

April 12, 1960

R. J. STEGEMEIER
LIQUID FILLED WELL HEATER

2,932,352

Filed Oct. 25, 1956

2 Sheets-Sheet 1

FIG. 1.

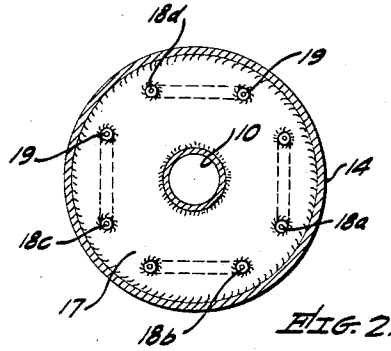
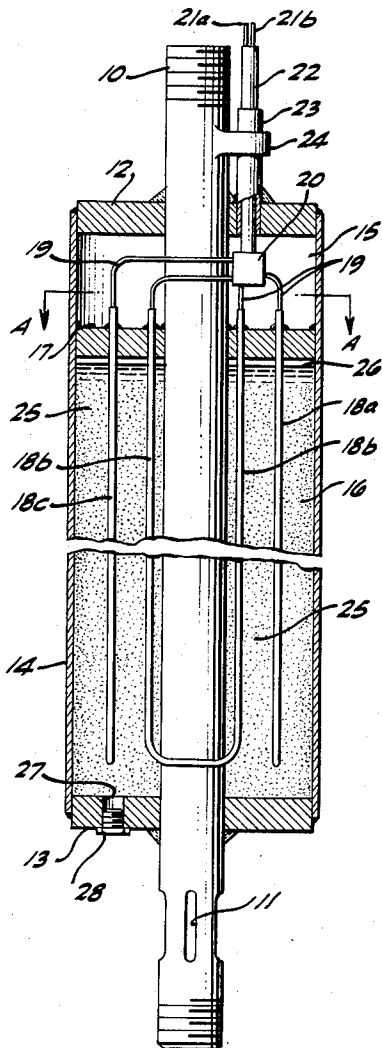
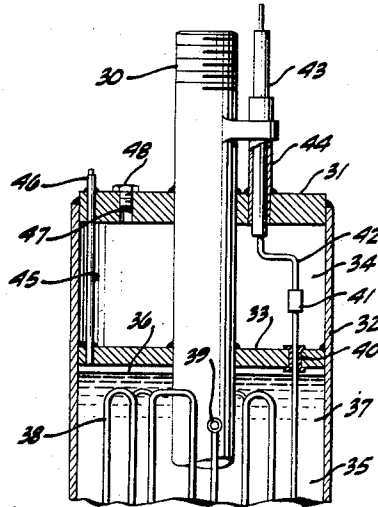


FIG. 3.



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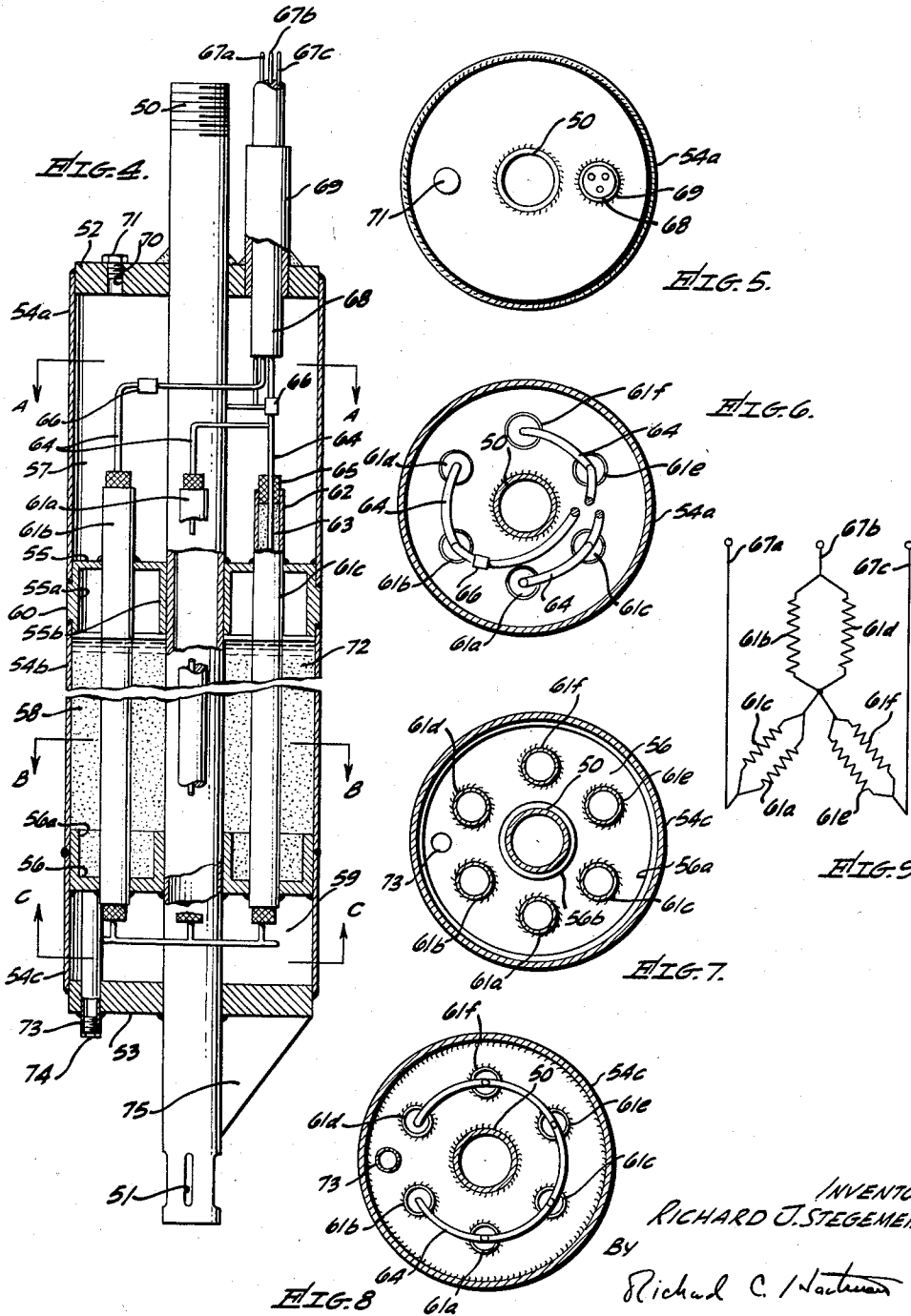
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LIQUID FILLED WELL HEATER

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Application October 25, 1956, Serial No. 618,218

12 Claims. (Cl. 166—60)

This invention relates to an electrical well heating device, and in particular concerns an electric well heater of the type in which a liquid heat transfer medium is employed to conduct heat from an electrically resistant heating element to the radiating surfaces of the device.

In the copending application of James M. Covington, Serial No. 255,961, filed November 13, 1951, Now U.S. Patent No. 2,836,248, there is disclosed and claimed an electric well heater which essentially comprises an electrical resistance heating coil or the like submerged in a body of a heat-conducting electrically insulating liquid disposed within a fluid-tight container which is adapted to be lowered into a well bore and through which well fluids can be pumped to the earth's surface. Said liquid body serves to electrically insulate the turns of the heating coil and to transfer heat away from the heating element to the walls of the heater from whence it is radiated or conducted to the producing formation and/or the well fluids being pumped from the well. The use of a heat-conducting electrically insulating fluid in this manner reduces construction and maintenance costs, and greatly increases heater efficiency. In the copending application of Clayton A. Carpenter, Serial No. 428,753, filed May 10, 1954, now U.S. Patent No. 2,794,504, there is disclosed and claimed an improved liquid-filled heater, the improvement consisting in replacing part of the heat-conducting electrically insulating liquid with a particulate heat-conducting electrically insulating refractory solid. Said heater is very similar to the Covington heater except that the heating element is submerged in a body of particulate solid with a heat-conducting electrically-insulating liquid filling the spaces between the particles of said solid.

While the Covington and Carpenter heaters have proven very satisfactory from the standpoints of operating efficiency and freedom from burning out of the heating element, some difficulty has been experienced with respect to the connection between the heating element and the cable which supplies electric current thereto. Said connection usually involves the use of plastic materials to seal the end of the power cable, and many of such materials soften and deteriorate at elevated temperatures in contact with organic heat-transfer liquids or the vapors thereof. For this reason, the connection between the heating element and the power cable occasionally fails and permits said liquid or vapor to enter the power cable itself and cause deterioration of the same. Furthermore, when the power cable comprises metal-sheathed sections welded together, the welding operation causes any organic liquid or vapor which has penetrated inside the cable to carbonize and cause short-circuits between the conductor and the metal sheath. These difficulties are avoided in the device of the present invention, which is directed to a well heating device comprising a heat-transferring body of liquid or a mixture of liquid and solid, and provided with an internal sealing element which functions to keep liquid and/or vapors out of contact

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with the connection between heating element and the cable which supplies electric power thereto.

In the accompanying drawings which form a part of this application, Figure 1 is a vertical elevation, partly in cross-section to show internal constructional details, of a well heating device which embodies the principle of the invention in its simplest form; Figure 2 is a cross-sectional view taken along line A—A of Figure 1; Figure 3 is a partial vertical elevation, partly in cross-section, illustrating an alternative form of device; Figure 4 is a vertical elevation, partly in cross-section, of a third form of device; Figure 5 is a top view of the device of Figure 4; Figures 6, 7 and 8 are cross-sectional views taken along lines A—A, B—B and C—C, respectively, of Figure 4; and Figure 9 diagrammatically illustrates the electrical connections in the device of Figure 4.

Referring now to Figures 1 and 2, in which like numerals designate like parts, the heater there shown consists of a central imperforate conduit 10 threaded at its upper end to engage a well tubing string, not shown. The lower end of conduit 10 is provided with one or more slots or other apertures 11 through which oil may enter conduit 10 to be pumped to the earth's surface by the well pump. Usually, the latter is positioned in the tubing string above the heater, and the lower end of conduit 10 serves as the conventional "skeeter bill" at the bottom of the tubing string; if desired, however, the heater may be located at some intermediate point along the tubing string, and the lower end of conduit 10 may be threaded as shown to engage a lower section of tubing. Annular shaped upper and lower closures 12 and 13, respectively, are affixed in spaced relationship on conduit 10 between the slotted and upper threaded portions thereof, and support cylindrical shell 14 at their peripheries. The assembly is of welded or equivalent construction so that upper and lower closures 12 and 13 define an elongated fluid-tight container coaxially disposed around conduit 10. The annular space between conduit 10 and shell 14 is divided into a relatively short upper space section 15 and relatively long lower space section 16 by a fluid-tight diaphragm 17 which is welded or otherwise affixed to the inner surface of shell 14 and the outer surface of conduit 10 to form fluid-tight seals therewith. The electrical resistant heating element takes the form of four U-shaped "Cal-rod" heating units 18a, 18b, 18c and 18d positioned symmetrically around conduit 10 in the annular space between conduit 10 and shell 14. Each of heating units 18a—18d is mounted with its free ends extending through diaphragm 17 up into upper space section 15 and its loop end extending down into lower space section 16 of said annular space. As is well known, a "Cal-rod" unit consists of an electrical conductor surrounded by a layer of packed magnesium oxide or other mineral insulation which is in turn surrounded by a metal sheath. Each of heating units 18a—18d is held in position by having its upper ends welded to diaphragm 17 as shown. Within upper section 15, the metal sheath and insulation at the ends of heating units 18a—18d is stripped off to expose conductors 19 which lead to a junction box or the like 20 where they are electrically connected in parallel to conductors 21a and 21b of power supply cable 22. The latter passes to the surface of the earth and a source of electrical energy, not shown. At the point where it passes through upper closure 12, cable 22 is supported by being encased in a short length of rigid conduit 23 supported on conduit 10 by bracket 24. Within lower space section 16 of the device, a body 25 consisting of a mixture of a particulate heat-conducting refractory solid and a heat-conducting liquid is disposed between conduit 10 and shell 14 and around heating units 18a—18d, and substantially fills said section to

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level 26. Said mixture is introduced into lower space section 16 through a filler hole 27 in lower closure 13, which hole is normally closed by plug 28. As will readily be apparent, the heat-conducting liquid (and/or vapors thereof generated when the heater is operated) cannot come into contact with junction box 20 or the end of cable 22 within upper space section 15 by reason of the fact that diaphragm 17 is sealed to conduit 10, shell 14 and heating units 18a—18d as by welding, thus hermetically insulating upper space section 15 from lower space section 16 containing said liquid.

Referring now to Figure 3, the portion of the heater there shown comprises a central fluid-conducting conduit 30, and upper closure 31, an outer shell 32, and a diaphragm 33 hermetically separating the internal annular space into an upper space section 34 and a lower space section 35. The latter is filled to level 36 with a body of a heat-conducting electrically-insulating liquid 37. The heating element 38 takes the form of a length of bare Nichrome wire wound in the form of a vertical serpentine inscribed on the surface of an imaginary cylinder coaxially located in lower space section 35 between conduit 30 and shell 32. Each of the longitudinal traverses of heating element 38 is supported on conduit 10 by stand-off insulators or the like, not shown. One end of heating element 38 is electrically connected to conduit 10 by a stud bolt 39, and the other end passes upwardly through diaphragm 33 into upper space section 34 via a fluid-tight electrically-insulating bushing 40. Within upper space section 34, the end of heating element 38 is electrically connected via connector 41 to conductor 42 of single-conductor power cable 43. The latter extends through upper closure 31 via supporting conduit 44 to a source of electrical power at the earth's surface. Said power source is connected across conductor 42 of cable 43 and the well tubing, whereby the latter serves as one of the conductors supplying electric current to heating element 38. Lower space section 35 is filled with the heat-conducting electrically-insulating liquid by means of filler pipe 45 communicating between lower space section 35 and the exterior. Filler pipe 45 is welded or otherwise hermetically sealed at the point where it extends through upper closure 31 and diaphragm 33, and is normally closed by plug 46. An opening 47, normally closed by plug 48, is provided for purging upper space section 34 of all moisture prior to use.

Referring now to Figures 4-8, which illustrate a third form of heater within the scope of the invention and in which like numerals designate like parts, the heater there shown comprises a central fluid-conducting conduit 50, threaded at its upper end and provided with fluid-intake ports 51 at its lower end. Upper and lower closures 52 and 53 are welded or otherwise hermetically sealed to conduit 50 in spaced relationship and are likewise sealed at their peripheries to a coaxial shell 54 comprising upper, middle and lower sections 54a, 54b and 54c, respectively. Within the annular space defined by upper and lower closures 52 and 53, the inner surfaces of shell sections 54a—54c and the outer surface of conduit 50, upper and lower diaphragms 55 and 56, respectively, divide said space transversely into a relatively short upper space section 57, a long middle space section 58, and a relatively short lower space section 59. Upper diaphragm 55 is provided with downwardly projecting outer and inner skirt portions, 55a and 55b, respectively, which snugly engage shell 54 and conduit 50, respectively. Outer skirt portion 55a comprises a peripheral rib 60 whose thickness equals that of shell 54. The lower edge of upper shell section 54a engages and is sealed (as by welding) to the upper edge of rib 60, and the upper edge of middle shell section 54b engages and is similarly sealed to the lower edge of rib 60. Inner skirt portion 55b of upper diaphragm 55 is likewise sealed to conduit 50. Lower diaphragm 56 is provided with upwardly projecting outer and inner skirt portions 56a and 56b, respec-

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tively, which snugly engage and are sealed to lower shell section 54c and conduit 50, respectively. The lower edge of middle shell section 54b is welded to the upper edge of lower shell section 54c where their edges overlap outer skirt portion 56a of lower diaphragm 56. The heating element takes the form of six "Cal-rod" units 61a—61f, respectively, vertically and symmetrically disposed around conduit 50 in the annular space between conduit 50 and shell 54. The upper end of each of said units extends through upper diaphragm 55 into upper space section 57, being welded or otherwise sealed to upper diaphragm 55 at the point where it passes therethrough. The lower ends of said units are similarly sealed to and extend through lower diaphragm 56 into lower space section 59. Within upper and lower space sections 57 and 59, respectively, the metal sheath 62 and insulation 63 of each of the "Cal-rod" units is removed to expose the internal conductor 64. The open ends of the units are closed by insulating plugs 65 (preferably constructed of the fluorocarbon polymer known as "Teflon") through which conductor 64 extends. Each of said plugs is sealed to the section of sheath 62 which extends beyond insulation 63. Within lower space section 59, conductors 64 are electrically connected together, as is particularly shown in Figure 8. Within upper space section 57, the conductors 64 of adjacent "Cal-rod" units are electrically connected together and each pair of units is electrically connected via a connector 66 to one of the conductors 67a, 67b or 67c of three-conductor power cable 68, as is particularly shown in Figure 6. Cable 68 extends through upper closure 52 via a fluid-tight seal formed with supporting conduit 69, which is in turn sealed to upper closure 52, and passes to a source of three-phase electrical current at the earth's surface, not shown. Upper closure 52 is provided with a port 70, normally closed by plug 71, through which a dry gas can be introduced into upper space section 57 for the purpose of removing all moisture therefrom and for testing the effectiveness of the seals. Middle space section 58 is substantially filled with a mixture of a particulate heat-conducting refractory solid and a heat-conducting liquid 72 via filler pipe 73 which communicates between said space section and the exterior of the heater, being hermetically sealed to lower closure 53 and lower diaphragm 56 at the points where it extends therethrough. After filling the heater, filler pipe 73 is closed at its outer end by plug 74. A triangular gusset 75 welded to conduit 50 and lower closure 53 provides structural rigidity to the assembly.

As will be readily apparent, "Cal-rod" units 61a—61f in Figures 4-8 are Y-connected in parallel pairs to a three-phase source of power. Figure 9 shows the equivalent electrical circuit. In order to provide space for thermal expansion, the "Cal-rod" units may be partially coiled around conduit 50; for example, by rotating lower diaphragm 56 and the lower ends of the "Cal-rod" units some 90°—360° with respect to upper diaphragm 55 and the upper ends of the "Cal-rod" units.

Many variations in constructional details other than those described above and illustrated by the several figures of the drawings may be made without departing from the scope of the invention. In its broadest aspects, the invention consists in an electrical well heater comprising an elongated fluid-tight closed container which is capable of being lowered into a well bore, an imperforate conduit of smaller diameter than said container extending therethrough; a fluid-tight partition extending transversely across the space enclosed by said container and hermetically dividing said space into a relatively short upper space section and a relatively long lower space section; an electrical resistance heating element disposed within said lower space section between the lateral walls of said container and said conduit; a body of heat-conducting liquid surrounding said heating element and substantially filling said lower space section, said liquid body being an electrical insulant when said heating element takes the

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form of a bare uninsulated electrical conductor; electrically conductive means for supplying electric current to said heating element from an outside source; and means positioned within said upper space section for electrically connecting said heating element to said conductive means.

The electrical resistance heating element may take the form of an uninsulated coil, straight lengths of relatively heavy Nichrome wire or even silicon carbide rods mounted parallel to the central conduit. Alternatively, the heating element may be of the electrically insulated type, e.g., of the aforementioned "Cal-rod" or equivalent type. Since alternating current is usually preferred in the interests of reducing transmission costs, it is advantageous that the heating element be substantially non-inductive, and in heaters of relatively high heat capacity it is usually advantageous to provide for the use of polyphase current. Thermostatic devices may be employed to control the temperature attained within the heater. The walls of the device may be of fluted shape or may be fitted with internal or external fins to promote the radiation of heat therefrom. The central conduit may likewise be fitted with heat-conducting fins or the like to promote the transfer of heat thereto. Also, thermal insulating or directing means may be employed within the body of the heater to confine the flow of heat either towards the exterior walls thereof or towards the central conduit, and various types of sealing and insulating means may be employed for passing the power cable into the interior of the heater as well for connecting the power cable to the heating element. Said cable may contain all of the conductors required to power the heating element, or one of said conductors may consist of the well tubing and/or well casing.

The liquid body which surrounds the heating element and serves to transfer heat therefrom to the walls of the heater is preferably both heat-conducting and electrically-insulating. A wide variety of suitable liquids is known and many are available commercially for use in liquid-filled electrical apparatus such as transformers, condensers, etc. Since the difficulties which the present well heater structure obviates arise only when the heat-conducting liquid is a material which tends to soften and/or dissolve rubber or plastic insulating elements associated with electrical conduits and/or which tends to carbonize when heated to high temperatures, i.e., is an organic material, the liquid body is an organic compound or a mixture of organic compounds, e.g., mixtures of high-boiling petroleum hydrocarbons known as transformer oils, mixed chlorinated diphenyls and naphthalenes, mixed alkylated diphenyloxides, etc. A particularly preferred liquid of this type is the mixture of diphenyl and diphenyloxide sold under the trade name of "Dowtherm." However, it is not always necessary that the liquid have good dielectric properties; when the heating element is covered with efficient fluid-tight electrical insulation, e.g., as in the aforementioned "Cal-rod" units, the heat-conducting liquid need not be a particularly good insulator. When it is desired that the transfer of heat from the heating element to the walls of the heater be via a mixture of solid and liquid, such solid may be any particulate solid which is a relatively good conductor of heat and is capable of withstanding elevated temperatures. As with the liquid heat transfer agent, it is preferred that such solid be a non-conductor of electricity. Suitable materials of this nature include finely-divided silica or alumina, glass or porcelain beads, granular slag, etc. Relatively dense, as opposed to porous, materials are preferred by reason of their better heat conductivity. Dry 30- to 100-mesh quartz sand has been found to give excellent results. When the heating element is itself insulated, e.g., is of the "Cal-rod" type, the particulate solid may be an electrical conductor, e.g., steel balls, iron filings and the like. In such case, it is also possible to employ a mixture of an electrically conductive solid and an electrically-insulating liquid, or vice versa.

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Operation of the present type of heater is no different from that of prior practice, and it is ordinarily desirable that the heater be operated more or less continuously with relatively low power consumption during pumping of the well. Usually the heater is located at the bottom of the tubing string, i.e., below the well pump, and may be positioned in the well bore so as to transfer heat to the producing formation either through the liquid pool at the bottom of the well or through the gas phase above said pool. In some instances it is advantageous to heat and pump while maintaining a substantial back-pressure on the well. As stated, the heater is usually operated on alternating current, 220-550 volts A.C. being commonly employed, although direct current may also be used. Usually it is desirable that the heater be of such capacity and be operated at such a power level that between about 0.02 and about 2 kilowatts are dissipated in the form of heat per foot of formation subjected to heating.

Other modes of applying the principle of my invention may be employed instead of those explained, change being made with respect to the means or elements employed, provided the apparatus stated by any of the following claims, or the equivalent of such stated apparatus, be produced.

I, therefore, particularly point out and distinctly claim as my invention:

1. An electric heater for use in oil wells comprising an imperforate conduit adapted to be coupled to the well tubing; a coaxial imperforate tubular shell of substantially larger diameter than said conduit; spaced imperforate annular closures forming fluid-tight seals between said conduit and said shell; a fluid-tight partition extending transversely across the annular space between said conduit and said shell, said partition hermetically dividing said space into an upper space section of relatively short length and a lower space section of relatively long length; an electrical resistance heating element disposed below said partition within said lower space section, said heating element having at least one of its terminal ends extending upwardly through said partition and terminating within said upper space section; electrically conductive means for supplying electric current to said heating element from an outside source; connecting means disposed above said partition within said upper space section for electrically connecting said conductive means to said terminal end of said heating element; means for electrically insulating said heating element from said conduit; and a heat-conducting organic liquid substantially filling said lower space section and surrounding said heating element therein, said liquid having a deteriorating effect on plastic insulating materials and tending to carbonize at high temperatures.

2. A well heater as defined by claim 1 wherein said lower space section is substantially filled with a heat-conducting particulate solid, and said liquid occupies the space between the particles of said solid.

3. A well heater as defined by claim 1 wherein the said liquid is an electrical insulant.

4. A well heater as defined by claim 1 wherein one terminal end of the said heating element is electrically connected to said conduit.

5. A well heater as defined by claim 1 wherein said heating element is surrounded by a layer of packed comminuted mineral insulation contained in an imperforate metal sheath.

6. A well heater as defined by claim 2 wherein said particulate solid and said liquid are both electrical insulants.

7. An electric heater for use in oil wells comprising an imperforate conduit adapted to be coupled to the well tubing; a coaxial imperforate tubular shell of substantially larger diameter than said conduit; spaced imperforate annular closures forming fluid-tight seals between said conduit and said shell; a fluid-tight partition extending transversely across the annular space between said

conduit and said shell, said partition hermetically dividing said space into an upper space section of relatively short length and a lower space section of relatively long length; an electrical resistance heating element disposed below said partition within said lower space section, said heating element being surrounded by packed comminuted mineral insulation contained in an imperforate metal sheath and said heating element, mineral insulation and sheath extending through said partition and terminating within said upper space section; electrically conductive means for supplying electric current to said heating element from an outside source; connecting means disposed above said partition and within said upper space section for electrically connecting said conducting means to the end of said heating element therein; a body of a heat-conducting electrical insulating particulate refractory solid substantially filling said lower space section; and a body of a heat-conducting electrical-insulating organic liquid occupying the spaces between the particles of said solid, said liquid having a deteriorating effect on plastic insulating materials and tending to carbonize at high temperatures.

8. A well heater as defined by claim 7 wherein said liquid is a mixture of diphenyl and diphenyloxide.

9. An electric heater for use in oil wells comprising an imperforate conduit adapted to be coupled to the well tubing; a coaxial imperforate tubular shell of substantially larger diameter than said conduit; upper and lower fluid-tight partitions extending transversely across the annular space between said conduit and said shell, said partitions hermetically dividing said space into an upper space section of relatively short length, a middle space section of relatively long length, and a lower space section of relatively short length; a heating element disposed between said upper and lower partitions and within said middle space section, said heating element comprising an electrically resistive conductor surrounded by packed comminuted mineral insulation contained in an imperforate metal sheath, the upper end of said heating element extending upwardly through said upper partition and terminating within said upper space section and the lower

end of said heating element extending downwardly through said lower partition and terminating within said lower space section; electrically conductive means for supplying electric current to said electrically resistive conductor from an outside source; connecting means disposed above said upper partition within said upper space section for electrically connecting said conductive means to the upper end of said electrically resistive conductor; means for electrically connecting said conductive means to the lower end of said electrically resistive conductor; a body of a heat-conducting electrically insulating particulate refractory solid substantially filling said middle space section; and a body of a heat-conducting electrical-insulating organic liquid occupying the spaces between the particles of said solid, said liquid having a deteriorating effect on plastic insulating materials and tending to carbonize at high temperatures.

10. A well heater as defined by claim 9 wherein the said liquid is a mixture of diphenyl and diphenyloxide.

11. A well heater as defined by claim 9 wherein the said heating element takes the form of a plurality of elongated electrically resistive conductors, each of which is surrounded by packed comminuted mineral insulation contained in an imperforate metal sheath, disposed within said middle space section substantially parallel to the axis of said conduit.

12. A well heater as defined by claim 9 including means communicating between said middle space section and the exterior of the device for introducing said solid and liquid into said middle space section; and means for closing said communicating means.

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