May 21, 1957 C. A. CARPENTER 2,792,895

WELL HEATER

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FIG. 1.

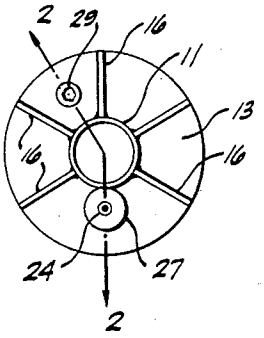
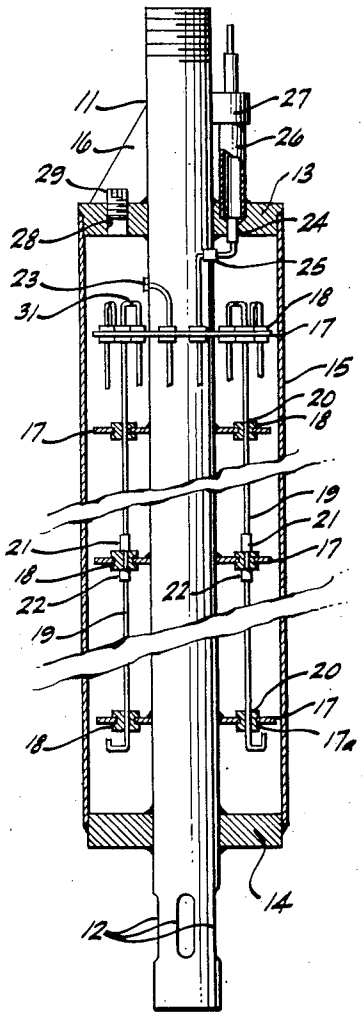


FIG. 2.



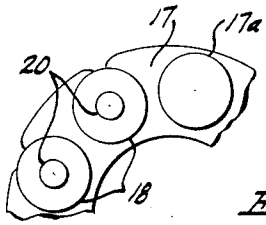


FIG. 3.

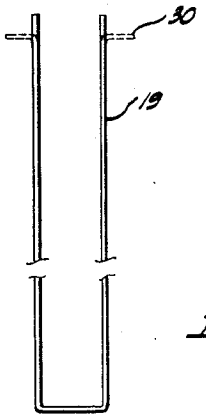


FIG. 5.

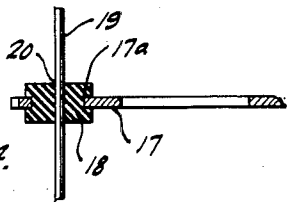


FIG. 4.

INVENTOR.
CLAYTON A. CARPENTER,
BY
Richard C. Hartman
ATTORNEY.

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WELL HEATER

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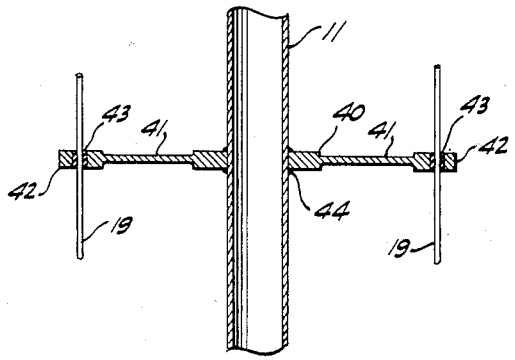


FIG. 6.

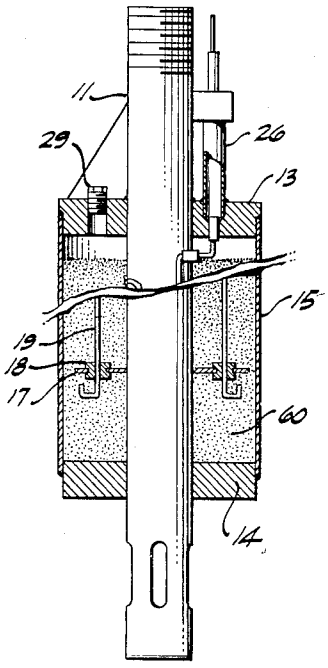


FIG. 10.

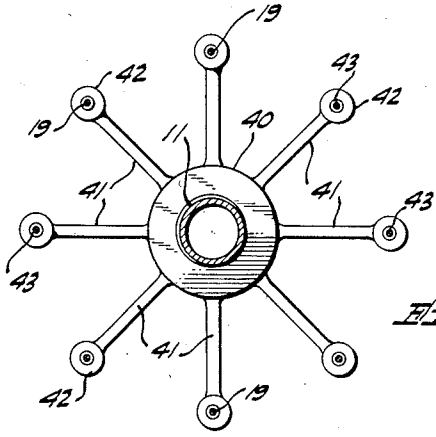


FIG. 7.

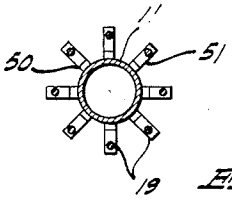


FIG. 9.

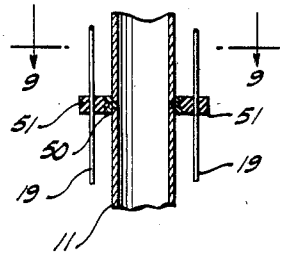


FIG. 8.

INVENTOR
CLAYTON C. CARPENTER.

BY
Richard C. Fortman

ATTORNEY.

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2,792,895

WELL HEATER

Clayton A. Carpenter, La Habra, Calif., assignor to Union Oil Company of California, Los Angeles, Calif., a corporation of California

Application May 3, 1954, Serial No. 427,180

13 Claims. (Cl. 166—61)

This invention relates to an apparatus for heating oil wells and the like, and in particular relates to an electric well heater of improved and simplified design and construction.

The concept of applying heat to oil-bearing formations to increase the flow of oil therefrom is of long standing in the art of producing petroleum, and many devices have been proposed for generating heat within well bores. For the most part, the well heaters of the prior art have been electrically powered, with the heating element taking the form of a resistance coil or the like to which electric current is supplied through cables running down the well bore or through parts of the well structure itself, e. g., the well tubing, casing or sucker rods. In most instances it has been found that best results in heating wells are attained by heating more or less continuously at a relatively low rate of power consumption and while pumping oil from the well. Accordingly, the most desirable form of heater is constructed so as to comprise an oil-conducting conduit which can be coupled into and made a part of the tubing string and through which oil can be pumped to the earth's surface during heating. However, the structural limitations of this type of heater are such that difficulty is had in providing sufficient heating capacity without making the heater unduly large. Further difficulties are had in suitably insulating the turns of the resistance heating coil and in providing means for mounting the same within the heater so as to allow for expansion upon heating. The various heater designs which have been proposed to overcome these difficulties have involved complicated arrangements of electrical and thermal insulation, spring mounted coil forms, liquid circulating means, baffles, sealing means, etc., all of which unduly increase the cost of the heater and render it difficult to construct and maintain.

The well heater provided by the present invention is of extremely simple design and construction and has been found to be substantially trouble-free. Substantially no electrical or thermal insulation is employed, and the component parts can be mass-produced at very low cost. Assembly and maintenance costs are reduced to a minimum, yet the heater has been found to operate with maximum efficiency. In brief, said heater comprises an imperforate oil-conducting conduit having a cylindrical shell concentrically disposed around it and sealed thereto by annular end closures. The electrical resistance heating element is mounted in the annular space between the central conduit and the shell, and takes the form of a serpentine inscribed on an imaginary surface which extends longitudinally within said annular space and is spaced away from the conduit and the shell, said serpentine having relatively long traverses substantially parallel to the longitudinal axis of the conduit. The heating element is supported in this position by a plurality of insulated supports attached to the conduit, and each longitudinal traverse of the heating element is clamped at approximately its mid-point so as to allow for expansion both upwardly and downwardly upon heating. In a

preferred form of the device, one end of the heating element is internally grounded to the central conduit and the other end is connected to an insulated cable which passes through the walls of the heater via a fluid-tight seal and runs to the earth's surface and a source of electric current.

Referring now to the several figures of the accompanying drawings which form a part of this application and in which like numerals designate like parts:

Figure 1 represents a top plan view of one form which the present well heater may take;

Figure 2 represents a vertical elevation, partly in section, taken along line 2—2 of the heater shown in Figure 1;

Figure 3 is a fragmentary plan view of one type of member for supporting the heating element within the body of the heater;

Figure 4 is a fragmentary sectional elevation of one of said members and one of the insulators associated therewith;

Figure 5 is a vertical elevation of one of the loops of resistance wire which go to make up the heating element of the present heater;

Figures 6–9 are plan and elevation view of alternative means for supporting the heating element within the body of the heater; and

Figure 10 is a partial vertical elevation of a well heater constructed in accordance with the invention and in which a particulate solid is employed as a heat-conducting insulant.

Referring now to Figures 1 and 2, the heater therein illustrated comprises a central oil-conducting conduit **11**, the upper end of which is threaded to engage a section of well tubing and the lower end of which is perforated, as by slots **12**, to allow oil to enter the conduit and be drawn upwardly therethrough by the well pump, not shown. Annular upper and lower end closures **13** and **14**, respectively, are welded to conduit **11** as shown and form a fluid-tight seal therewith. Cylindrical shell **15** is welded around the peripheries of closures **13** and **14**, and together therewith forms a fluid-tight enclosure concentrically disposed around conduit **11**. Triangular webs **16** are welded to conduit **11** and the upper side of upper closure **13** to provide rigidity to the assembly.

Within the enclosed space formed by shell **15** and closures **13** and **14**, a plurality of supporting members taking the form of annular rings **17** are affixed, as by welding, in spaced relationship along the length of conduit **11** and in planes perpendicular to the axis thereof. Said rings are usually spaced about 3–5 inches apart. Each of said rings is provided with a concentric row of perforations **17***a* extending through its opposed faces, and each perforation carries a spool-shaped electrical insulator **18**. The rings are so aligned radially that straight lines parallel to the longitudinal axis of conduit **11** can be drawn through the respective insulators. The heating element **19** is formed of bare resistance wire, preferably Nichrome, threaded through holes **20** in insulators **18** so that it takes the overall form of a serpentine longitudinally inscribed on an imaginary cylinder coaxially disposed in the annular space between conduit **11** and shell **15**. At approximately its mid-point, each longitudinal traverse of the heating element is fitted with upper and lower clamps **21** and **22**, respectively, disposed on opposite sides of an insulator. Said clamps may take the form of simple sleeves which are crimped on the wire so as to prevent it from sliding within longitudinal opening **20** in insulator **18**. Each traverse is thus fixed at approximately its mid-point with respect to conduit **11**, and upon heating the heating element is free to expand both upwardly and downwardly. One end of heating element **19** is electrically grounded to conduit **11**

at terminal 23, and the other end is connected to insulated power cable 24 by a suitable connector 25. Cable 24 passes through upper closure 13 and is supported exteriorly by a relatively short length of rigid electrical conduit 26. The latter terminates in cap 27 which is welded to central conduit 11. Filler hole 28, which is normally closed by a plug 29, extends through upper closure 13 and provides a means for filling the heater with a particulate solid or a liquid as is hereinafter more fully explained.

Referring now to Figures 3 and 4 which illustrate certain details in the construction of a preferred means for supporting the heating element within the body of the heater, said means takes the form of a plurality of flat rings each having its outside diameter slightly less than the internal diameter of shell 15 and its inside diameter slightly larger than the outside diameter of conduit 11. In assembling the heater, the rings are slipped over conduit 11, and tack-welded in place more or less equally spaced along the length of conduit 11. Each of the rings carries a series of radially spaced openings 17*a* drilled or punched with their centers on a circle drawn between the inner and outer edges of the ring. The diameter and location of openings 17*a* are preferably such that their outer edges extend to within a relatively short distance, say ⅛ inch, from the outer edge of the ring. Insulators 18 are formed of an electrical-insulating material and must be capable of withstanding relatively high temperatures. Ceramic materials, e. g. porcelain, glass, steatite, etc., are eminently suitable. Each insulator takes the form of a relatively flat spool, or a cylinder with a peripheral groove, having an axial hole 20 which is slightly larger than the diameter of resistance wire 19 so that the latter is free to slide therein. The diameter of each insulator is just slightly less than that of openings 17*a* in ring 17. Each insulator is affixed to ring 17 by centering the insulator in perforation 17*a* and then applying pressure to the outer edge of the ring at a point closely adjacent to opening 17*a*, thereby permanently deforming the opening and causing its edge to fit within the peripheral groove of the insulator. After the insulators have been so installed, the periphery of the ring will have a scalloped appearance, as shown in Figure 3, by reason of its having been deformed at the outer edge of each opening 17*a*. This manner of assembling the insulators on the ring has proved very satisfactory in practice. If desired, however, two-piece lead-through insulators may be employed. It is usually most convenient to assemble the insulators on the rings as described prior to affixing the latter to the central conduit, and when so affixing the rings they should be carefully aligned so that the insulators on successive rings line up in straight lines substantially parallel to the axis of conduit 11.

As previously stated, the heating element 19 is composed of bare resistance wire looped back and forth parallel to the axis and upon the surface of an imaginary surface longitudinally disposed between conduit 11 and shell 15. Such element is readily constructed in place by bending suitable lengths of resistance wire into the form of a U as shown in Figure 5, and threading each arm of the U through the axial holes in adjoining insulators on successive supporting members 17. The free ends of the U are then bent outwardly and are clipped off as at 30 in Figure 5. A second U-shaped piece of resistance wire is threaded through the next adjoining two rows of insulators, and the open ends are bent outwardly as before. By welding together the outwardly bent ends of adjacent wires, as at 31 in Figure 1, the desired serpentine configuration will be obtained.

Referring now to Figures 6 and 7, which are elevation and plan view, respectively, illustrating the aforementioned spider arrangement, each spider comprises a hub portion 40 from which arms 41 extend radially. Each of arms 41 terminates in a boss 42 having a longitudinal opening in which is carried a sleeve 43 constructed of an electrical insulating material such as porcelain. The spider is affixed to central conduit 11 as by welding at 44. The resistance wire which forms heating element 19 passes through sleeves 43, and is free to slide therein as previously explained.

Referring now to Figures 8 and 9, which are elevation and plan views, respectively, illustrating the use of stand-off insulators to support the heating element, a series of such insulators is shown extending radially from central conduit 11 in the same plane. Each insulator consists of a metallic base portion 50, which threads into suitable threaded openings in conduit 11, and an insulator portion 51 which is composed of an electrical insulating material such as porcelain and which threadedly engages the base portion as shown. A longitudinal hole is provided near the outer end of each insulator portion 51 to receive heating element 19 in sliding engagement.

As will be apparent to those skilled in the art, various modifications of the above-described design may be made without departing from the scope of the invention. Thus, the supporting means for the heating element may take various forms other than the flat perforated rings illustrated in the drawing and described above, e. g., they may take the form of spiders spaced along the conduit and carrying insulators at the end of each radial arm thereof, or they may comprise stand-off insulators radially mounted on the central conduit in planes spaced along the length thereof.

Also, various types of sealing means may be employed for conducting the electrical supply cable through the walls of the heater, and the heating element may be arranged so as to accommodate three-phase current. If desired, the electric current may be fed to the heating element entirely by supply cables running through the well bore rather than by the grounded system illustrated. According to one modification, a grounded system is employed but the ground connection is made via the plug 29 in the filler hole 28 so that by removing said plug the heating element is un-grounded and its resistance to ground can be determined in testing for short-circuits.

As previously stated, filler hole 28 is provided in case it is desired to improve the transfer of heat from the heating element to the walls of the heater by filling the heater with a heat transfer medium. Such medium may take the form of a heat-conducting electrical-insulating liquid, e. g., the mixture of diphenyl and diphenyloxide known as "Dowtherm," as disclosed in the co-pending application of James M. Covington, Serial No. 255,961 filed November 13, 1951, or it may be a heat-conducting electrical-insulating particulate solid, e. g., silica sand, as disclosed in my co-pending application, Serial No. 428,753 filed May 10, 1954. Mixtures of solids and liquids may also be employed. Figure 10 shows the device of Figure 2 filled with a body of such a particulate solid 60 in contact with heating element 19, central conduit 11, and shell 15.

It will further be apparent that well heaters of the present type can readily be constructed of any desired size or capacity. The novel means of winding and supporting the heating element permits the substantial elimination of internal insulation and allows the maximum length of resistance wire to be advantageously disposed in a minimum of space. The elimination of internal insulation also contributes to ease and economy of construction and maintenance.

A typical well heater of the present type is constructed as follows: The central oil-conducting conduit consists of a 135" length of 2" API J–55 470# tubing. The shell consists of a 121½" length of 4.5" I. D. tubing. The bottom closure is machined from 0.675" hot-rolled steel, whereas the upper closure is similarly made from 0.75" steel. Thirty supporting rings, punched from 16 ga. hot-rolled steel, are spaced about 4" apart along the central conduit within the body of the heater, and each ring has 18 equally spaced 0.5" holes punched around its circum-

ference on a 3.5" diameter. The insulators are ceramic, 0.5" high and 0.5" in diameter, and have a .032" deep groove .094" wide inscribed around their peripheries. The insulators are mounted on the rings by deforming the outer edge thereof as herein described. The heating element is composed of U-shaped lengths of #12 Nichrome wire threaded from the bottom through adjacent insulators on each supporting ring, and then bent outwardly and welded to the adjoining length of Nichrome above the upper-most ring. A total of about 180' of Nichrome is employed, giving a cold resistance of about 18.5 ohms. Each resistance wire is secured at its approximate mid-point by crimping a short metal sleeve thereon on each side of the insulator which is located at about the mid-point of the heater. One terminal of the heating element is brazed to the central conduit and the other is connected to a single-conductor power cable which is passed through the upper closure via a fluid-tight seal as herein described. The heater is filled to a level within about 2" of the top with dry 30- to 100-mesh quartz sand introduce through an 0.375" hole in the upper closure. A heater so constructed has a nominal power rating of about 7.5 kw. at a surface supply voltage of about 385 volts A. C.

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. 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 oil-producing formation either through the oil 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 volt A. C. being commonly employed, although direct current may also be employed. 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 2.0 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 as regards the elements or means employed provided the device stated by any of the following claims, or the equivalent of such stated device, be obtained.

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 tubular shell of substantially larger diameter than said conduit; spaced annular closures forming a fluid-tight seal between said conduit and said shell; an electrical resistance heating element disposed within the annular space between said conduit and said shell in the form of a serpentine inscribed on an imaginary surface extending longitudinally within said annular space and in spaced relationship to said conduit and said shell, the longitudinal traverses of said serpentine being substantially parallel to the longitudinal axis of said conduit; electrically insulated means for holding said heating element so disposed within said annular space, said means being supported on said conduit at spaced intervals and engaging the longitudinal traverses of said heating element in sliding relationship; means for affixing said heating element with respect to said conduit at approximately the mid-points of the longitudinal traverses of said heating element; and electrically conductive means for supplying electric current to said heating element from an exterior source.

2. A well heater in accordance with claim 1 wherein the said electrically conductive means comprises means for electrically connecting one end of said heating element to said conduit and at least one insulated electrical conductor electrically connected to said heating element and passing to the exterior of the heater via a fluid-tight seal.

3. A well heater in accordance with claim 1 containing a particulate heat-conducting electrical-insulating refractory solid in the annular space between said conduit and said shell in contact with said heating element, said conduit and said shell.

4. A well heater in accordance with claim 1 wherein the said means for supporting the heating element comprises a plurality of relatively flat rings coaxially attached to the said conduit at spaced intervals along the length thereof between said spaced annular closures, each of said rings having a concentric circular row of openings extending through the opposed faces thereof and said rings being so aligned that radially corresponding openings in said rings lie in substantially straight lines substantially parallel to the longitudinal axis of said conduit; and a plurality of electrical insulating members affixed to said rings, said members having longitudinal openings in register with the openings in said rings, and the longitudinal traverses of the said heating element passing through said openings in said insulating members and said rings.

5. A well heater in accordance with claim 4 wherein the means for affixing the said heating element with respect to said conduit comprises upper and lower sleeves affixed to each of the longitudinal traverses of said heating element respectively immediately above and immediately below one of said insulating members located at the approximate mid-point of said longitudinal traverse.

6. A well heater for use in oil wells comprising an imperforate conduit adapted to be coupled to the well tubing; a coaxial tubular shell of substantially larger diameter than said conduit; upper and lower annular closures providing a fluid-tight seal between said conduit and said shell; a plurality of relatively flat rings each provided with a concentric circular row of openings extending through its opposed faces, said rings being affixed to said conduit at spaced intervals along the length thereof between said annular closures in planes substantially perpendicular to the longitudinal axis of said conduit and being so aligned that radially corresponding openings lie in substantially straight lines substantially parallel to the longitudinal axis of said conduit; an electrically non-conductive member carried in each of said openings, each of said members having a longitudinal opening extending therethrough and in register with each of said openings in said rings; an electrically resistive conductor carried in the openings in longitudinal rows of said non-conductive members, said conductor thereby taking the form of a serpentine with relatively long traverses substantially parallel to the longitudinal axis of said conduit; upper and lower sleeves attached to each of the longitudinal traverses of said conductor respectively immediately above and immediately below one of said non-conductive members located at the approximate mid-point of said traverses; and electrically conductive means for supplying electric current to said conductor from an exterior source.

7. A well heater in accordance with claim 6 wherein the said electrically conductive means comprises means for electrically connecting one end of said resistive conductor to said conduit and an insulated conductor electrically connected to the other end of said resistive conductor and passing to the exterior of the heater via a fluid-tight seal.

8. A well heater in accordance with claim 6 containing a particulate heat-conducting electrical-insulating refractory solid in the annular space between said conduit and said shell, in contact with said electrically resistive conductor, said conduit and said shell.

9. An electric heater for use in wells comprising an imperforate conduit adapted to be coupled to the well tubing; a coaxial tubular shell of substantially larger

diameter than said conduit; upper and lower annular closures providing a fluid-tight seal between said conduit and said shell; a plurality of spiders having radial arms and affixed to said conduit at spaced intervals along the length thereof between said annular closures in planes substantially perpendicular to the longitudinal axis of said conduit, said spiders being so aligned that the outer extremities of their corresponding radial arms lie on substantially straight lines substantially parallel to the longitudinal axis of said conduit; an electrically non-conductive member carried on each of the radial arms of each of said spiders; an electrically resistive conductor supported along its length on longitudinal rows of said non-conductive members, said conductor thereby taking the form of a serpentine with relatively long traverses substantially parallel to the longitudinal axis of said conduit; upper and lower sleeves attached to each of the longitudinal traverses of said conductor respectively immediately above and immediately below one of said non-conductive members located at the approximate mid-point of said traverses; and electrically conductive means for supplying electric current to said conductor from an exterior source.

10. An electric heater for use in wells comprising an imperforate conduit adapted to be coupled to the well tubing; a coaxial tubular shell of substantially larger diameter than said conduit; upper and lower annular closures providing a fluid-tight seal between said conduit and said shell; a plurality of stand-off insulators affixed at their bases to said conduit so as to extend into the annular space between said conduit and said shell in radial disposition and in a plurality of planes perpendicular to the longitudinal axis of said conduit and spaced at intervals along the length of said conduit between said annular closures; an electrically resistive conductor supported along its length on longitudinal rows of said insulators, said conductor thereby taking the form of a

serpentine with relatively long traverses substantially parallel to the longitudinal axis of said conduit; means for rigidly affixing said conductor to said insulators at approximately the mid-point of each of said traverses; and electrically conductive means for supplying electric current to said conductor from an exterior source.

11. A well heater in accordance with claim 1 containing a particulate heat-conducting electrical-insulating refractory solid in the annular space between said conduit and said shell and in contact with said heating element, said conduit and said shell; and a heat-conducting electrical-insulating liquid filling the spaces between the particles of said solid.

12. A well heater in accordance with claim 6 containing a particulate heat-conducting electrical-insulating refractory solid in the annular space between said conduit and said shell and in contact with said heating element, said conduit and said shell; and a heat-conducting electrical insulating liquid filling the spaces between the particles of said solid.

13. A well heater in accordance with claim 9 containing a particulate heat-conducting electrical-insulating refractory solid in the annular space between said conduit and said shell and in contact with said heating element, said conduit and said shell; and a heat-conducting electrical-insulating liquid filling the spaces between the particles of said solid.

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