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3,254,012

METHOD OF CATHODICALLY PROTECTING HEAT-INSULATED PIPES

Filed July 20, 1962

Fig. 1.

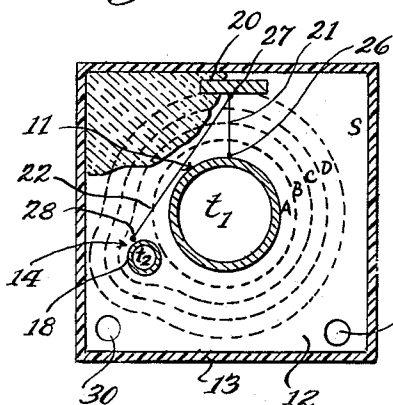


Fig. 2.

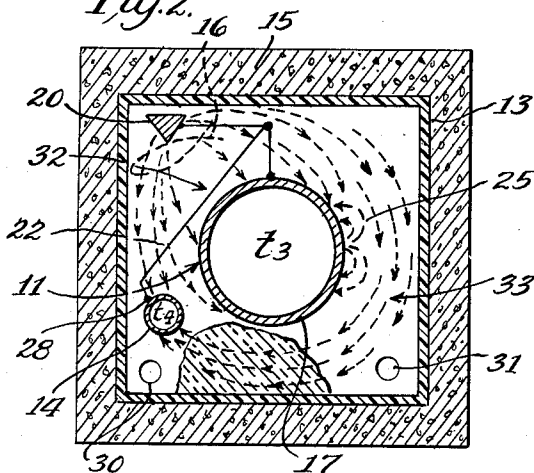


Fig. 3.

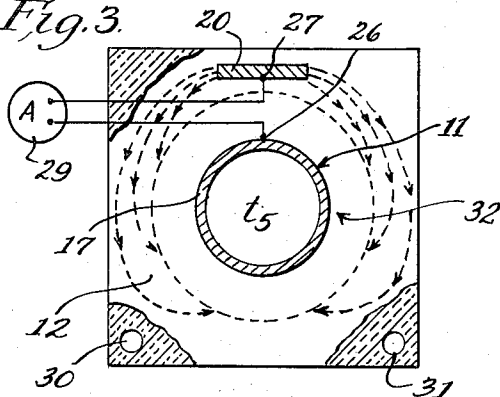


Fig. 4.

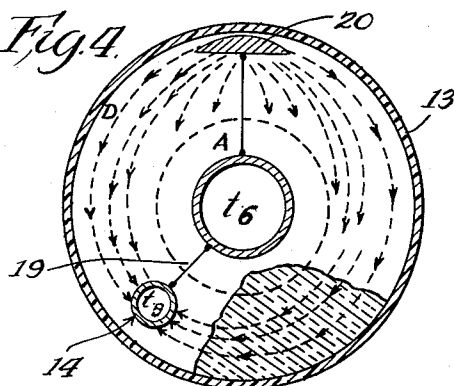


Fig. 5.

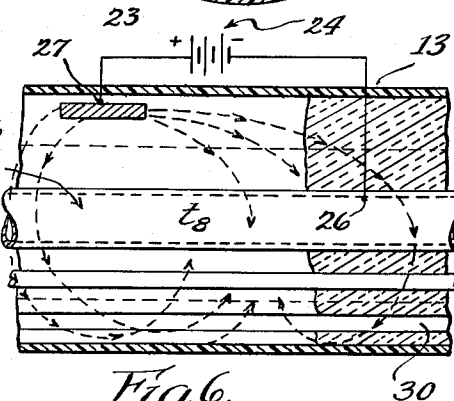
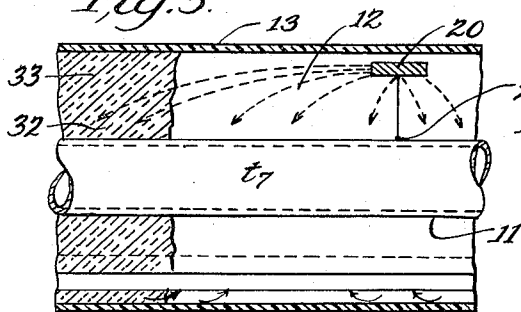
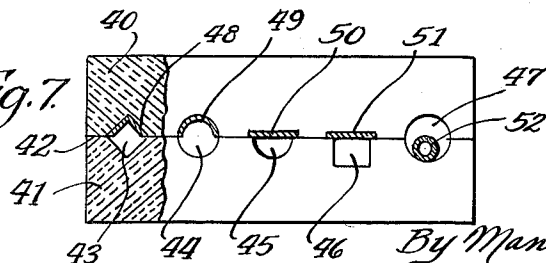


Fig. 7.



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METHOD OF CATHODICALLY PROTECTING HEAT-INSULATED PIPES

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8 Claims. (Cl. 204-147)

The present invention relates in general to corrosion prevention systems and has more particular reference to the prevention of corrosion in heat distribution systems. In a broad sense, the present invention relates to improved and novel cathodic protection circuits, but the invention is particularly suited to and finds special utility in fluid-carrying in heat distribution systems.

The present invention is filed as continuation-in-part of a prior filed application Serial No. 205,023 filed June 25, 1962. Application Serial No. 205,023 is in turn a continuation-in-part application of a prior filed application, Serial No. 786,169, filed January 12, 1959, now United States Patent No. 3,045,708, and the entire disclosure of the latter application is hereby specifically incorporated herein by reference, to the extent that it is not inconsistent herewith.

The cathodic protection system of the present invention avoids and eliminates many of the objectionable and costly features of prior art structures and methods. It is an important feature of the invention that the cathodic protection is, in effect, provided at only such times and only in response to conditions which dictate its desirability or need. This "responsive" energization is automatic and is achieved simply, without additional equipment, and without additional expense. Not only is the system brought into operation automatically, but the degree of protection provided is also keyed, automatically, to the specific demands or requirements, at any particular time. These novel features result in extended life for the electrodes and the other circuit elements of the cathodic protection system and provide important reductions in operation and maintenance costs. The unique features of the present invention will be brought out more clearly in the following paragraphs as the invention is described with reference to, and is distinguished from, prior art systems.

In many installations, the difference of potential between the pipe or conduit and the soil or other medium in which the pipe or conduit is buried or embedded is of an appreciable magnitude and results in the flow of circulating electrical galvanic currents between the pipe and the surrounding material. This flow of destructive galvanic or destructive electrolytic current causes removal of metal from the pipe or conduit at points where the current leaves the pipe. The word "current," as used in this application, refers to the flow of current from a positive electrode to a negative electrode, rather than to electron flow.

An important method for deterring the corrosion of underground metallic structures is cathodic protection. This method involves maintaining the metallic structure cathodic or negative with respect to the ground or to the other material in which the pipe or conduit is embedded. It is to an important improvement in this cathodic protection method that the present invention is directed.

Linear metallic structures, such as pipelines used in the transportation of gas, oil, water and the like, and pipes and conduits used for heat distribution are particularly susceptible to corrosion and more or less rapid disintegration when the soil or the other medium in which they are buried or embedded is of a character to set up electrolytic action between the differing metallic elements of the lines or conduits.

The presence of mill scale, rust, and the contact with

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the ground itself are contributing factors to the corrosion process. Pipelines buried or embedded in poorly drained ground, in acid or in alkaline soil, or in other media which are damp or which are conductive, are often subject to extremely rapid corrosion. Under some conditions, unprotected lines often corrode to an extent which renders their replacement necessary within a few years and often in as short a time as three years.

In a preferred embodiment of the cathodic protection system of this invention the system is electrically isolated from the surrounding environment. A particularly satisfactory isolation medium consists of a moisture and vapor-impermeable sleeve, film, or sheath of a rubber-like or plastic material such as polyvinyl chloride, polyethylene, polypropylene, polyester sheeting, etc.

The present invention prevents the development of local anodes and local cathodes on metal pipe or conduit and the resulting electrical corrosion, is obviated. When moisture is present in the insulation material surrounding the pipe or conduit, or when other conditions exist which render the insulation conductive, in accordance with the practice of the invention, an electrical circuit is automatically established in which the pipe or conduit is the cathode and a sacrificial or an inert electrode is the anode.

A fundamental feature of the present invention is that it provides a method of selectively regulating current flow in a cathodic protection circuit by utilizing, as a nonlinear resistive impedance in the anode-cathode circuit, the insulating material surrounding the pipe or other conduit sought to be protected.

It is another important feature of the present invention that selective corrosion is minimized or obviated. Selective corrosion may be described as that phenomenon whereby one portion of metallic parts is corroded while other portions are not. The occurrence of selective corrosion is believed to be due to the presence of several different factors of both chemical and physical nature. These factors are related not only to the nature of the metal in question but also to the composition and constituents of the water, or moisture, or medium in contact with the metal.

When two different areas of a piece of metal are immersed in water or are in contact with an electrically conductive medium, the areas may be considered as equivalent to two electrodes in short circuit through the metal itself. Under such conditions, a difference of potential usually arises between the two areas, this difference being dependent upon the nature of the layer with which the surfaces of the two areas are covered, upon the action of oxygen in the air before immersion, or by reason of other chemical reactions on the surface of the metal. Under the influence of this difference of potential, one area becomes an anode and the other a cathode. A galvanic element forms and local electrolysis of the metal surface occurs. This electrolysis constitutes attack of the metal itself. The present invention is effective to prevent the type of corrosion described above by providing an improved cathodic protection system.

The essential elements and the organization of a cathodic protection system or installation are well known and will be summarized herein only for the purpose of defining the field of the invention.

The prior art cathodic protection systems have evolved into two separate and distinct categories, the sacrificial anode systems and the impressed current systems. The present invention finds utility in both, that is, in systems using sacrificial electrodes and in systems in which an externally applied E.M.F. constitutes the electromotive driving force.

Cathodic protection systems are based upon the well known phenomena relating to the interaction of metallic

ions generated by the galvanic dissociation of an electrolytic solution, a corroding or anodic metal, and a relatively noncorroding or cathodic metal. The chemical and electrical activity of the system is due to a flow of current passing through the electrical conductor connecting the anode and the cathode. The flow of current causes metallic ions to go into solution at the anode and it is this dissolution of the anode that constitutes the important problem faced in many industrial installations.

The theory of anodic dissolution is well established in the art and will not be treated exhaustively herein. There will, however, be references to particular phases of the well known reactions.

Cathodic protection systems act to prevent galvanic corrosion or dissolution by supplying external current to the corroding or anodic metal in an amount sufficient to negatively polarize the metals, that is, to impress electrons upon the metals to polarize these metals above the dissolution potential of each so that they cease to ionize into solution or to dissolve. Under these conditions, there will be no corrosion or dissolution.

While in many cases, the electrodes involved in the electrolytic process are composed of two dissimilar metals, each occupying a different position in the electromotive series, these "dissimilar metals," as used herein are intended to include also those systems in which only a single metal is involved, but in which the physical and chemical characteristics of the environment produce anode-cathode relationships. For example, impurities and mill scale produce many cathodic areas, known as local cathodes, and corrosion occurs in the remaining local anode areas, the many galvanic couples thus formed resulting in dissolution or galvanic pitting in that area of the steel or other metal. The local anodes, local cathodes relationship described above may also be prevented by applying an external voltage to the metal to be protected to render the metal cathodic. An alternate method involves the use of sacrificial electrodes. Both techniques are described in the following paragraphs.

The sacrificial anode systems function to provide the protecting or elevating external current by means of an anode or metal which is higher in the electrochemical series than the metal to be protected. The metals which are highest in the electrochemical or the electromotive series are those metals which are most "electropositive," that is, those metals which have the greatest propensity to form positively charged ions. For example, metals such as sodium, potassium and magnesium are high in the electromotive series and the noble metals such as gold and platinum are low. Such a protective anode, having a higher potential, has a greater tendency to pass from the atomic to the ionic state, that is, to be oxidized, and will, by reason of this greater electropositeness, generate a flow of current through an external conductor connecting the dissimilar metals. This flow of current will prevent local current from flowing between the local anodes and the local cathodes of the steel sheet or plate and corrosion will be prevented.

In typical sacrificial anode systems anodes of magnesium or of similar electropositive metals are used. In order to provide cathodic protection over an extended period of time, the consumable or sacrificial anodes must be large enough to provide adequate electron flow or current flow during the protective period and until the normal replacement time. This is a serious disadvantage. In some installations, the disadvantage has been offset by inserting a fairly large resistance into the electrical circuit connecting the electrodes and reducing this resistance as required over a period of time. The cost of replacing anodes can be fairly high, both from a material and a labor standpoint. Thus, frequent replacement is undesirable.

In one preferred embodiment of the present invention, sacrificial electrodes are used. For example, when improvements of the present invention are incorporated in

an assembly utilizing a sacrificial anode, that anode is a metal or alloy which has a higher anodic solution potential than does the material of the conduit to be protected. When the conduit is made of iron, a suitable sacrificial metal anode may be zinc, aluminum, magnesium or alloys of these metals with one another. Magnesium and its alloys are particularly desirable and advantageous because of their high anodic solution potential with respect to ordinary steel. Metals above magnesium in the electrochemical series are ordinarily not as suitable because they react so rapidly with water as to have an undesirably short life.

The impressed current systems of the prior art provide cathodic protection, not through the use of sacrificial metals or electrodes high in the electrochemical series, but by means of a metal or other material low in the electrochemical series and used as an anode. In this system, a direct current is impressed upon the structure to be protected to provide the necessary protective current. Ordinarily, a relatively inert metal, or a nonmetal conductor, is used as the anode to obviate galvanic processes. As a result, the life of the anode may be greatly extended, and the need for frequent replacement is obviated.

However, as in the case of the sacrificial anode systems, the current input to the cathode or protected metal must be high enough to protect areas remote from the anode. High current flow is undesirable, not only from economic considerations, but because these high currents result in the formation of undesirable coatings on the cathode in the region near the anode. In addition to producing thick layers of corrosion products, high current flow has the additional undesirable effect of stripping, from the metal to be protected, paint or other protective films.

In the impressed current systems, the D.C. voltage source may be a battery, a low voltage alternating current transformer associated with a suitable rectifier, a direct current generator, or other current source capable of supplying unidirectional current, all well known in the art. The positive terminal of the current source is connected to an anode and the negative terminal of the source is connected to the pipe or conduit to be protected. Protective electrical current from an external source of D.C. voltage is impressed upon the metal member, as for example upon the metal conduit or pipe, to counteract its normally anodic state and to make it cathodic, maintaining the pipe or conduit at a potential lower than that of the surrounding medium, thus reducing corrosion.

Metallic structures which may require cathodic protection are of the various types, including earth-buried linear structures such as pipelines for the transportation of fluids or gases, and earth-buried unit structures such as structural tower footings, tanks, oil well casings and the like. While finding utility in each of these various types of structures, the present invention is peculiarly well adapted to heat distribution system pipes and conduits in which the pipes or conduits are encased in a thermally insulating material. The description herein-after will be directed primarily to such heat distribution systems although it is to be understood, of course, that such application is merely illustrative of the merits of the present invention and is not to be considered a limitation thereof.

The present invention finds utility in field-fabricated, poured-in-place heat distribution systems, as for example in systems in which the pipes or conduits are supported by the insulating concrete or other surrounding media. The invention is equally useful in systems in which the pipes are supported on conventional guides, rollers or rockers, and in which the insulation consists of insulating concrete or of bituminous material.

Still another system in which the present invention finds utility is heat distribution systems in which pre-formed or sectional insulation is used and in which these

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preformed insulation sections are applied to pipes or conduits which are supported on conventional supports and guides and positioned in tunnels or above grade.

Heat distribution systems of the type in which the present invention finds particular utility consist of one or more fluid-carrying pipes transmitting heated fluid and in which the pipes are surrounded by or embedded in a thermal insulation material. The invention is useful in underground systems in which both the pipe and the surrounding insulation are buried in the ground. It also finds utility in overhead heating systems in which the pipe and the surrounding insulation are supported in air by means of suitable mechanical structures either above grade or in tunnels.

The deleterious effects of water and of moisture in the insulation have long been known and it has been the custom to protect the insulation from water infiltration from either the ground or from rain by means of a casing which may be either of metallic or of nonmetallic construction.

In spite of the many methods which have been devised to prevent the transmission of water or water vapor through the insulation to the enveloped pipe, water and water vapor still remain the primary adverse elements contributing to the corrosion of insulated pipes and conduits. Depending upon the particular installation or structure involved, water enters the distribution systems and the insulation from internal pipe breaks or leaks, through infiltration from ground water, from flooded manholes, or as a result of exposure to precipitation or to rain.

The presence of water or of moisture in the insulation surrounding the pipe of heat distribution systems gives rise to several problems. The particular problem presented will depend upon how much water is present in the insulation and upon other factors. For example, should the insulation become flooded as a result of a major break in the fluid distribution system, or from ground water flooding, or from the flooding of manholes as a result of severe rains, the insulation may undergo irreparable and permanent damage because of the violent boiling action which takes place within the insulation as the heat of the heat distribution system produces steam within the insulation itself. Under these conditions, excessive heat loss occurs and, in addition, the boiling action also causes extensive pipe or conduit corrosion.

A less obvious, but nevertheless equally serious condition, and one which may continue over extended periods of time and possibly throughout the entire operating life of the heat distribution system, is the presence of relatively small concentrations of water or water vapor in the insulation. The presence of this moisture in the insulation causes a reduction in the insulation performance, and it is known that as little as 1% increase in moisture content may result in as much as 2 to 4% increase in the thermal conductivity, with associated thermal losses. In addition to constant and continuous corrosion of the metal conduit, there is also a significant increase in the cost of transporting the heated fluid. It is to the solution of these and other related problems that the present invention is directed.

It is a principal object of the present invention to provide an improved corrosion prevention system which acts to provide protection only when protection is required and which is inactivated under conditions and during those periods when protection is unnecessary.

It is another object of the invention to provide a unique cathodic protection system useful in both sacrificial anode systems and in impressed current systems.

Another object of the invention is to provide a novel cathodic protection system in which an insulating material surrounding the metal conduit constitutes, under certain conditions, an electrical element or component of the protective circuit.

Other aims and objects of the invention are: to pro-

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vide a sacrificial anode system in which the anode will not be sacrificed except under conditions which would otherwise result in corrosion of the protected conduit or pipe; to provide an impressed current system in which current will flow only during those periods and under those conditions under which protection of the pipe or conduit sought to be protected is required; to provide a novel cathodic protection system which is simple in operation, easy to maintain, and which is characterized by extended service life of the anodic materials; to provide a method and an apparatus for regulating the current flow in a cathodic protection circuit in a manner so that this current flow corresponds to and is correlated with the conditions which give rise to the need for cathodic protection; to provide an improved method of selectively regulating the current flow in a cathodic protection system; to provide an improved method of selectively regulating the current flow in a cathodic protection system; to provide an improved sacrificial anode assembly which has inherently incorporated therein means for selectively regulating the current flow capable of being drawn therefrom; to provide a cathodic protection system for heat distribution pipes and conduits and in which the pipes or conduits and their enveloping insulation are electrically isolated from the surrounding environment; to provide continuous monitoring of a cathodic protection system so as to indicate whether the conduit to be protected is in fact being provided with protection; to provide an automatic signalling mechanism for indicating the presence of water or moisture in insulation enveloping the conduits of a heat distribution system; and to provide a system of automatic cathodic protection in which both the period or time of operation and the area or loci of current flow correspond to and are limited to the time and the place when and where protection is required.

Other objects and features of the present invention will be readily apparent to those skilled in the art from the following specification and appended drawings wherein are illustrated preferred forms of the invention, and in which:

FIGURE 1 is a transverse sectional view of a thermally insulated and electrically isolated conduit and showing a sacrificial electrode embedded in the normally nonconducting insulating material. FIGURE 1 also shows a schematic representation of the distribution of heat zones radially with respect to the longitudinal axis of the conduit or pipe;

FIGURE 2 is a cross sectional view of a conduit embedded in an insulating material and showing the distribution of electrical forces between a sacrificial electrode embedded in the insulating material and the conduit when the insulating material becomes electrically conductive by reason of the presence of moisture;

FIGURE 3 is a transverse sectional view of a conduit embedded in an insulating material in accordance with the practice of the invention and showing the distribution of electrical forces between the sacrificial electrode embedded in the insulating material, and the conduit. The figure suggests schematically that there is no electrical conductivity in the area immediately adjacent the periphery of the conduit when that portion of the insulation is substantially dry;

FIGURE 4 is a transverse sectional view of a principal conduit and a second conduit embedded in insulating material and depicts the conditions which pertain when the area adjacent the principal conduit is dry and nonconductive while the area adjacent the secondary conduit is damp and therefore conductive;

FIGURE 5 is a schematic elevation, partly in section, showing the distribution of electrical forces between a sacrificial electrode embedded in the insulating material and a conduit embedded in the same insulating material;

FIGURE 6 is a schematic elevation, partly in section, depicting the method of using an impressed current type

electrode system in conjunction with a conduit and showing both the electrode and the conduit embedded in heat insulating material; and

FIGURE 7 is a transverse sectional view of thermal insulation material and showing several possible shapes or forms of evaporative channels useful in the invention. The figure also shows several ways in which appropriate electrode materials, when used in the evaporative channels either as partial forms or otherwise, may be made a part of the cathodic protective system. The figure is purely diagrammatic and is not intended to show the entire conduit structure.

Referring more particularly to the drawings, there is shown in FIGURE 1 a pipe or conduit 11 embedded in a thermal insulation material 12. The thermal insulation material is normally electrically nonconducting when dry and becomes electrically conducting when damp or wet. Also shown in the transverse sectional view of FIGURE 1 is a second conduit or pipe 14 displaced from the principal conduit 11 and extending substantially parallel to that conduit. An electrode 20 is positioned within the thermal insulating material 12 but is displaced from the conducting surfaces of the conduits. A conductor 21 connects (as indicated at 27) the electrode 20 to the conduit 11 preferably at a point 26 on its surface. The conduit 14 is also connected to the electrode 20 by means of a conductor 22. The conductors 21 and 22, connecting the sacrificial electrode 20 to the conduits 11 and 14, are insulated along their lengths to prevent undesirable electrolytic action between the conductors and the electrode or the conductors and the conduits. Here, again, the connection to the conduit 14 is preferably at a point 28 on its surface 18. In some arrangements, in which two or more conduits are contained within the same envelope of embedding insulating material, one or more of the conduits may be suspended from or supported from another of the conduits or pipes. In such installations the supporting strap or bar hanger may comprise a conducting material and in such cases it is unnecessary to include a special conductor running between the electrode 20 and each of the conduits involved. Alternatively, a conductor 19 may connect one conduit to another, as indicated in FIGURE 4.

Also shown in FIGURE 1 are evaporation channels or air circulation channels 30 and 31. The channels are effective to facilitate the removal of moisture which may be present in the insulation. Air may be circulated through the channels either by means of natural drafts or by means of forced ventilation. A more complete discussion of the role and function of the channels may be found in application Ser. No. 786,169, filed January 12, 1959, now United States Patent No. 3,045,708. One or more channels may be used and these may be located in any preferred position between the pipe or conduit and the outside or peripheral surface of the insulating material. In some installations, it may be considered preferable to omit the channels altogether.

As has been pointed out, the present invention has particular utility in heat distribution systems. In FIGURE 1, the pipe or conduit 11 depicted may be used as a steam conduit carrying steam at a temperature of, for example, 350° F. The normal effect of the heated fluid contained or transported in the conduit 11 is to drive moisture and water vapor from the insulating material immediately adjacent the outer wall of the conduit 11. In particular installations in which moisture or water vapor is originally present in the thermal insulation material, the heated conduit will have the effect of driving the moisture radially away from the pipe or conduit. The percent moisture will vary, increasing as the distance from the conduit wall outward increases. For purposes of illustrative disclosure, the several areas extending outwardly of the pipe are designated in FIGURE 1 as A, B, C, and D. The outermost area is designated generally as S. The effect of moisture in the thermal insulation material is gen-

erally to increase the conductivity or to decrease the resistivity of the composition. For example, in the case of a Portland cement and vermiculite thermal insulating concrete the following table indicates the relationship between the percent moisture content of the thermal insulating concrete and the electrical resistivity of the concrete.

TABLE I

Change in electrical resistivity of Portland cement and vermiculite thermal insulating concrete with increasing moisture content

Percent moisture content	Resistivity Ohms
0 -----	100×10^6
10 -----	1×10^6
25 -----	4×10^4
50 -----	2.5×10^4
100 -----	1×10^4

It is evident from the foregoing table that there is a definite dependency and relationship between the electrical resistance of the insulation material and the moisture content of the material. This relationship will, of course, be different for different types of insulation material but generally it may be assumed that the electrical resistivity will decrease with increasing moisture content and the effect of the heat in conduit 11 will be to render the annular region A essentially dry and, therefore, substantially non-conductive while the surrounding area B which contains, or may contain, more moisture would be more conductive, and the areas C and D would in turn be increasingly conductive. If, in the hypothetical situation discussed, the area A is substantially dry it will be non-conductive and as a result there will be an incomplete circuit with respect to the sacrificial electrode 20 shown in FIGURE 1. Under these conditions, there will be no flow of cathodic protection current, but at the same time there will be no need to energize the cathodic protection circuit since the absence of moisture in the region A will preclude corrosive attack of the conduit or pipe 11 which might otherwise result from local corrosion currents.

The distribution of moisture concentration in the area adjacent the second conduit 14 shown in FIGURE 1 will depend upon its proximity to and the temperature of the principal conduit 11 as well as upon the temperature of the fluid carried by the conduit 14. Cathodic protection current will flow between the electrode 20 and the shell of the conduit 14 only under conditions such that moisture in the insulation material adjacent the shell renders the insulation conductive and permits the flow of current. Thus, as in the case of the principal conduit 11, there will be a flow of cathodic protection current only when there is a need for such protection.

In the embodiment of the invention depicted in FIGURE 1, the electrode 20 is of the sacrificial type and may be made of magnesium, a magnesium alloy or of any other metal or alloy relatively high in the electromotive series. It will be readily apparent that instead of the sacrificial electrode system it is possible to use an impressed current system, as indicated schematically in FIGURE 6. In the case of the impressed current cathodic protection system the electrodes may be of the inert type as, for example, of carbon.

In a preferred embodiment of the invention, the insulating material surrounding the pipe or conduit is a lightweight insulating concrete made with the following ingredients:

Portland cement -----	lbs.	94
Expanded vermiculite -----	cu. ft.	6
Emulsified asphalt -----	gal.	3
Water -----	gal.	21

Many other insulation compositions, well known in the art, may be used. An exhaustive discussion of the method of pouring and forming the insulation layer may be found

in application Ser. No. 786,169, filed January 12, 1959, now United States Patent No. 3,045,708. Special insulation formulations are to be found in application Ser. No. 205,023 filed June 25, 1962. Each of the aforementioned disclosures is specifically incorporated herein by reference.

The external form of the envelope of insulating materials surrounding the pipe or conduit may take any preferred shape. As shown in FIGURE 1, the overall cross section is rectangular but other shapes are equally suitable, and FIGURE 4 depicts a second preferred embodiment. In some installations, it is considered desirable to envelop the insulation composition in a vapor and water impermeable sheath or film 13. The role of the water vapor and water impermeable sheath or film 13 is to isolate the insulated fluid-carrying pipes from the surrounding media. This isolation is not only of the physical type but in effect constitutes an electrical isolation from the soil in which the assembly is embedded or from ambient atmosphere. The enveloping sheath or film 13 may be composed of a plastic composition such as polyvinyl chloride, or polyethylene or a polyester film etc. Alternatively, it may consist of an asphaltum or bituminous coating composition, or a sheet metal casing rendered nonconducting on its surface by suitable paints, coatings or films applied thereto. In order to impart additional structural strength to the overall assembly and to isolate the assembly from surrounding media, a structural concrete envelope 15 may be provided as indicated in FIGURE 2. Again, the rectangular cross sectional configuration is merely one preferred embodiment and other forms or shapes are equally suitable.

Referring now to the conduit installation of FIGURE 2, there is shown schematically a system in which the presence of moisture in the insulation material surrounding the conduit renders the insulation conductive. The situation depicted is one which could obtain by reason of the original moisture of the concrete not having as yet been dissipated by the heat of the fluid contained in the conduit 11. As a result, the insulation material in contact with and extending outwardly of the conduit contains sufficient moisture to render it electrically conductive. In accordance with the practice of the invention, a cathodic protection circuit is automatically set up. This circuit involves, by way of example, a sacrificial electrode 20, a conductor 21 connecting the electrode to the surface 17 of the conduit 11, and a return circuit which is through the moisture-containing insulation material 12. The dotted lines 16 indicate, schematically, conductive paths or paths of current flow between the electrode 20 and the surface 17 of the conduit 11. The lines 25 indicate, graphically, areas of local corrosion resulting from the presence of moisture in contact with the surface 17 of the conduit 11. As long as the particular situation depicted in FIGURE 2 exists, the cathodic protection circuit will continue to function and will thereby prevent the corrosion of the conduit.

The ultimate effect of the transmission in the conduit 11 of a heated fluid at an elevated temperature t_5 which may be, for example, 350° F. or higher, or lower, will be, as indicated in FIGURE 3, to drive moisture away and outwardly of the exterior surface 17 of the conduit 11. When this occurs, there is formed in the annular surrounding the conduit 11 a dry expanse 32 of insulation which is by reason of the absence of moisture rendered nonconductive. An effect concurrent with the disappearance of moisture in the insulation immediately surrounding the conduit 11 is to obviate the requirement of cathodic protection circuits. Consistent with this requirement, it is a feature of the present invention that the energization of the cathodic protection circuit is then automatically terminated.

It is an important feature of the present invention that both the initiation and the termination of current flow in the cathodic protection system may be indicated visually by means of an ammeter 29 or some other electrically

responsive indicator. The indicator would signal the cathodic protection circuit to be in operation, and that moisture was present in or had invaded the system. One, thus being apprised of this fact, could immediately take whatever steps might be called for to correct the condition or to make any necessary repairs.

An alarm device, audible or visual, may be substituted for the ammeter, or both an alarm circuit and a current-indicating circuit may be provided concurrently. Many suitable standard electrical circuits, well known in the art, may be drawn upon. The present invention is directed not to any particular circuit arrangement as such, but to the combination of an automatically actuated cathodic protection circuit, operating only when protection is required, and an indicating or alarm circuit actuated to present an audible or visual indication upon initiation of current flow in the cathodic protection circuit.

Under the normal and usual operating conditions, the passage or presence of heated fluid at an elevated temperature t_5 within the conduit 11 is effective to maintain the area immediately surrounding the conduit moisture-free and, therefore, noncorrosive. As the moisture is driven radially from the area of the conduit it will permeate the insulation farther removed from the conduit to produce a conductive or a damp insulation zone 33. In the course of this transition, moisture and water will collect in the vents 30 and 31 and these vents will facilitate the gross removal of the moisture from the assembly. Should the apparatus or heating plant be shut down with resultant cooling of the fluid in the conduit, or should moisture or water invade the insulation adjacent the conduit as a result of some other occurrence, the insulation near to and in contact with the conduit will again become conductive and the cathodic protection system operation will again be invoked. Thus, when cathodic protection is unnecessary, no current will flow in the system. On the other hand, when conditions exist which would normally result in corrosion of the conduit, the operation of the cathodic protection system is initiated automatically and functions to prevent corrosion of the metal surfaces. It is obvious that the system will function essentially in the same manner whether the electrode is a sacrificial electrode as indicated schematically in FIGURE 3 or whether it is an inert electrode as shown in FIGURE 6. As previously pointed out, the inert electrode 23 of FIGURE 6 is associated with an impressed current circuit including a source of D.C. E.M.F. 24.

It has become common practice, and such procedures are often dictated for economic reasons, to include within a single insulation envelope two or more conducting conduits or pipes. A system such as this is depicted graphically in FIGURE 4 in which there is a principal conduit 11 at a temperature t_5 and a second conduit 14 at a temperature t_6 . These temperatures may or may not be the same in any given situation. Assuming for the purposes of illustration that the fluid contained in the principal conduit 11 is at a temperature of approximately 350° F. or 500° F. and that the fluid in the conduit 14 is at some lower temperature as, for example, 190° F., and that there was originally moisture substantially throughout the expanse of insulation material 12, there will be developed a situation in which the high temperature of the principal conduit will drive the moisture from the area immediately adjacent the peripheral wall of the conduit and render that insulation dry to the point where it is essentially nonconductive. This relatively dry area A is located in the region between the outer wall of the conduit 11 of FIGURE 4 and the dotted line which is shown as defining an annulus surrounding the principal conduit. Under the conditions defined, the temperature of the fluid contained in the second conduit 14 is not sufficiently high to ensure that at all times there will be no water vapor in the insulation immediately surrounding the conduit 14. Thus, a condition may obtain in which the insulation surrounding the principal conduit 11 is dry and nonconduct-

ing while the insulation surrounding the second conduit 14 contains moisture and is conductive. In this type of situation the automatic cathodic protection circuit of the invention will operate to supply cathodic current to the second conduit 14 but there will be no flow of current between the electrode 20 and the principal conduit 11. The protective current will flow only when and where it is needed. Effective protective current is supplied to the smaller pipe 14 without the expenditure of unneeded current to the principal conduit. Should the temperature of the fluid contained in the conduit 14 ultimately have the effect of driving moisture from the insulation immediately surrounding that conduit, current between the conduit 14 and the electrode 20 will be interrupted and this interruption will coincide with the absence of need for cathodic protection.

Whereas, ordinarily the utilization of a relatively few sacrificial electrodes per unit length of pipe or conduit causes considerable variation in potential along the conduit, in accordance with the practice of the present invention, as indicated in FIGURE 5, a much more uniform potential is realized along the expanse of the pipe. The zone 33 of thermal insulation remote from the conduit 11 has a relatively high moisture content and consequently a low electrical resistance. This condition establishes, in essence, a continuous electrical conductor extending linearly along the conduit but spaced therefrom. This annular zone surrounding the conduit 11 may be considered to act as a coaxial conductor of relatively large cross section and, consequently, of relatively low electrical resistance. In principle, the highly conductive annular portion may be considered to serve as a buss bar available at all times to supply any demands for protective cathodic current. The dry area 32 as depicted schematically in FIGURE 5 is essentially a nonconductor and, under the conditions indicated, no current will flow between the electrode 20 and the conduit 11. If, however, moisture or water should invade the annular space 32 immediately surrounding the conduit 11 and the moisture should reach the shell or surface 26 of the conduit, an electrical circuit would automatically be completed from the electrode 20 through the conducting areas 33 (and 32) and a cathodic protection circuit would automatically be activated. Finally, as the high temperature 17 of the fluid in the conduit 11 heats the surrounding thermal insulation and drives the water from the insulation, the insulation becomes essentially nonconductive and the cathodic protection circuit is opened. Thus, as previously described, the cathodic protection circuit of the invention serves to protect the conduit contained in the thermal insulation under those conditions where protection is required and no current is utilized during periods or under conditions where protection is unnecessary. Water which accumulates in the insulation 12 or which is driven to the peripheral areas of the insulation by reason of the high temperature of the conduit 11 is removed through the evaporation channel 30 located within the insulation 12 between the heated fluid-conducting pipe 11 and the outer boundary of the insulation 12. The role and the utility of the evaporation channels are now more fully described in application Ser. No. 786,169, now United States Patent No. 3,045,708, of which the present application is a continuation-in-part. The evaporation channels may be of any preferred or convenient cross sectional configuration 43, 44, 45, 46 and 47 as indicated schematically in FIGURE 7. Where metal forms 48, 49, 50 and 51 are used in producing the channels or vents, these forms may be left in place. When the forms are made of appropriate electrode material, namely, metals which are electropositive with respect to iron (i.e., higher in the electrochemical or electromotive series than iron), they may be connected at spaced intervals to the heating pipe and become a part of a cathodic protective system of the sacrificial electrode type. Alternatively, a continuous pipe or member 52 of like electrode material may be in-

serted in one or more vent channels 47 and appropriately connected at spaced intervals to the heating pipe for the cathodic protection. This arrangement has the important advantage that the electrode may be readily replaced if and when replacement becomes necessary. Of course, if the cathodic protective system is of the impressed voltage type, the electrode materials may be selected accordingly, as previously described.

It is believed that the invention and its numerous attendant advantages will be fully understood from the foregoing description, and it is obvious that numerous changes may be made in the form, construction, and arrangement of the several parts without departing from the spirit and scope of the invention, or sacrificing any of its attendant advantages, the forms herein disclosed being preferred embodiments for the purpose of illustrating the invention.

What is claimed is:

1. The method of protecting a metallic pipe in a heat distribution system, which is adapted to carry a heated fluid therethrough, from the corrosive deteriorating effects of moisture externally thereof which consists of
 - (a) telescopically mounting the pipe within a tubular sheath of water impervious material;
 - (b) substantially filling the space between the sheath and the pipe with thermally insulating material which is characterized by having good dielectric properties when dry but having some electrical conducting properties when wet;
 - (c) mounting one or more electrodes in contact with the insulating material in the sheath in radially spaced relation to the pipe, and operatively distributed along the length of the pipe, with means associated therewith for making the pipe the cathodic portion and the electrodes the anodic portion of a cathodic protective system; and
 - (d) circulating a heated fluid through the pipe to cause moisture within the thermally insulating material surrounding the pipe to be driven radially outwardly toward the sheath to thereby open-circuit the cathodic protective system,
 whereby when the heat distribution system is first installed and before the circulation of heated fluid therethrough, and when circulation of the heated fluid may be seasonally terminated thereby causing redistribution of moisture within the thermally insulating material, and when moisture may otherwise reach the proximity of said pipe as by leaks in the tubular sheath or in the pipe itself, the cathodic protective system provides continual protection for the pipe against corrosion.
2. The method as set forth in claim 1 in which a longitudinally extending air vent passage is provided within said insulating material, radially spaced from the pipe, and extending the full length of such material, for removing moisture that is driven toward the vent passage by the circulation of heated fluid through such pipe.
3. The method as set forth in claim 1 in which the cathodic protective system includes indicating means for observing the flow of current through the cathodic protective system.
4. The method as set forth in claim 1 in which the pipe is made of ferrous material and in which the cathodic protective system is of the sacrificial electrode type with the electrodes being made of a metal which is electropositive with respect to the material of the pipe.
5. The method as set forth in claim 2 in which one or more electrodes of the cathodic protective system are located in said air vent passage.
6. The method as set forth in claim 1 in which the tubular sheath is of electrically nonconducting material in addition to being water impervious.
7. The method of protecting a metallic pipe in a heat distribution system, which is adapted to carry a heated fluid therethrough, from the corrosive deteriorating effects of moisture externally thereof which consists of

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- (a) telescopically mounting the pipe within a tubular sheath of water impervious, electrically non-conducting material;
- (b) substantially filling the space between the sheath and the pipe with thermally insulating material of a type which will not conduct electricity when dry but will conduct electricity when damp or wet;
- (c) providing in the thermally insulating material a longitudinally extending air vent passage which extends the length of the insulating material and is radially spaced from the pipe;
- (d) mounting a sacrificial electrode in contact with the insulating material in the sheath, in radially spaced relation to the pipe, and with the sacrificial electrode extending substantially continuously through the length of the sheath and being electrically connected to the pipe by metallic conductors at spaced points along the length of the pipe, to thereby provide a sacrificial electrode protective system; and
- (e) circulating a heated fluid through the pipe to cause moisture in the insulation material surrounding the pipe to be driven outwardly toward the sheath and toward the vent passage to thereby open-circuit the sacrificial electrode protective system and to force the moisture into said air vent for conduction away from said distribution system,
- whereby when the heat distribution system is first installed and before the circulation of heated fluid there-through, and when circulation of the heated fluid may be seasonally terminated, thereby causing redistribution of

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moisture within the system, and when moisture otherwise may reach the proximity of said pipe, the sacrificial electrode protective system provides continual protection for the heated pipe.

8. The method as set forth in claim 7 in which the sacrificial electrode is located in said air vent passage.

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