. 1 is an elevation of a portion of a pier;

Fig. 2 is an elevation of a pier construction which is used for drilling an oil well;

Fig. 3 is a section taken along line 3—3 of Fig. 1;

Fig. 4 is one-half of the shield shown in Fig. 3;

Figs. 5 and 6 show a modification of the form of electrically connecting the shield to the pile; and

Fig. 7 is a section taken along the line 7—7 of Fig. 2.

Fig. 1 shows a pier construction of which 1 is the deck, 2 is a number of steel piles driven in the sea bottom 3. The sea surface is shown at 5. The limit of wave action is illustrated by the nine 5^a. The shield 4 is comprised of two sections of the same construction, for instance, made from bent, flat steel plates. The shield sections carry flanges 6 having holes 7. The sections are bolted together by bolts 8, as shown in Fig. 3, so that contact is made at the flanges of the I-beam. The shield rests on the sea bottom or is in close promixity to the sea bottom.

Instead of mounting the shield as in Fig. 3, it may be clamped to the web by clamps 9 welded to the inside surface of the shield so as to provide an opening 10 in addition to space 11. Fig. 6 shows a more flexible connection between the shield and the beam. Clamps 12 are attached to

the flanges of the beam and connected by an insulated and waterproofed wire to the shield. Open spaces 11 and 10 are thus also provided to form a relatively quiescent cell. By these connections any load imposed on piles 2 is not transferred to the shield.

The shield is open at the top and bottom. The sea water in spaces 11 or 10 and 11 communicates with the rest of the sea but is quiescent and relatively stationary. At the sea bottom, in depth in excess of 20 or 30 feet, where wave action is not present and only ocean currents occur, little or no agitation of the water in spaces 11 or 10 occurs. For example, in employing piling of the form of an 8" or 10" H column, in depths in excess of 30 feet, the shield may be from about two to three feet high. The shield is thus sufficient to surround the zone of the beam subject to critical corrosion and the zone in which the outside fiber of the beam is subjected to greatest stress as a result of bending. Thus the shield does not reach the zone of wave action and the cell is not subjected to wave action.

The load imposed on the beam, for instance, by a loaded truck passing over the pier, or wave or wind action, causes a flexible load which is concentrated in the region surrounded by the shield. This load is not carried by the shield and little or no transference of load to the shield occurs.

This load transference is further minimized and avoided by the connections shown in Figs. 5 and 6. The column then is a stressed member while the shield is not stressed by imposed load.

I have found that with such construction substantially no corrosion occurs either on the inside of the shield or on the column. The shield is corroded substantially entirely on the outside of the shield, i. e., on the side exposed to the sea. The column above the shield shows little or no corrosion. This portion of the beam is relatively less loaded than is the section shielded. Contiguous to the pile so protected, other piles not so protected and exposed to the sea are corroded excessively so as to be substantially worthless as a supporting member. This corrosion occurs at the region within two or three feet of the bottom, that is, in the area which in my system is enclosed by the shield. Above this region the corrosion is markedly less, showing, as in the case of the protected pile, little or no corrosion. Noticeably the degree of corrosion in the corroded area of the unprotected pile is concentrated in magnitude near the point of restraint in the ocean floor, being of maximum amount in the area where the outer fiber of the metal is subjected to the greatest stress due to the bending moment in the beam.

Thus, for example, in a beam, such as a steel 10" H-column used as a support for a pier, I have found corrosion is concentrated in an area about one to two feet high, starting about two to four inches above the point where the H-column is held and restrained by the ocean bottom. Little or no corrosion occurred at the web until excessive corrosion of the flanges had occurred. The corrosion at the web is apparently a result of local pitting action, and in this regard is similar to the limited corrosive pitting throughout the whole length of the pile. At the flange, however, a material reduction occurs. It is noteworthy, according to my experience with such 10" H-columns, that this reduction in area occurs within a limited zone, starting in the example given at about two to

four inches above the point of restraint in the ocean bottom and is concentrated in an area equal to about 14 to 16 inches in length. The corroded area is definite and the recess forms a sharp angle with the normal surface of the pile. The corrosion appears remarkably symmetrical about the two principal axes of the cross sections and noticeably uniform throughout the region of corrosion. Substantially the entire corrosion occurs at the flanges, the corrosion at the web being primarily a pitting action. This zone, in this specification, is referred to as the zone of "corrosivity" of the loaded beam or pile. Since the fractional reduction area resulting from loss of metal in the flanges has an effect on the strength of the beam in excess of the ratio of the lost area to the total original cross sectional area, the loss of metal at this point is a critical factor in the reduction of the strength of the beam and has a large effect on the life of the structure, as will be recognized by those skilled in the art.

While I have illustrated my invention by reference to a shield of limited length, i. e., enclosing the area of maximum stress and extending to below the limit of active wave action, it, of course, will be understood that the shield may be longer and extend around the pile to a greater height above sea bottom. It will also be possible to extend the shield so that it will enclose all of the pile submerged in the sea and even extend above the water level.

While I have illustrated the beam employed as an I- or H-beam, the invention is as well applicable to other shapes of beams of iron or steel, such as iron or steel pipe columns such as illustrated in Fig. 2, solid steel or iron columns of various cross sectional design, and also to compound girders formed of a plurality of metal shapes. The girders in the portion that is submerged, and particularly in the region of high stresses, may be enclosed by a shield such as illustrated.

Figs. 2 and 7 show the application of my invention as applied to a steel pipe or casing. In Fig. 2, 13 is a steel conductor of a well drilled into the ocean bottom, as is common in many submarine oil wells. A shield 14 made of iron or steel, and, if desired, of the same or similar composition as that of the pipe, is provided at or near the ocean bottom in the region of high stresses. As previously indicated, this shield may be made of any length and need not be localized to the region of highest stresses. Thus, it may be extended upward and may encase the caisson throughout its total immersion. Preferably, the shield need not be made any longer than needed to encase the area of large stresses on the caisson, and desirably the shield should extend to below the limit of wave action.

The shield may be in the form of a cylindrical shield made of two semi-cylindrical halves 15 and 16 which are bolted together around the pipe or caisson 13 and spaced therefrom to provide a space 17. Lugs may be provided on the inside of the shield to give electrical contact with the caisson by abutting against the exterior wall of the caisson. However, as shown in Fig. 7, the semi-cylindrical portions may be constructed so that one end 18 is one side of the center line and the other side 19 extends beyond the diameter 20—21. Mating lugs 22 are provided on the semi-cylindrical halves. The shield is assembled by bolting the halves together. There is thus provided an opening 17

on both sides of the tube 13 and contact is made between the shield and the tube 13 at 23. However, the shield may be of sufficient diameter to provide a free space filled with sea water all around the tube 13 and electrical contact made by means of clamps similar to that shown in Fig. 5 and Fig. 6. Obviously, a circular clamp will need to be used, as will be evident to those skilled in the art.

The central conductor tube 13 may be loaded, as it frequently is during the drilling of a well or when it is used in a pumping well. The load is, however, not transferred to the shield which is thus an unstressed member.

The shield illustrated here for application to the caisson is equally applicable where the caisson is used as a pile or other supporting member. This is illustrated as a pipe pile at 13'. The shield is illustrated at 14'. The construction of the shield and its mounting on 13' may be similar to 13 and 14.

In all these forms the space between the guarded member, i. e., 2 and 13, and the guard member, i. e., the shield, is filled with sea water. The sea water inside the shield is quiescent. The sea current and possibly wave actions sweep across the outside of the shield.

While I do not wish to be bound by any theory of the action of my system of protection, I believe the following considerations are important in explaining the reason for the success of my system of corrosion protection.

As a result of this arrangement, the shield forms a relatively quiescent cell of sea or other water which has a different composition (for example, oxygen concentration) from the outside of the cell. The water in contact outside the cell is constantly swept away and replenished by sea or other water containing higher concentrations of oxygen. The water inside the shield is not replaced and is relatively stagnant. Under these conditions, apparently the electrolytic action is such as to cause a preferential corrosion of the exterior of the steel shell. Additionally, the shield protects the beam from the erosive action of the ocean currents and the action of sand carried by such currents. This, I believe from my observations, is of lesser importance than the electrochemical effects of the difference in composition of the water in the cell and outside the cell acting on the steel or iron of the shield and beam.

Whatever be the true theoretical explanation of the phenomenon present in my system of corrosion protection, it is highly effective to prevent corrosion in a situation in which, until my discovery, no adequate corrosion protection had been found. I have thus found a particularly effective corrosion protection system which is applicable and effective for metallic structures, and particularly iron or steel structures, which are immersed in sea water, river, lake, or other underground and ground water, and particularly so where the water is in motion or exposed to the air so that it may contain oxygen or become mixed with waters which contain oxygen. I will call such water which contains oxygen "aerated" water, or "moving aerated water" if such waters are subjected to currents therein.

I have found after extensive tests that in the system illustrated in Figs. 1, 3, and 4 substantially no corrosion of the beam and of the inside of the shield opposite the beam occurs, and that only the ouside of the shield facing the sea corrodes. The original cross sectional area of the beam is

preserved except for surface pitting, no notching or loss of area occurs, and the strength of the beam is not materially impaired by corrosion. For all practical purposes, the beam may be said to have been uncorroded, whereas a beam in adjacent position on the pier which was unprotected by my system showed the corrosion previously described.

It will thus be seen that I have been able to protect a member which normally would be subject to excessive corrosion by sea water by placing a shield between the member and the corrosive fluid, i. e., sea water. I have been able to protect this guarded member, which may be stressed and therefore would be expected to have its corrosion accelerated, by means of a relatively less loaded guard member in electrical contact with the loaded member. By employing the less loaded member as a shield between the loaded member and the sea water so that the sea water is quiescent between the guarded member and the guard member while in relatively greater motion on the outside of the guard member, I have overcome the inherent property of the loaded member to be anodic to the relatively less loaded member. Whereas, as would be expected under such conditions, the loaded member would be preferentially corroded, I have discovered that in my system the relatively less loaded member is preferentially corroded.

While I have described a particular embodiment of my invention for the purpose of illustration, it should be understood that various modifications and adaptations thereof may be made within the spirit of the invention as set forth in the appended claims.

I claim as my invention:

1. A system for protection of steel members against localized corrosion of said members under local stress, which comprises a structural steel member immersed in sea water, which member is subjected to stress at an area of the surface of said member immersed in said water, a structural steel envelope enveloping said area and directly connected electrically with said stressed members, which envelope is relatively unstressed and adapted to permit the formation of a quiescent cell of said water between said envelope and said member when said system is immersed in sea water, said quiescent cell being at said stressed area.

2. A system for protection of steel members against localized corrosion of said members under local stress, which comprises a guarded metallic member immersed in corrosive waters, taken from the class of sea water, rivers, lakes, ground and underground waters, which member is subjected to stress in an area at the surface of said member immersed in said water by an imposed load, and a relatively unstressed metallic envelope directly connected electrically with said stressed member, enveloping said stressed member in the region of its maximum stress and spaced therefrom to form a relatively quiescent cell of water in contact with said stressed area, the stresses imposed on said metallic envelope being materially less than the stresses imposed on said member by said imposed load and said envelope being more corrosible than said stressed member by said waters.

3. A system of corrosion protection for metallic marine structures subjected to localized corrosion under local stress, comprising steel beams positioned in the marine bottom and supporting said structures, substantially unstressed metallic shields directly connected electrically to said beams positioned at the marine bottom and spaced from said beams and surrounding said beams in the region of the maximum stress to form a quiescent cell of water between a beam and its shield.

4. A system of corrosion protection for metallic marine structures subjected to localized corrosion under local stress, comprising steel beams positioned in the marine bottom and supporting said structures, unloaded metallic shields for said beams surrounding said beams in the region of the maximum stress and spaced from said beams to form a quiescent cell of water between a beam and its shield, and a direct electrical connection between said beam and said shield.

5. A system of corrosion protection for metallic marine structures subjected to localized corrosion under local stress, comprising steel beams positioned in the marine bottom and supporting said structures, substantially unstressed metallic shields for said beams positioned at the marine bottom and spaced from said beams to form a quiescent cell of water between a beam and its shield, and a direct electrical connection between said beam and said shield, said shield extending to a height sufficient to suround the zone of corrosivity of said loaded beam but insufficient to reach into the zone of active wave action.

6. A marine structure subject to localized corrosion under local stress, comprising a structural steel column composed of a web and flanges positioned in the sea bottom and extending above the water level, a supported structure on said column, and a substantially unstressed structural steel shield surrounding said column positioned at the marine bottom, said shield contacting said column at its flanges and being spaced from its web to form a quiescent cell of water between the interior of said shield and the web and said flanges.

7. A marine structure subject to localized corrosion under local stress, comprising a structural steel column composed of a web and flanges positioned in the sea bottom and extending above the water level, a supported structure on said column, and a substantially unstressed structural steel shield surrounding said column, said shield contacting said column at its flanges and being spaced from its web and positioned at the marine bottom to form a quiescent cell of water between the interior of said shield and the web and said flanges, said shield being exposed on the exterior side thereof to the sea, said shield extending to a height above sea bottom and being positioned upon said column adjacent the zone of corrosivity of said beam.

GARTH L. YOUNG.

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