

[54] **SYSTEM FOR ELECTRICALLY HEATING FLUID-CONVEYING PIPE LINES AND OTHER STRUCTURES**

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[51] Int. Cl. H05b 3/00, F24j 3/04

[58] Field of Search.....219/300, 301, 10.49, 10.51, 219/535; 137/341; 138/33; 174/15

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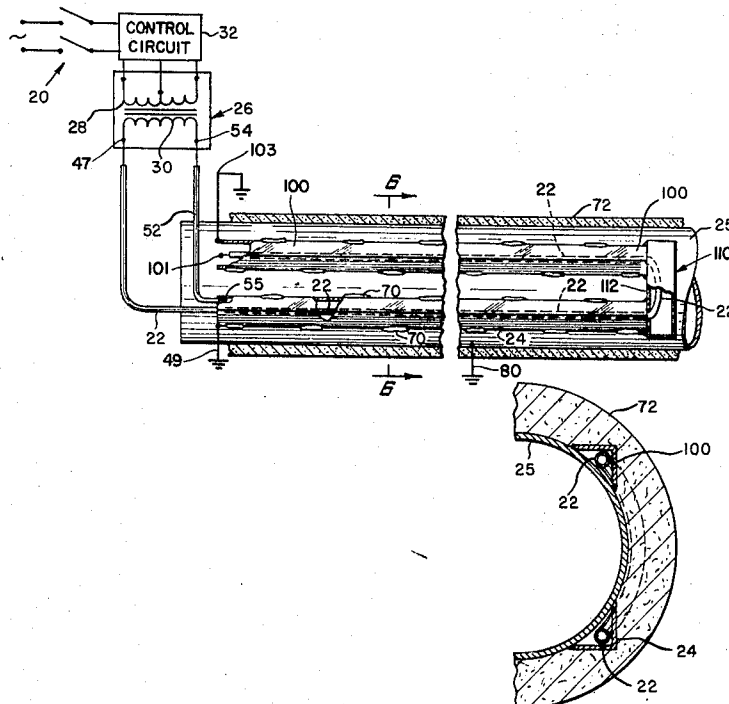
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[57] **ABSTRACT**

A heating system for electrically heating an electrically conductive fluid-transportation pipe or other electrically conductive structure by positioning an electrically conductive cover or shroud on the pipe to cover a peripheral portion of the pipe and an electrical conductor extending along the periphery of the pipe so as to complete a magnetic field path through the covered, peripheral pipe portion. The cover and the conductor are serially connected in a load circuit across an A.C. power supply source that alternating current flowing in the pipe and the cover is concentrated at and thereby substantially confined to the covered peripheral pipe portion and the inner surface of the cover as a result of the magnetic field that is produced by alternating current flowing through the conductor. The cover is fixed to the pipe by spaced apart stitch welds extending along opposite sides of the cover. The stitch welds on one side of the cover are staggered relative to the stitch welds on the other side thereof. Means are provided for substantially cancelling any current leakage straying along the outer periphery of the pipe from the portion that is covered by the cover.

5 Claims, 9 Drawing Figures



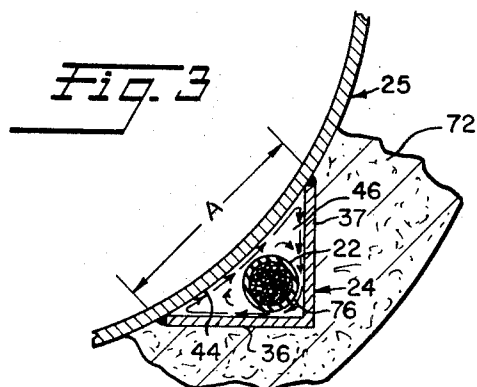
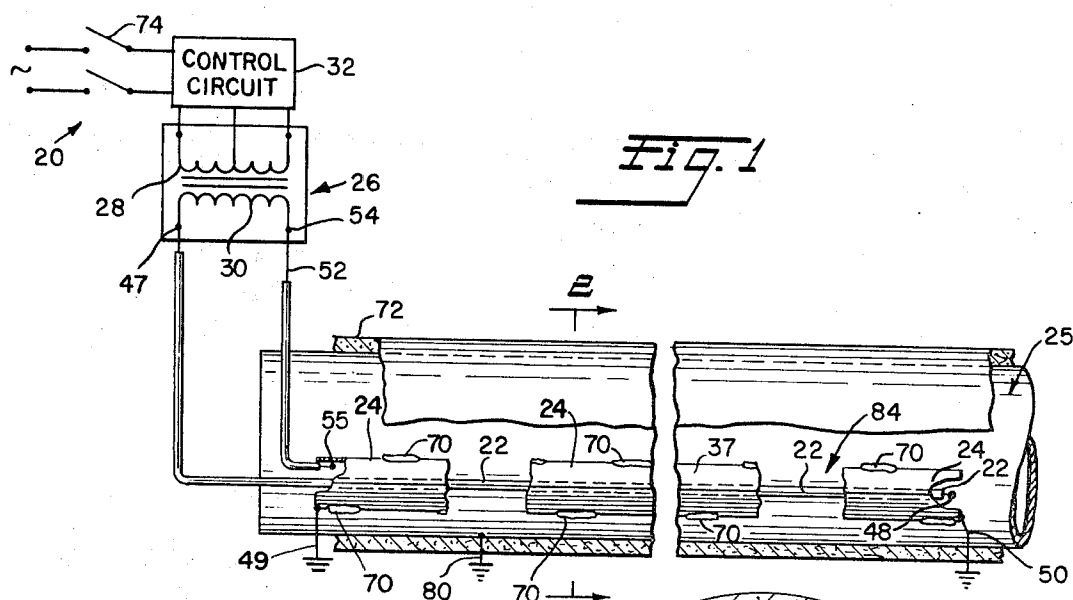
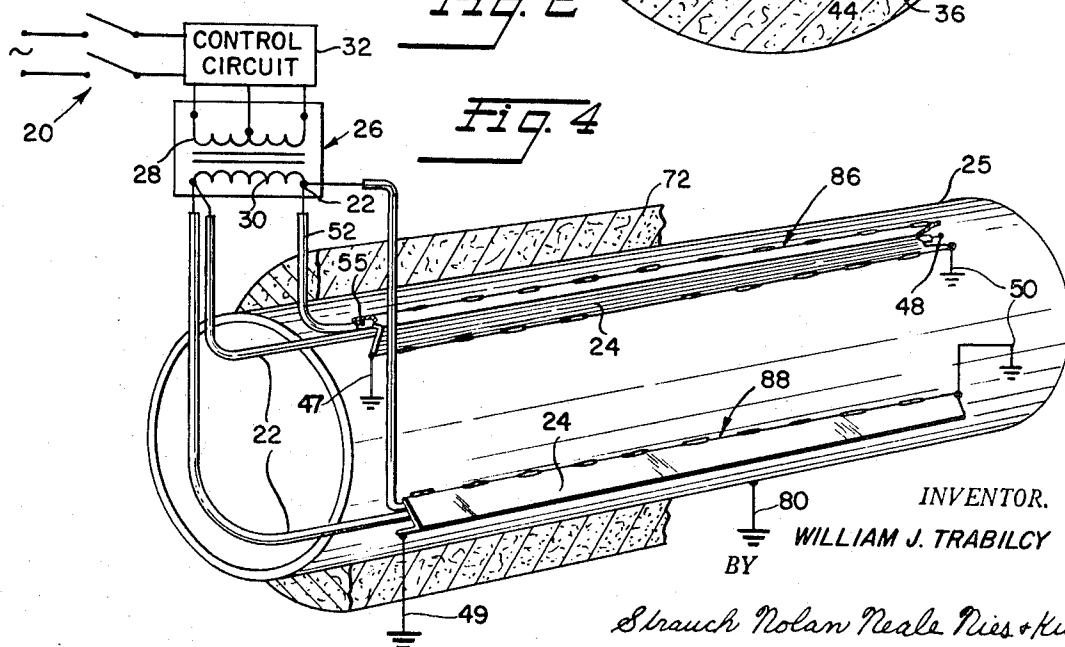
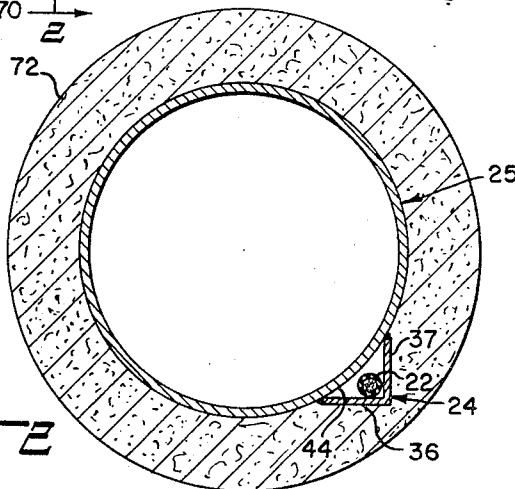


Fig. 2

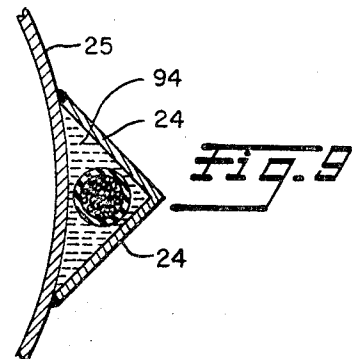
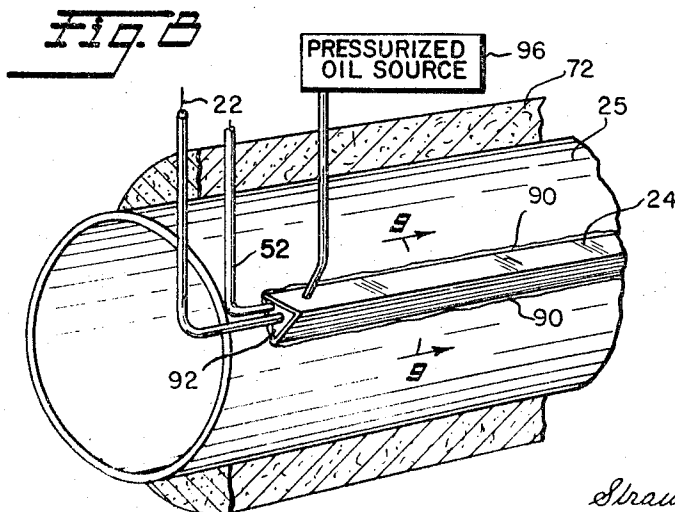
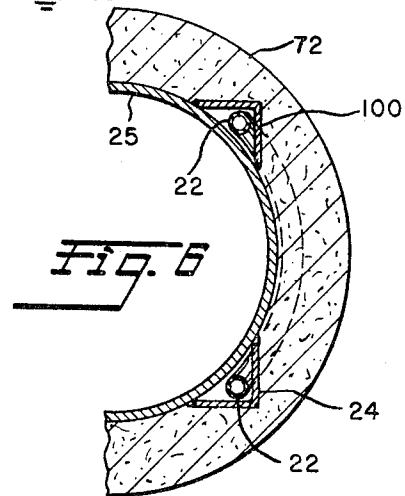
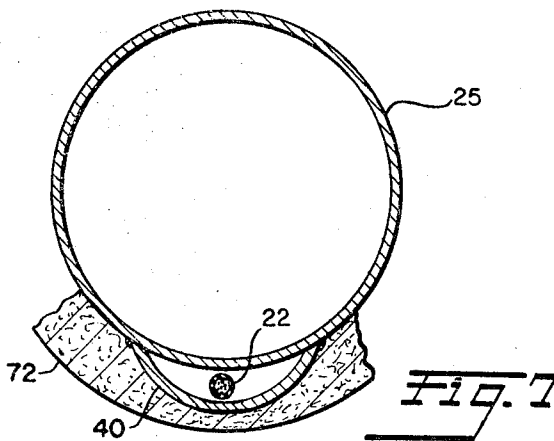
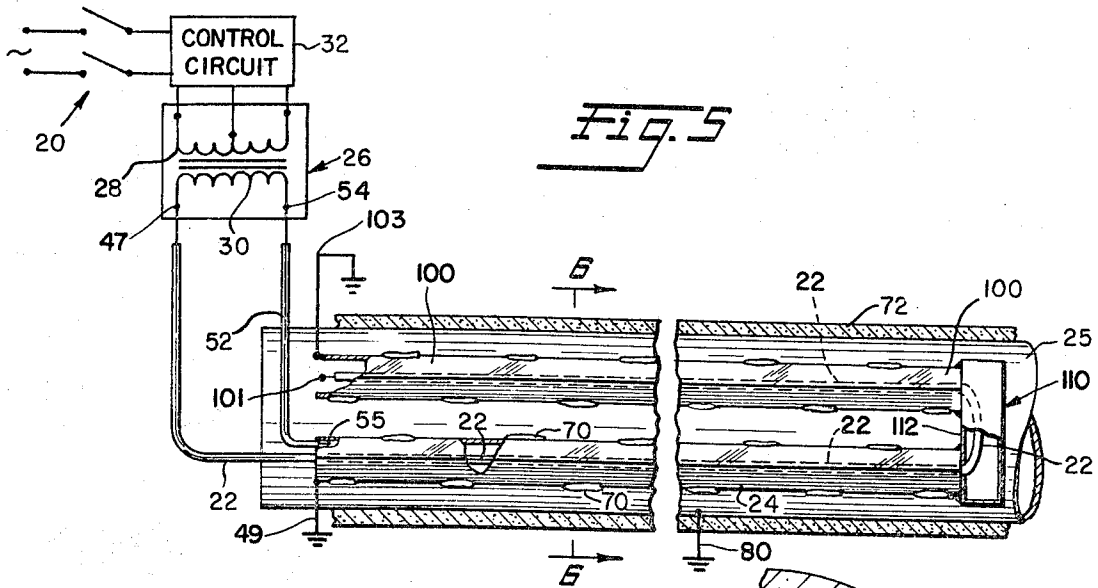


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SYSTEM FOR ELECTRICALLY HEATING FLUID-CONVEYING PIPE LINES AND OTHER STRUCTURES

FIELD OF INVENTION

This invention relates to electrical heating systems that are particularly applicable for heating fluid-transporting pipe lines or other structures by passing an electrical current through the wall of the pipe line or other structure.

BACKGROUND

In recent years, a significant need has developed for an efficient, inexpensive system for heating relatively large and usually long pipe lines that are used in conveying flowable materials in a liquid state from one place to another. For example, a project is currently under consideration for piping oil some 800 miles from the Arctic North Slope in Alaska to shipping facilities at the Port of Valdez. Commercially feasible and technically practical heating systems proposed prior to this invention are, however, unsatisfactory in one way or the other for service with this type of pipe line installation.

There are many different types of pipe line heating systems available. For example, it heretofore has been the practice to heat fluid-conveying pipe lines by steam heated tracer lines, electrically heated tracer lines, electrical wrap-around cables, or embedded or sheath-contained electrical heating elements, all of which effect a transfer of heat to the flow line entirely by conduction and convection. These pipe line heating systems each have shortcomings and disadvantages which make their use generally objectionable. The disadvantages for some of these prior pipe line heating systems are discussed and evaluated in detail in U.S. Pat. No. 3,423,570 issued to W. J. Trabilcy on Jan. 21, 1969 for Electrical Radiant Heating System for Fluid-Receiving Conduit Structures, among others.

One type of electrically heated tracer line is described in U.S. Pat. No. 3,293,407 issued to M. Ando on Dec. 20, 1966, for Apparatus for Maintaining Liquid Being Transported in a Pipe Line At An Elevated Temperature. With this type of heating system, the heat generating pipe, which is separate from the fluid-conveying pipe line, is usually extended along the outside of the pipe line in the form of a tracer, and an electrical, heat-generating current is passed through the heat-generating pipe but not through the fluid-conveying pipe line. This is accomplished by creating a magnetic field around an inner conductor which passes through the current-carrying, heat generating pipe to concentrate the current flowing in the heat-generating or heat-tracing pipe mainly along the inner periphery of the heat-generating pipe. This type of heater is also disclosed in U.S. Pat. No. 2,802,520 issued to W. J. Trabilcy on Aug. 13, 1957 for Transportation System for Viscous Liquids.

The type of electrically heated tracer pipe described in U.S. Pat. No. 3,293,407 has three major disadvantages. First, the heat developed by passing a current only through the heat-generating tracer pipe must be transferred entirely by conduction and convection to the fluid-conveying pipe line. This mode of heat transfer is inefficient particularly when compared with so-called pipe line impedance heating systems in which

the heat-generating current is passed directly through the wall of the fluid-conveying pipe line.

Second, the inner conductor of the above-mentioned electrically heated tracer line can easily burn up unless the heat is properly and quickly dissipated from the heat-generating pipe. To avoid this objectionable condition the heat-generating pipe, in practice, is usually placed in an oven. The oven is formed by spacing oversized flow line thermal insulation radially from the periphery of the flow line by a series of axially spaced, annular spacers that are assembled on the flow line. This factor alone adds considerably to the expenses of labor and materials, particularly for long pipe lines of relatively large diameter.

Third, unavoidable current leakage passing from the heat generating tracer line to the flow line and drained off through electrical ground connections creates an electrolytic action that may cause deterioration of buried pipes, electrical conduit, and the like as well as other equipment that may be connected or adjacent to the pipe line.

Apart from the foregoing conduction type of pipe line heating systems wherein heat is transferred by conduction to the flow line, impedance type heating systems have satisfactorily been developed and used in various applications to heat pipe lines. Examples of such systems are disclosed in the afore-mentioned Trabilcy U.S. Pat. No. 2,802,520, U.S. Pat. No. 2,909,638 issued to W. J. Trabilcy on Oct. 20, 1959 for System For Preheating and Transporting Viscous Fuel and the Like, and U.S. Pat. No. 2,981,818 issued to W. J. Trabilcy on Apr. 25, 1961 for Type Metal Transportation System. In the impedance of eddy current type of heating systems disclosed in each of these patents, the electrical, heat-generating current is passed directly through the flow line so that the flow line becomes the load or heating element to transfer heat directly to the fluid in the flow line. This mode of heating is very efficient, and it heats the fluid in the flow line more rapidly than those systems in which the heat must be transferred entirely by conduction and connection from a steam tracer or other heat generating pipe extending along the outside of the flow line.

The systems disclosed in the above-mentioned Trabilcy patents for passing the electrical, heat-generating current directly through the wall of the flow line are exceptionally satisfactory and economical for small and medium size pipe line installations. But they are not as economical for use with relatively large pipe lines. In this connection, the heat is generated by applying an A.C. potential directly to an electrically conductive pipe line to create a potential difference between the pipe and ground as well as spaced points along the pipe. It therefore is sometimes necessary to electrically isolate the current-carrying pipe line from ground and equipment such as valves which may be installed in or connected to the pipe line. Special flange assemblies are usually utilized to electrically isolate valves, pumps, and similar equipment from the current-carrying pipe line, and it will be appreciated that the cost of such flanges increases as the pipe diameter increases.

SUMMARY AND OBJECTS OF INVENTION

The present invention advantageously preserves impedance type heating of the fluid-conveying pipe line,

but avoids the disadvantages of the prior impedance type heating systems as well as the shortcomings associated with the other heating systems considered above.

According to this invention, an insulated electrical conductor is positioned preferably along the outer periphery of the fluid-conveying pipe and an open sided, electrically conductive shroud or cover member is positioned over the conductor to cover the conductor and a peripheral portion of the fluid conveying pipe line. The electrical conductor therefore extends through a space peripherally or circumferentially delimited by the conductor-covering shroud and the covered portion of the fluid-conveying pipe line, which is also made of electrically conductive material.

One end of the electrical conductor is electrically connected to one terminal of a suitable A.C. power source. The other end of the conductor may be connected to the pipe adjacent to and preferably just under the adjacent end of the shroud. A second power source terminal is connected to the pipe adjacent to and preferably just under the end of the shroud remote from the connection between the covered conductor and the pipe, thereby completing the load circuit and applying A.C. voltage across the load. The pipe itself is normally connected to ground, and the shroud-covered conductor is electrically insulated from the pipe and the shroud except for its previously mentioned connection to the pipe. With this circuitry, current for one-half cycle will flow from the power source, through the shroud-covered conductor and back to the source through the inner periphery of the shroud and the outer, shroud-covered portion of the pipe line periphery.

Confinement of the current flowing in the pipe and the shroud to the inner surface of the conductor-covering shroud and the shroud-covered outer portion of the pipe is achieved by utilizing the shroud and the shroud-covered pipe line portion to peripherally surround the shroud-covered conductor and by the magnetic field produced around the conductor as a result of passing alternating current therethrough. In essence, a coaxial conductor effect is achieved wherein current flowing in the outer conductor is confined to or concentrated at the inner periphery of the outer conductor by the magnetic field around the inner conductor. This phenomenon is frequently referred to as skin or proximity effect.

From the foregoing it is clear that current flowing in the fluid-conveying pipe line will produce heat in the pipe line in a manner similar to the impedance type heating systems described in U.S. Pat. Nos. 2,802,520, 2,909,638, and 2,981,818. However, in the system of this invention the heat-generating current flowing in the pipe will be confined substantially to the shroud-covered periphery of the pipe line. With the heating system of this invention, therefore, current can be made to flow through only a portion of the pipe line periphery, and even though the pipe line periphery constitutes an integral electrical conductor, the remainder of the fluid-conveying pipe will be at ground potential. In other words,—and disregarding any current leakage—there will be no potential difference at spaced points along the remainder of the fluid-conveying pipe or between any point on the remainder of the

fluid-conveying pipe and ground. Furthermore, the exterior surface of the shroud will also be at the potential of the pipe, namely ground.

As a result, the economical disadvantages of the prior pipe line impedance type heating systems as applied to relatively large pipe lines are avoided in that the system of this invention does not require the fluid pipe line to be electrically isolated from ground or from valves or other equipment connected in or to the pipe line. Standard flanges and other fittings may therefore be utilized in fabricating the pipe line, and no precautions are required for electrically isolating the pipe line from ground. Indeed, the fluid-conveying pipe line in this invention, in contrast, is normally clamped to ground.

It furthermore will be appreciated that the pipe line system containing this invention is safe and effectively shock-free. In this connection, the contacting of any exposed portion of the pipe line or the conductor-covering shroud will normally not result in a shock or spark. In addition, it will be appreciated that no current flows along the inner periphery of the fluid-conveying pipe line. Thus, electrically conductive liquids, such as caustic solutions, may safely be transported since they will be electrically disassociated from the current carrying portions on the pipe line and the conductor-covering shroud.

All of the foregoing advantages are realized, in addition to preserving the basic advantage that is achieved by passing the heat-producing current directly through the fluid-conveying pipe. This heating of the fluid-conveying pipe results in the efficient and rapid transfer of the heat to the fluid in the pipe line. Furthermore, by establishing mechanical contact between the conductor-covering shroud and the fluid-conveying pipe, the heat produced in the shroud as a result of passing the heat-producing current through the shroud will be transferred by conduction through the fluid-conveying pipe to the fluid in the pipe.

By virtue of the rapid heat dissipation that takes place by electrical heating of the fluid conveying pipe line, there is no need for over-sized insulation and other parts which are required to form an oven for dissipating the heat from conventional tracer type heating pipes. With the present invention, therefore, a significant savings in thermal insulation is realized without danger of burning up the inner conductor in the heater. By virtue of this and other factors, the system of this invention is inexpensive, as well as being reliable, safe, efficient and easy to install.

In addition, the system of this invention can easily be made explosion proof by providing a seal between the conductor-covering shroud and the fluid-conveying pipe. The sealed-off enclosure containing the inner conductor may be filled with a suitable fluid. Alternatively, the sealed-off enclosure may be filled with a suitable high dielectric transformer type oil which has the advantage of providing an effective heat transfer path for conducting heat from the inner conductor to the fluid-conveying pipe. The oil may furthermore be pressurized to detect leaks.

Although most of the current flowing in the conductor-covering shroud and the pipe line between spaced apart connection points at the ends of the shroud is concentrated at the inner periphery of the channel and

the covered outer peripheral portion of the fluid-conveying pipe, some current leakage unavoidably occurs. While the potential from this current leakage is very small and therefore is not hazardous, it could promote an electrolytic action to cause the deterioration of the pipe line, equipment connected thereto, and equipment in the proximity of the pipe line. According to a further aspect of this invention, this current leakage may be neutralized or cancelled by providing two conductor-covering, coextensive, side-by-side shrouds, by extending the inner conductor serially through the spaces delimited by the two shrouds, by connecting the end of the conductor remote from the power source to the adjacent end of the second shroud, and by electrically connecting that end of the first channel which is remote from the second shroud to the A.C. power source. Thus for each A.C. half-cycle, the magnetic fields around the two covered sections of the inner conductor will be opposing each other when viewed relative to a given direction along the pipe. It was found that this arrangement cancels the leakage current, thereby effectively eliminating equipment-deteriorating electrolytic action.

In addition to heating pipe lines, the heating system of this invention may be utilized with equal advantage to heat other fluid-receiving structures, such as tanks, for example. Indeed, oil tanks may safely be heated with the system of this invention. Also, the system of this invention may be employed to heat other forms of structures such as space heating plates or frames.

With the foregoing in mind, it is a major object of this invention to provide a novel system for efficiently and inexpensively heating fluid-conveying pipe lines and other structures.

A more specific object of this invention is to provide a novel pipe line heating system which overcomes the disadvantages of prior impedance pipe line heating systems, but yet achieves the heating of the pipe line by passing a heat-producing current directly through the pipe line.

Another object of this invention is to provide a novel electrical heating system for pipe lines wherein leakage currents are neutralized or cancelled to eliminate equipment-deteriorating electrolytic action.

These and other objects will appear as the description proceeds in connection with the appended claims and annexed, below-described drawings.

DESCRIPTION OF DRAWINGS

FIG. 1 is a partially schematic, partially sectioned, longitudinal elevation illustrating one embodiment of this invention for heating a fluid-conveying pipe line;

FIG. 2 is a section taken substantially along lines 2—2 of FIG. 1;

FIG. 3 is a fragmentary enlargement of the cross-sectioned heater shown in FIG. 2;

FIG. 4 is a partially schematic, perspective view of another embodiment of this invention;

FIG. 5 is a partially schematic, partially sectioned, longitudinal elevation of still another embodiment of this invention;

FIG. 6 is a fragmentary section taken substantially along lines 6—6 of FIG. 5;

FIG. 7 is a transverse section similar to FIG. 2, but illustrating still another embodiment of this invention;

FIG. 8 is a fragmentary partially schematic perspective view illustrating a further embodiment of this invention;

FIG. 9 is an enlarged section taken substantially along lines 9—9 of FIG. 8.

DETAILED DESCRIPTION

Referring to FIG. 1, the heating system of this invention mainly comprises a suitable A.C. power source 20, an electrically insulated conductor 22, and an electrically conductive cover or open-sided shroud 24 for conductor 22. A liquid-conveying or transportation pipe line to be heated is indicated at 25.

The A.C. power source 20 may advantageously comprise a transformer 26 having a primary winding 28 and a secondary winding 30. Primary winding 28 is connected across a power line which furnishes A.C. current at a suitable frequency. Power sources supplying current at commercially available frequencies, such as, for example, 60 cycles, may be utilized with this invention.

Advantageously, a temperature responsive control circuit 32 may be provided to compensate for temperature-induced variations in the electrical resistance of pipe line 25 and shroud 24. Preferably, control circuit 32 is of the type described in the aforementioned Trabily U.S. Pat. No. 2,981,818. According to this patent, the control circuit is responsive to temperature induced variations in the electrical resistance of the pipe line to re-establish and restore a pre-selected power input to the secondary load circuit. In this invention, shroud 24 and a portion of pipe line 25 form a part of the electrical load, and when the temperature of the pipe line and the shroud increases, the electrical resistance of the pipe line and the shroud will increase to cause a corresponding decrease in the load current, unless otherwise compensated for. In response to the temperature variations the control circuit 32 varies the number of transformer primary coils that are connected across the voltage source to thereby vary the voltage induced in the secondary so as to maintain the power input at a desired level. For this purpose, primary winding 28 is of the multiple-tap type as shown.

As shown in FIGS. 1—3, conductor 22 extends along the outer periphery of pipe line 25. Shroud 24 is positioned over conductor 22 to cover conductor 22 and a portion of pipe line 25. Shroud 24 may be of any configuration having an open side and shaped so that when it is positioned on the pipe line it acts as a cover for conductor 22 and a peripheral portion of pipe line 25.

In this embodiment, shroud 24 is in the form of a conventional structural angle iron having a pair of mutually perpendicular legs respectively indicated at 36 and 37 in FIGS. 2 and 3. Alternately, shroud 24 may be, by way of example, a three-sided, structural channel (not shown), or it may be a smoothly contoured member which is curvilinear in cross section as indicated, for example, at 40 in FIG. 7. The particular cross-sectional configuration of channel 24 is not important so far as operation is concerned.

In the embodiment shown in FIGS. 1—3, shroud 24 is straight and extends longitudinally along pipe line 25 so that it is parallel to the longitudinal axis of the pipe line. Alternatively, shroud 24 may extend in any desired direction along the pipe line, and it need not be

straight. Instead, it may be curved, or it may be made up by perpendicularly extending sections to extend along an unshown branch line that would be connected by an unshown tee or elbow to pipe line 25. Shroud 24 may furthermore be shaped to follow any bends in pipe line 25.

As shown in FIGS. 2 and 3, shroud 24 is seated against pipe line 25 so that the peripheral pipe line portion indicated at 44 closes the open side of shroud 24. Shroud 24 thus cooperates with portion 44 to peripherally enclose a space indicated at 46. Conductor 22, which extends longitudinally of shroud 24, extends through space 46. One end of conductor 22, extending beyond shroud 24, is connected to a terminal 47 of secondary winding 30. The opposite end of conductor 22 is electrically connected to pipe line 25 adjacent to and preferably just under the adjacent end of shroud 24. This connection is indicated at 48 in FIG. 1. Alternatively, conductor 22 may be connected directly to shroud 24. This end of shroud 24 and pipe line 25 are advantageously grounded as indicated at 50.

The entire portion of conductor 22 that is covered by shroud 24 is covered with electrical insulation so that except for the connection 48, conductor 22 is electrically insulated from shroud 24 and pipe line 25. The end of shroud 24 opposite from connection 48 may be grounded as indicated at 49. The second terminal 54 of secondary winding 30 is connected by an electrically insulated conductor 52 to the pipe line at a region adjacent to and preferably just under the end of shroud 24 that is grounded at 49. The connection between conductor 52 and pipe line 25 is indicated at 55 in FIG. 1. Alternatively, conductor 52 may be connected directly to the shroud.

As shown, conductor 22 may be a suitable cable having a current-conducting core covered with electrical insulation and sized to carry the current drawn by the load.

The position of conductor 22 within space 46 is not critical. Conductor 22 may be seated on and thus supported by one of the legs 36 and 37 of shroud 24. Alternatively, conductor 22 may rest on the periphery of pipe line 25, or it may be centrally located in space 46 in spaced relation to shroud 24 and pipe line 25.

Shroud 24 is advantageously fixed to pipe line 25 by any suitable means such as welding. If shroud 24 is to be welded to the pipe line (which is usually steel pipe), it is evident that shroud 24 also will normally be made of steel or other suitable, ferric material that is easily welded to the pipe by conventional and inexpensive techniques. Shroud 24 may be fixed to pipe line 25 by stitch welding as indicated at 70 in FIG. 1. The stitch welding comprises spaced apart welding strips along the edges of both of legs 36 and 37 as shown.

Stitch welding shroud 24 to pipe line 25 is advantageously economical, and the stitch welds 70 provide adequate area for transferring heat by conduction from shroud 24 to pipe line 25. It is not necessary that shroud 24 be welded to pipe line 25 continuously along the entire lengths of legs 36 and 37 to provide the necessary area for conducting heat from shroud 24 to pipe line 25. Stitch welds 70 are quite adequate for this purpose, and they are less expensive as compared with the continuous welds.

Furthermore, it is also not essential that shroud 24 be welded to pipe line 25. Instead, shroud 24 may be held in place by any suitable means such as, for example, straps or bands extending around the periphery of pipe line 25.

As shown in FIG. 1, transformer 26 may be energized by closing a switch 74. The transformer secondary load circuit for one direction of current flow may be traced from terminal 47, through conductor 22, through shroud 24 and portion 44 of pipe line 25 (as will be explained in greater detail shortly) and back to terminal 54 through conductor 52.

The current passing through conductor 22 will produce a magnetic field or loop peripherally around the conductor as indicated at 76 in FIG. 3. The direction of field 76 will, of course, be determined by the direction of current flowing through conductor 22. Owing to the magnetic field 76, the current density will not be distributed uniformly throughout shroud 24 and pipe line 25. Instead, field 76 will concentrate the current in shroud 24 and pipe line 25 to the inner periphery or inwardly facing surface of shroud 24 and that outer peripheral portion of pipe line 25 that is covered by shroud 24, assuming, of course, that the thickness of pipe line 25 and channel 24 are greater than the penetration depth of the current. This phenomenon is frequently referred to as "proximity effect". As shown, the stitch welds 70 along the edge of leg 36 on one side of shroud 24 are staggered with respect to the stitch welds 70 along the edge of leg 37 on the opposite side of shroud 24.

According to this invention, shroud 24 serves to close a loop that passes around conductor 22 and through the pipe line portion 44. In effect, the pipe line portion 44 acts as a keeper to close the gap defined by the open side of shroud 24. By peripherally surrounding conductor 22 with shroud 24 and the pipe line portion 44, the current flowing in pipe line 25 and shroud 24 will be concentrated at and substantially confined to the outer periphery of the shroud-covered pipe line portion 44 and to the inner periphery of shroud 24 by the magnetic field which is produced around conductor 22 by flow of alternating current therethrough. It will be noted that the illustrated staggered arrangement of welds 70 on opposite sides of shroud 24 provide for a more uniform distribution of heat in the pipe as compared with an arrangement of unstaggered stitch welds. To achieve this condition, the closed path peripherally surrounding conductor 22 and defined by shroud 24 and the covered pipe line peripheral portion 44 is required to be substantially free of air gaps. However, relatively small air gaps, as between the pipe line periphery and legs 36 and 37 can be tolerated. Furthermore, it is not necessary that shroud 24 or pipe line 25 be made of ferro-magnetic material to achieve the foregoing skin or proximity effect. This skin effect may be achieved with copper.

In the circuit shown in FIG. 1, therefore, alternating current flowing between connections 48 and 55 will be concentrated at and substantially confined to the outer peripheral pipe line portion covered by shroud 24 and the inner surface of shroud 24, even though the entire pipe line is a single, integral conductor.

The depth that the current will penetrate into shroud 24 and pipe line 25 will, from known formulas, be a

function mainly of the electrical resistance of the material and the frequency of the A.C. current. The penetration depth is very small and is normally on the order of 1 mm, particularly for commercially available frequencies such as 60 cycles. Standard fluid-conveying pipes and standard structural members, such as shroud 24, commonly have thicknesses that are significantly greater than 1 mm or any other expected current penetration depth. For example, structural members such as, plates or angle irons and fluid-conveying pipes normally are at least 2 mm thick and usually more.

Except for negligible current leakage, therefore, no current will flow along the outer periphery of shroud 24 or the inner periphery of pipe line 25. Moreover, no current passing between connections 48 and 58 will flow in that part of pipe line 25 that is not covered by shroud 24. Instead, the energized portion of pipe line 25—or more particularly the portion of pipe line 25 carrying the heat-generating current—is indicated by the dimension A in FIG. 3, and in this pipe line portion, the current will only flow along the outer periphery, and not along the inner periphery.

Thus, the portion of pipe line 25 which is not covered by shroud 24 and the outer surface of shroud 24 are substantially at ground potential particularly since shroud 24 and pipe line 25 are grounded by the connections at 50 and 49. Furthermore, pipe line 25 will normally be grounded at other points as at 80 in FIG. 1. Thus, the exposed surfaces of pipe line 25 and shroud 24 will be substantially at ground potential.

By passing an electrical current through pipe line 25 it will be appreciated that heating of the pipe line takes place. Sometimes, this mode of heating is referred to as heating by joules heat. The current-generated heat in pipe line 25 is transmitted directly to the fluid (such as oil) in the pipe line. Producing heat by passing current directly through the outer periphery of the pipe line portion 44 has a number of advantages as compared with those heating systems in which all of the generated heat must be transferred to the pipe line by conduction.

First, the temperature gradient between pipe line 25 and the fluid in the pipe line is not as great as the gradient between the fluid and a steam or electrically heated tracer line extending along the outside of the pipe line and requiring all of the heat to be transferred to the pipe line by conduction and convection. Second, the heat generated by passing a current directly through portion 44 of pipe line 25 is quickly dissipated or distributed so that it is not necessary to build ovens or to take other precautionary measures to keep conductor 22 from burning up by the local heat generated in the pipe line and shroud 24. So-called impedance heating of pipe line 25 provides for a quicker and more efficient heating of the pipe line and the fluid in the pipe line as compared with steam or electrically heated tracer lines.

Since it is unnecessary to make an oven in the pipe line thermal insulation for the heating system of this invention, the thermal insulation 72 may be of the simplified configuration as illustrated in FIGS. 1 and 2. As shown, this standard form of thermal insulation does not require any special construction to accommodate the heating system of this invention. Thus, the costs of fabricating and installing the thermal insulation are minimized.

In addition to the heat generated by passing current through pipe line portion 44, the heat generated in shroud 24 by passing part of the current therethrough will be transferred by conduction to pipe line 25 and from there to the fluid in the pipe line.

Since current flow in pipe line 25 and shroud 24 is confined to the channel-covered outer periphery of pipe line portion 44 and to the inner surface of shroud 24, and, more particularly, since the remainder of pipe line 25 and channel 24 is at or substantially at ground potential, no problems or difficulties are encountered by utilizing standard electrically conductive flanges or other connections for valves, pumps or other equipment that may be installed in the pipe line. Furthermore, it is not necessary, and in fact not desired to electrically isolate pipe line 25 from ground. The economical disadvantages associated with the application of prior pipe line impedance heating systems to relatively large diametered pipes are therefore avoided without sacrificing the basic advantage of such prior systems, namely the passing of heat-generating current directly through the pipe line itself.

The heater shown in FIGS. 1-3 is simplified, relatively inexpensive construction as well as being easily to install. Standard inexpensive structural members, such as angle irons are economically employed as the shroud 24, and costs of mounting the cover or shroud 24 on the pipe line are relatively low. In addition, no modification of the pipe line is required and no special parts such as heat dissipating ovens or electrically insulated flanges are required in the pipe line construction.

In the embodiment just described one heater unit (namely one shroud 24 and one conductor 22) as generally indicated at 84 is employed to heat pipe line 25. If additional heating capacity is desired, a plurality of heater units may be employed as shown in FIG. 4. These heater units are respectively indicated at 86 and 88.

Heater units 86 and 88 are each of the same construction as the heater unit shown in the embodiment of FIGS. 1-3, like reference characters being applied to designate like parts and circuit connections. In the embodiment of FIG. 4, heater units 86 and 88 are connected in parallel to the transformer secondary winding 30. Both heater units 86 and 88 are spaced apart in generally parallel relation and extend longitudinally relative to the pipe line axis.

Additional heating capacity may be achieved by increasing the pipe line area that is covered by shroud 24. This may be done by increasing the angle between channel legs 36 and 37.

If an anti-explosion construction is desired, space 46 may completely be enclosed in the manner shown in FIG. 8. In this embodiment, continuous welds 90 extending the length of shroud 24 are formed along legs 36 and 37. The open ends of shroud 24 are closed by plate members 92 (one shown) which are welded to shroud 24 and pipe line 25 as shown. At one end, conductors 22 and 52 extend through apertures in one of the plate members 92 with a fluid tight fit. For the embodiment of FIG. 1, it is not necessary to extend conductor 22 through the end plate 92 at the other end of shroud 24. Thus the space defined by shroud 24, plate members 92 and the covered periphery of pipe line 25 is sealed to provide a fluid or liquid-tight enclosure in-

dictated at 94 in FIG. 11. A suitable anti-explosion or inert fluid may be introduced into enclosure 94. Advantageously, a high dielectric, transformer type oil may be introduced under pressure into enclosure 94 from a suitable source 96 (see FIG. 8). The oil fills enclosure 96, and, in addition to its electrical insulating properties, it serves as a good heat conduction path for conducting heat generated in conductor 22 directly to pipe line 25 and through shroud 24 to the pipe line. Pressurization of the oil serves to detect leaks.

Although substantially all of the current flowing in pipe line 25 and in shroud 22 is concentrated at the shroud-covered pipe line peripheral portion and at the inner periphery of shroud 24, some current leakage usually occurs along the pipe line. The potential of this current leakage is negligible, and the magnitude of the leakage current is also very small and insignificant and is normally drained off through ground connections to the pipe. The current leakage, therefore, is not hazardous, but it may, under certain conditions, create an electrolytic action to promote deterioration of the pipe line, equipment (such as valves and pumps) connected to the pipe line and equipment in the proximity of the pipe line (such as buried electrical cable). FIG. 5 shows a load circuit that effectively cancels or neutralizes the leakage current flowing along the pipe line.

As shown, a second shroud 100 is provided for in addition to shroud 24. Shroud 100 may be of the same construction as shroud 24. Shrouds 24 and 100 are coextensive and are positioned on the outer periphery of pipe line 25 in parallel, spaced apart, side-by-side relationship. Shroud 100 may be welded to pipe line 25 in the same manner as shroud 24. Both shrouds are shown to be parallel with the longitudinal axis of pipe line 25.

With continued reference to FIG. 5, conductor 22 extends from its connection to transformer 26, passes first through the space delimited by shroud 22, then loops back and passes through the space delimited by shroud 100. Thus conductor 22 passes serially through the spaces delimited by shrouds 24 and 100 respectively so that shrouds 24 and 100 cover successive sections of conductor 22.

The portion of conductor 22 extending between shrouds 24 and 100 may be pulled through a suitable pull box 110. Pull box 110 is particularly useful in anti-explosion systems and, for convenience, may be fabricated from steel or other ferric material that is easily welded to pipe line 25. Pull box 110 has an open bottom and interfittingly seats on the periphery of pipe line 25. The side walls of pull box 110 may be welded to pipe line 25. The adjacent ends of shrouds 24 and 100 may be welded to the side wall 112 of box 110 as shown. It will be appreciated that box 110 is in the form of a shroud and covers the conductor portion extending between shrouds 24 and 100. Box 110 will act in the same manner as shrouds 24 and 100 to confine current flow.

Still referring to FIG. 5, the end of conductor 22 remote from its connection to transformer 26 is connected to pipe line 25 adjacent to and preferably just under the adjacent end of shroud 100 which is remote from pull box 110. This connection is indicated at 101. The adjacent end of shroud 100 may be grounded as indicated at 103. With this circuitry, current in one

direction may be traced from terminal 47 and through conductor 22 to connection 101. From connection 101 current flows back along the inner periphery of shroud 100 and the shroud covered outer peripheral portion of pipe line 25 to pull box 110. From here the current flows along and is confined to the box-covered outer peripheral portion of pipe line 25 to the adjacent end of shroud 24. Current then flows to connection 55 along the inner periphery of shroud 24 and the shroud-covered outer peripheral portion of the pipe line as previously described. From connection 55 the current passes along conductor 52 to terminal 54 to complete the circuit.

The wall thicknesses of pull box 110 is made greater than the penetration depth of the alternating current. As a result, no current will flow along the outer surface of box 110 although some current will be flowing along the inner surface of box 110.

As a practical matter, pull box 110 is optional and may be eliminated particularly for systems that are not to be made explosion-proof. Without pull box 110, current flow will be the same as that just described for the embodiment of FIG. 5. Without pull box 110 it will be noted that current flow between the adjacent shroud ends remote from connections 55 and 101 will be along a confined, small uncovered outer peripheral portion of pipe line 25. The current in this region will flow along essentially the shortest path between the adjacent ends of shrouds 24 and 100 will tend to follow the illustrated portion of conductor 22 extending between shrouds 24 and 100. Current flow between these adjacent ends of shrouds 24 and 100, instead of straying, will substantially be confined to the above-mentioned path. The area of this path along the pipe line periphery is very small and insignificant, and the potential drop in this area is very small and negligible. Thus, even without pull box 110, current flowing in the pipe line will still mainly be confined to the shroud covered pipe line peripheral portions.

The effect of passing alternating current through the section of conductor 22 that is covered by shroud 100 is the same as the previously described effect achieved by passing alternating current through the section of conductor 22 that is covered by shroud 24. But since channels 24 and 100 and their covered conductor sections are side-by-side, the two magnetic fields produced around the two covered sections of conductor 22 will be opposing each other as viewed in a given direction longitudinally along pipe line 25. It was found that this arrangement providing the opposing magnetic fields is effective to substantially cancel any current leakage flowing along pipe line 25 from shroud 24 and 100, and the covered peripheral portions of the pipe line. As a result, the electrolytic action is avoided. In addition, the arrangement shown in FIG. 5 provides for increased heating capacity as compared with the single heater arrangement shown in FIG. 1.

With the heater system of this invention the watt density (watts per square inch of current-conducting pipe line area) will be relatively low. Low watt density is highly desirable, for it indicates that the temperature of the liquid and the non-current carrying pipe portions approach the temperature of the current carrying portions of the heater. In other words, low watt density indicates that heat is not being localized at the heater to

cause the heater to overheat. For example, to heat about 1,000 feet of 16 inch diameter pipe, insulated with 2½ inch thick thermal insulation, from 0° to 150° F., the energy input will be about 36 watts per linear foot of pipe and the watt density will be about 1 watt per square inch of current-carrying pipe line area.

From the foregoing description it will be appreciated that shroud 24 cooperates with only a predetermined portion of pipe line 25 to define a second conductor which peripherally surrounds at least a portion of conductor 22. A portion of pipe line 25 thus forms a part of this second conductor, and the outer periphery of pipe line portion 44 and the inner periphery of shroud 24 define the inner periphery of this second conductor. The magnetic field around conductor 22 thus confines current flowing in pipe line 25 and shroud 24 to only those surfaces of pipe line 25 and shroud 24 which define the inner periphery of the second conductor. It also will be appreciated that conductor 22 is connected at 48 to this second conductor and that this second conductor is connected to conductor 52 and 55.

I claim:

1. A pipe line heating apparatus comprising an electrically conductive fluid transport pipe having magnetic properties, at least one electrically conductive member having magnetic properties, said member being positioned on the outer periphery of said pipe to cover a portion of said outer periphery and cooperating with said pipe to define a hollow heat generating conduit that has a part of its wall in common with a portion of said pipe, an electrical conductor peripherally surrounded by said hollow conduit and extending along the outer periphery of said pipe, the effective length of said electrical conductor that is peripherally surrounded by said hollow conduit being electrically insulated from said hollow conduit, means providing a source of alternating current and having first and second terminals, said hollow conduit and said electrical conductor being serially connected across said first and second terminals to pass heat-producing alternating current through said hollow conduit and said electrical conductor for providing a current-produced magnetic field around said electrical conductor, said magnetic field causing the current flowing in said hollow conductor to be concentrated at the inner periphery of said hollow conduit, the wall thickness of said conduit

being greater than the penetration depth of the alternating current flowing therethrough, and spaced apart stitch welds extending along opposite sides of said electrically conductive member and fixing said electrically conductive member to said pipe, the stitch welds on one side of said electrically conductive member being staggered relative to the stitch welds on the other side of said electrically conductive member.

2. The pipe line heating apparatus defined in claim 1 wherein said electrically conductive member is a structural angle iron.

3. The pipe line heating apparatus defined in claim 1 comprising means for electrically grounding said pipe and said electrically conductive member to maintain the non-current carrying portions of said pipe and said electrically conductive member at least substantially at ground potential.

4. The pipe line heating apparatus defined in claim 1, comprising means for substantially cancelling any current leakage straying along the outer periphery of said pipe from the portion that is covered by said electrically conductive member.

5. The pipe line heating apparatus defined in claim 1, comprising a further electrically conductive member having magnetic properties, said further electrically conductive member being positioned on the outer periphery of said pipe to cover a further portion of said outer periphery and cooperating with said pipe to define a further hollow heat generating conduit that has part of its wall in common with said further portion of said pipe, said further conduit and first-mentioned conduit that is defined by said one member being in side-by-side spaced apart relation, the effective length of said electrical conductor extending serially through said first-mentioned and further conduits, and circuit connection means providing current flow from said source that, in one direction, passes serially through said conductor, said first mentioned conduit and said further conduit to create a further magnetic field that peripherally surrounds the portions of said conductor in said further conduit, said further magnetic field and the first mentioned magnetic field being in opposing relation to substantially cancel any current leakage straying along the outer periphery of said pipe between said one electrically conductive member and said further electrically conductive member.

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