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SYSTEM AND METHOD FOR PROTECTING
PIPES AND OTHER CURRENT CONDUCT-
ING STRUCTURES AGAINST ELECTRO-
LYTIC CORROSION

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1

My present invention relates to a system and method for eliminating corrosion of pipe lines and other stray current conducting structures and more particularly to a system and method for neutralizing long line, galvanic and stray current corrosion in pipe lines and sheathed cables without the use of ground electrodes as now practiced.

An object of my invention is to provide a system by which the flow of corrosion producing currents between the surface of a metallic current conducting structure and a surrounding earth or other electrolytic media may be eliminated.

Another object of the invention is to provide a method by which a neutralizing electrical potential may be established along a buried pipe line or other structure which may be exposed to the corrosive electrolyzing action of different types of soil and/or a surrounding electrolytic media.

Other objects and advantages of the invention will be in part evident to those skilled in the art to which the invention appertains and in part pointed out hereinafter in the following description taken in connection with the accompanying drawing; wherein

Figure 1 is a diagrammatic view illustrating conditions upon a pipe line which my invention is adapted to remedy,

Figure 2 is a view similar to Figure 1 diagrammatically illustrating a prior art method by which the conditions contemplated by my present invention may also be remedied,

Figure 3 is a view graphically illustrating the current flow conditions in a hypothetical case,

Figure 4 is a view similar to Figure 3 showing the current conditions as they are established in this instance by the system and method of my invention,

Figure 5 shows a modified form of the circuit illustrated in Figure 4 of the drawing,

Figure 6 is a graphic view illustrating the formula by which the potential values in any particular case may be determined, and

Figure 7 is a diagrammatic view showing the current values found to exist in a system installation of the invention.

In general, corrosion on long pipe lines, lead cable sheaths, or other conductors installed underground or under water, can be attributed either to local electrolytic action, to long line or stray current action, or to the combined action of these two.

In any local electrolytic action the corrosion is caused by differences in the surface of the metal that is exposed to the contacting soil or water. These differences in the surface of the

2

metal may be due to crystal structure, hardness, strains, impurities in the metal, such as carbon, or to contact with clay, rocks, or other metallic structures.

From experience it has been found that the average potential gradient found in the soil adjacent to a steel pipe line or main, due to local current which will cause self-corrosion, is approximately one-third millivolt per centimeter.

As distinguished from local action, long line currents are due to either stray currents from an electric railway or other grounded direct current circuit, or, are electric currents generated galvanically by contact with different soils, and/or differences in the amount of water, salt, or air contents of the soil at two spaced points along a pipe line or buried cable. In some instances these different types of soils may be only a few feet apart and in some cases the different current generating soils may be several miles apart.

The portions of the line which will be corroded by the discharge of the electric currents thus generated can in most cases be located by an electrolysis survey. One such survey may be made by measuring the current flowing at various points in a pipe line or other conductor and then determining the loss of current between any two points there along. Another such survey may be made by measuring directly the current flowing from the pipe line and into the soil, with an earth current meter of the well known McCollum type.

In Figure 1 of the drawing there is shown a plotting of the earth currents which might be found to exist upon a line by a survey of the above type. This plotting diagrammatically represents conditions that will be found to exist along a line laid through, or across, two generally encountered contrasting types of soil, such as clay and loam. These two soils are known to have an electrolyzing action of opposite polarities and will set up a difference of potential between them whenever they are connected or short-circuited by a metallic conductor as, for example, a line of pipe 10. This will cause a current to flow in the metallic conductor which will be in the direction, here indicated by the arrow upon the pipe 10. This galvanically generated current will be discharged from the metallic conductor or pipe 10 and into the clay or anodic area, causing corrosion, and then return to the metallic conductor in the loam, or cathodic area. Under these conditions the potential gradient in the soil at the pipe surface, due to long line currents, may reach values as high as 5 millivolts per centimeter, or more.

In the past to reduce, or eliminate this cor-

rosive action of local and long line currents it has been the practice to use a so-called electrical or cathodic protection method, which will now be described in connection with Figure 2 of the drawing. In this prior art system a ground electrode or anode 11 is installed at C, as here shown, and this electrode is connected to the positive terminal of a source of direct current 12, while the negative terminal of the source of current 12 is connected to the pipe 10 at or near a point of maximum current discharge, D. Under these conditions the current discharged by the anode 11, in this instance, should be sufficient to produce a potential gradient in the surrounding clay soil, which will counteract the potential gradient produced by any existing long line or local currents flowing in the pipe 10. The main objections to this system of protection are that, if the cathodic protection is to be practical and economical, the ground electrode must have sufficient area to give a low resistance ground connection for electrode 11 which may extend from 500 to 1000 ft. or more along the pipe line being protected. The amount of electrode surface required will vary directly as the specific resistance of the soil. Therefore if a low resistance ground connection of .05 to .1 ohm is to be obtained, in soil having a specific resistance of 5000 to 10,000 ohms per cubic centimeter, an excessive amount of electrode material will be required. At the same time, if a higher resistance ground of from .5 to 1.00 ohm or higher is used to economize on electrode material, and an increased potential is applied, this will cause a greater power loss and the annual charge for electric power will reach excessive values. A high ground electrode potential will also cause high potential gradients in the adjacent soil, which in turn, may cause other difficulties such as severe cathodic protection interference when used near other buried conductors, such as pipes or lead-covered cables of a city network.

In Figure 3, there is shown a portion of the pipe line 10, with a supposed earth current profile on either side of a neutral point O. For the purpose of the present discussion the soil current profile is here shown in the form of a straight line. As here indicated the current generated in the buried conductor 10 by the different soils along the line will enter the conductor 10 within the area A—O and leave the pipe line 10 within the area O—B. In other words, the flow of current to or from the pipe line 10 will be determined by its electrical potential whether negative or positive, with respect to the surrounding medium through which it passes.

Now with reference to Figure 4 of the drawing it will be seen that if an opposing electrical potential is established along the same length of pipe line 10 a condition can be set up which will prevent the flow of corrosion producing current. For example as here shown, when a direct current from an outside source is passed through a poorly insulated buried conductor such as the pipe line 10, and in the same direction as the galvanic current of Figure 3, a portion of this applied current will flow from that portion of the pipe line 10 within the A—O area, and enter that portion of the conductor or pipe line 10 within the O—B area. The magnitude of this applied opposing current is a function of the applied voltage, the pipe resistance, and the leakage resistance to the ground or other surrounding medium. By now comparing the

showings of Figures 3 and 4, it will be seen that the stray or leakage currents produced by the applied direct current, as indicated by vertical arrows in Figure 4, will be in opposed relationship to the soil currents produced by the galvanic action of the soil, as indicated by vertical arrows in Figure 3, which cause corrosion of the pipe line 10 at B. In other words in Figure 3 the stray or leakage currents are indicated by the vertical arrows as flowing from the least corrosive soil to the pipe 10 in area A and from the pipe to the more corrosive soil in area B. Whereas, in Figure 4, the conditions of current flow are shown by corresponding arrows as in a reversed direction. This is due to the potential polarity established along the pipe line by the applied current generated at the source 13. From this it will be seen that by combining the circuits of Figures 3 and 4, a condition of equilibrium may be established. The superimposed direct current from the outside source 13, when properly adjusted will neutralize the pipe-to-soil and soil-to-pipe currents within areas O—B and A—O and in this manner the long-line-current corrosion at O—B will be eliminated without the use of a ground electrode or the prior art method, as has been described above. In this instance any increase in the applied current above the minimum value required for complete neutralization would cause the pipe line 10 to receive additional protection within the area O—B by the current received through the soil, but this current would be in opposition to the current discharged by the former cathodic portion of the line between A and O. Therefore, this portion of the line which was originally negative to the soil, would now become positive and corroding. As a consequence the corrosion would be simply shifted from one end of the buried conductor to the other. In the simple circuit described, the current in the buried pipe line 10 cannot be increased above the amount required for complete neutralization of stray currents without producing corrosion at some other point. This method of eliminating stray, or long line current corrosion, is particularly applicable to long pipe lines in mildly corrosive soils, and to lead-covered cables in city networks where the standard form of cathodic protection with ground electrodes would cause cathodic protection interference on adjacent buried structures.

The portion of the conductor between A—O, of Figure 3, which was originally negative to the soil, is now in Figure 4 merely serving as a conductor to carry the applied neutralizing direct current to the midpoint O and to the corroding portion of the pipe line 10 within the area O—B. Therefore as illustrated in Figure 5 of the drawing this part of the applied current circuit can be replaced by a conductor, R_g , having the same resistance, R_p , as the length of buried conductor A—O which it replaces, and which, as assumed, has the same resistance as the pipe line or conductor O—B. When the resistance R_g , is equal to the resistance O—B, the potential to ground at the point O will remain zero and the potential at the other points along the pipe line from O to B will remain as shown graphically in Figure 4. When the series resistance from P to O, of Figure 5, is greater than 50% of the total resistance of the portion of the circuit P—O—B, the potential at O will be lower than the soil potential and will approach the potential of B. In an actual field installation, it is seldom possible to obtain an exact compensation of the soil cur-

5

rents by the neutralizing current at all points along the buried conductor. This is due to the non-uniformity of the distribution of the corroding soil currents. However, in order to overcome these irregularities and to afford protection to the remaining portion of the pipe line 10 not included between O and B, a certain amount of current must be received from the soil. This condition can be established by combining the neutralizing circuit with a form of cathodic protection, by providing a ground G on the positive terminal as shown by dotted lines in this figure. This ground G or anode, being at a higher positive potential than either O or B, will cause both of these points and all of the intervening line to pick up current from the surrounding soil, as in the usual cathodic protection system. The amount of current discharged by the ground electrode G can be varied by adjusting the potential at the direct-current terminals, changing the resistance between the positive terminal and the connection to the pipe at O, or, placing a suitable resistance in series with the ground electrode G. The ground electrode G will also supply the current to protect the pipe line 10 at points extending beyond O—B.

As diagrammatically illustrated in Figure 6 of the drawing, the potential to ground, along a buried conductor of uniform resistance and leakage, when carrying a current that is conducted from a direct current source over a metallic circuit may be represented by a straight line. In this showing the horizontal abscissa A—B represents the zero or ground potential along the length of the conductor which extends from A to B. The potential to ground at any point, such as X, on the conductor A—B, is indicated by the ordinate y, extending from the axis A—B to the potential profile, a—b. This pipe potential may be either positive or negative to the soil. The value of this potential will vary with the location along the pipe on which the test is made and the magnitude of the potential, E_a , applied at the ends of the pipe A—B.

While the potential profile a—b, is here shown as a straight line for this discussion, it will be understood that this is strictly true only for a highly insulated pipe line or conductor when the stray currents are neutralized electrically, as described above. In other words, the form of this potential profile a—b will not be a straight line if the resistance of the buried conductor or the leakage resistance are not uniformly distributed along its length.

The profile of the soil current picked up along the line, on either side of O and B will follow an exponential curve of the following form:

$$I_1 = I_0 e^{-al}$$

Where;

I_0 = milliamperes per sq. ft. of pipe surface at O or B.

I_1 = milliamperes per sq. ft. of pipe surface at distance L, from O or B.

e = natural base of logarithms.

l = distance from O or B in units of thousands of feet, or miles.

$a = \sqrt{rg}$

r = resistance of pipe per unit length.

g = conductivity of pipe to soil per unit length of conductor.

In Figure 7 of the drawing there is shown a typical example of the current values which were

6

found to exist in an actual installation of my improved system upon 1000 foot length of a standard 6 inch main, buried in soil having the above referred to long line current generating characteristics. In this installation because of particular conditions, there was also embodied the feature of a cathodic ground, as described above in connection with Figure 5 of the drawing. In this instance it was found that a long line current flow of 8.45 amperes existed in the pipe line between the points of connection of the pipe line with the applied current source. In addition to this it was also found that a current of 1.0 ampere was flowing to the protected length of pipe line at one of these connections, while at the other end of the protected area a current of 1.05 amperes was also found to be flowing toward the protected area. In this particular instance, as here shown, the positive terminal of the applied source of neutralizing current was connected to the length of pipe by means of a conductor 14 and the negative side of this source of applied current was connected to the water pipe 10 through a conductor 15 at a distance of 1000 feet from the point of connection of the conductor 14. This flow of 8.45 amperes of current existing in the length of water pipe in question combined with the 1.05 amperes coming from the external portion of the water line, as indicated, produced a flow of 9.5 amperes in the conductor 15. While in the conductor 14 leading from the positive side of the applied current source there was a current flow of 7.45 amperes which combined with the 1.0 ampere current flowing in the water pipe externally of these connections accounted for the 8.45 amperes of current flow in the neutralized section of the pipe line. Since this 8.45 amperes flow required a potential gradient along the length of pipe in opposition to the potential gradient of the soil which was responsible for the long line current found to exist in the pipe line 10, it will be seen that the system provided a perfect neutralizing within the 1000 foot section being protected. Now, and as an additional adjunct, this diagram also shows a further conductor 16 with a ground G at its end which has been adjusted with respect to its total resistance to provide an ampere flow from the positive terminal of the applied current source to ground of 2.05 amperes, and since this value of current equals the sum total of the amperes flowing to the protected area between the connections formed by the conductors 14 and 15 it will be seen that the pipe line 10 will be protected for a considerable distance to either side of the particular length of pipe.

While I have, for the sake of clearness and in order to disclose the invention so that the same can be readily understood, described and illustrated specific devices and arrangements, I desire to have it understood that this invention is not limited to the specific means disclosed, but may be embodied in other ways that will suggest themselves to persons skilled in the art. It is believed that this invention is new and all such changes as come within the scope of the appended claims are to be considered as part of this invention.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. The method of preventing the corrosive action of electric currents flowing from a buried linear conductor, which comprises connecting the positive and negative terminals of a source of direct current electric power to the buried linear

conductor at spaced points to form a closed metallic circuit which will include that portion of the linear conductor to be protected, grounding the positive terminal of said source of electric power, and maintaining a flow of current in said closed metallic circuit and through the included portion of said buried conductor which due to resistance of said conductor will establish an electrical potential along said pipe line between said points of connection relatively negative to the potential of the earth in which the included portion of said linear conductor is buried.

2. In a system for protecting a buried metallic structure against the corrosive action of surrounding electrolytic earth current conducting soil, the combination with a buried metallic structure to be protected, of a source of direct current electric power, circuit forming connections extending from spaced points upon said buried metallic structure to the positive and negative terminals of said source of power, said circuit being arranged and adapted to include that portion of the metallic structure to be protected in a closed metallic circuit with said source of electric power, and a ground connection at the positive terminal of said source of power for rendering said circuit operable at a potential not higher than the prevailing potential of the surrounding earth in which said structure is buried.

3. A system for preventing corrosion in a buried current conducting metallic structure that extends through an electrolytic current conducting soil, which comprises a source of direct current electric power connected to said metallic structure at spaced points to form a closed metallic circuit which will include in series circuit with said source of electric power that portion of the metallic structure exposed to the corrosive action of the electrolytic current producing soil, the positive terminal of said source of said electric power being adapted and arranged by a ground connection to operate at a potential not higher than the prevailing electrical potential of the soil at said point, and means for regulating the

flow of current in said circuit and through the included portion of said metallic structure which will produce a potential drop in said closed metallic circuit and along the metallic structure from said point of grounding that will render the included portion of said metallic structure negative with respect to the electrolytic current conducting soil in which it is buried.

4. The method of preventing the corrosive action of electric currents flowing from a buried current conductive structure which comprises the connection of an independent source of direct current electric power to said structure at spaced points to include that portion thereof to be protected in series circuit with said source of power, grounding the positive terminal of said source of electric power to establish a relationship with the prevailing earth potential about the included portion of said structure, and circulating an electric current through said structure which will cause a potential drop between the points of positive and negative connection with said source of power and render the included portion of said structure negative with respect to the adjacent earth.

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