June 4, 1957 C. A. CARPENTER 2,794,504

WELL HEATER

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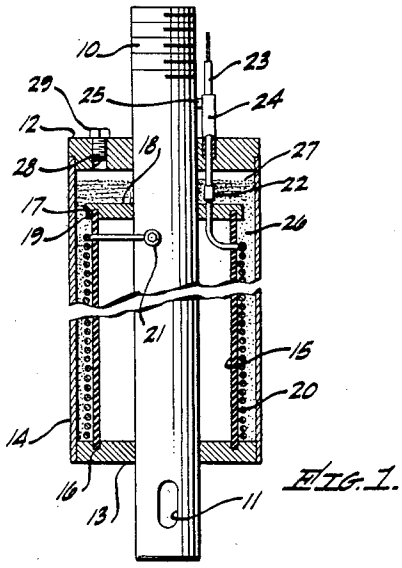


FIG. 1.

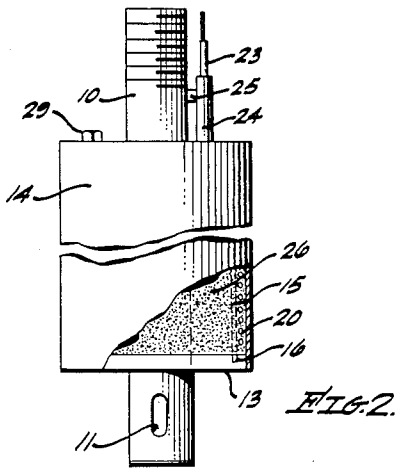


FIG. 2.

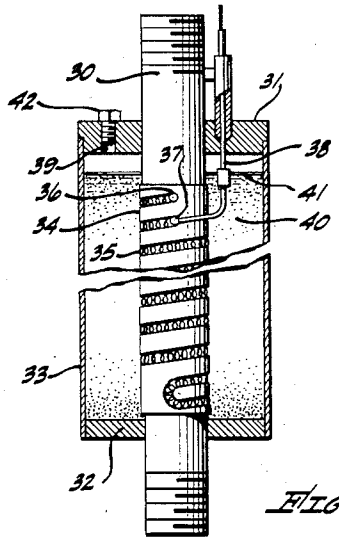


FIG. 3.

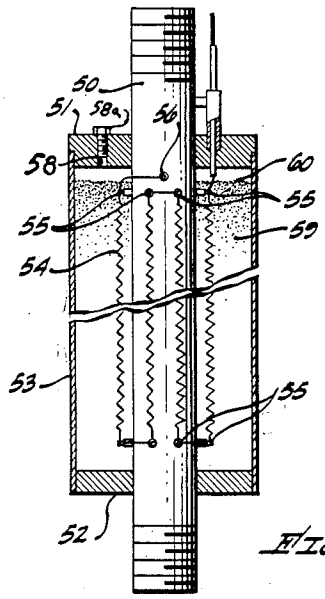


FIG. 4.

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WELL HEATER

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14 Claims. (Cl. 166—61)

This invention relates to an electrical well heating device, and in particular concerns an electric well heater of the type adapted for more or less continuous operation and comprising novel insulating and heat transfer means.

In the copending application of James M. Covington, Serial No. 255,961, filed November 13, 1951, 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 electrical insulating fluid disposed within a fluid-tight container which is adapted to be lowered into a well bore and through which the petroleum can be pumped from the well. Said fluid 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 oil-bearing formation and/or the oil 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. On the other hand, such fluid-filled heaters must be so constructed as to allow for expansion of the fluid upon being heated; in a typical heater of this type 15 feet long, 5 feet of the length is required solely to allow for expansion of the fluid.

I have now found that the need for providing such expansion space may be substantially eliminated without sacrificing the advantages of such type of heater by substituting a particulate solid material for a substantial proportion of the fluid insulating and heat transfer medium. More particularly, I have found that a well heater comprising a fluid-tight container adapted to be lowered into a well bore and provided with a coaxial oil-conducting conduit and with an electrical resistance heating element disposed within a body of a mixture of a particulate heat-conducting electrical-insulating solid material and a heat-conducting electrical-insulating fluid maintained within said container in the annular space between said conduit and the walls thereof is exceptionally simple to construct and maintain in service, and is highly efficient in transferring heat from said heating element to the oil-bearing formation adjacent the heater and/or to the oil which is pumped from the well. The solid materials employed as the heat transfer and insulating medium have relatively very low coefficients of thermal expansion and there is hence no need for building into the heater sufficient dead space to allow for any substantial degree of expansion of such medium upon heating. On the other hand, by providing sufficient of a heat-conducting electrical-insulating fluid to fill the spaces between the particles of solid material a high degree of heat transfer efficiency is attained. Also, such use of a particulate solid-fluid insulating medium permits the use of non-insulated heating elements and avoids the use of the multiple insulating wrappings which have characterized many of the prior art electric well heaters. Moreover, since the heating element is more or less completely embedded in a body of heat-conducting material, local overheating and consequent burning out

of the element is much less likely and in the event the element does burn out it can readily be replaced without having to remove and replace multiple wrapping of insulating tape and the like.

In the accompanying drawing which forms a part of this application,

Figure 1 is a vertical elevation, partly in section to show internal construction details, of one form which the heater provided by the invention may take;

Figure 2 is a vertical elevation of the heater shown in Figure 1 with the outer shell partially broken away to show the disposition of the insulating and heat transfer medium;

Figure 3 is a vertical elevation, partly in section, of another form which the heater may take; and

Figure 4 is a vertical elevation, partly in section, of third form of heater within the scope of the invention.

Referring now to Figures 1 and 2, wherein like numerals designate like parts, the heater therein shown consists of a central oil-conducting conduit **10** threaded at its upper end to engage the lower end of a well tubing string comprising a well pump, 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. The lower end of conduit **10** thus serves as the conventional "skeeter bill" at the bottom of the tubing string. Annular shaped upper and lower closures **12** and **13**, respectively, are supported in spaced relationship on conduit **10** between the threaded and slotted 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** and shell **14** define an elongated fluid-tight container disposed coaxially around conduit **10**. Within the annular space between conduit **10** and shell **14**, cylindrical coil support **15**, shown as being constructed of an electrical-insulating material, is coaxially disposed with its bottom edge being received by a circular groove **16** in the upper face of closure **13**. The upper edge of coil support **15** is received by a similar groove **17** in the bottom face of circular plate **18** affixed to conduit **11**. Groove **17** also carries a coil spring **19** or equivalent resilient means to maintain coil support **15** firmly positioned with room for thermal expansion. The heating element **20** is formed of electrical resistance wire wrapped around coil support **15** to form a continuous coil. If desired, coil support **15** may be provided with spiral grooves to receive the turns of heating element **20**. One end of said coil is grounded to conduit **10** at terminal **21**, and the other end is carried through suitable apertures in coil support **15** and plate **18** to the upper part of the heater where it is electrically connected by means of connector **22** to power supply cable **23**. The latter is passed through upper closure **12** via a fluid-tight seal, and is exteriorly supported by rigid conduit **24** supported on conduit **10** by bracket **25**. When the heater is positioned within the well, cable **23** passes upwardly through the well bore to one terminal of a source of electric current at the earth's surface. The other terminal of the current source is grounded to the well tubing or casing at the earth's surface. Within the heater a body of a mixture of a particulate heat-conducting electrical-insulating material and a heat-conducting insulating fluid **26** is disposed between coil support **15** and the interior surface of shell **14**, and fills the space above plate **18** to level **27**. Said mixture is introduced into the heater through filler hole **28** in upper closure **12**, which hole is normally closed by plug **29**. This particular heater is designed to radiate heat outwardly to an oil-producing formation adjacent shell **14**, rather than inwardly to the oil passing through conduit **11**; accordingly, plate **18** and coil support **15** are imperforate so as to prevent the

heat-conducting electrical-insulating mixture from entering and occupying the space between coil support **15** and conduit **10**, and coil support **15** is constructed of a heat-insulating material. If desired, said space may be filled with thermal insulation, e. g., asbestos fiber, exploded mica, etc.

Referring now to Figure 3, the heater therein shown comprises a central oil-conducting conduit **30** threaded at both ends to permit coupling into the well tubing string, and having upper closure **31**, lower closure **32** and outer shell **33** assembled thereon as shown to form an elongated fluid-tight container coaxially disposed around conduit **30**. Within the body of the heater, conduit **30** carries a spirally grooved sheath **34** in direct contact therewith and constructed of a heat-conducting electrical-insulating material, e. g., ferro-enamel. Electrical resistance coil **35** is mounted in the grooves of sleeve **34**, said grooves being shown as forming a double helix so that coil **35** will be substantially non-inductive. One end of coil **35** is grounded to conduit **30** at terminal **36**, and the other end is connected at insulated terminal **37** to power cable **38** which passes through closure **31** via a fluid-tight seal and leads to a source of electric current, not shown. Closure **31** is provided with a filler hole **39** through which the heater is filled with a mixture of a particulate heat-conducting electrical-insulating solid material and heat-conducting electrical-insulating fluid **40** to level **41**. Plug **42** normally closes filler hole **39**. This heater is designed to heat the oil passing through conduit **30** as well as oil-producing formations adjacent to shell **33**, heat being conducted to shell **33** through the particulate solid material **40** and to conduit **30** through sleeve or coating **34**.

Figure 4 shows a heater which is designed to transfer heat both to surrounding oil-producing formations and to the oil being pumped to the surface through a mixed solid-liquid heat-transfer and electrical-insulating medium. Said heater comprises a central oil-conducting conduit **50** which forms a part of the tubing string and through which oil is pumped to the earth's surface. Closures **51** and **52** and shell **53** define an elongated fluid-tight container coaxially disposed around conduit **50**. The heating element is a continuous coil of electrical resistance wire **54** disposed within said container between conduit **50** and shell **53**, and is supported on and spaced away from conduit **50** by means of stand-off insulators **55**. One end of coil **54** is grounded to conduit **50** at terminal **56**; the other end is electrically connected to power supply cable **57** which leads to a source of electric current not shown. Filler hole **58**, normally closed by plug **58***a*, is provided in closure **51** to permit the heater to be filled with a heat-conducting electrical-insulating solid-liquid mixture **59** to level **60**.

As will be apparent to those skilled in the art, many variations in constructional details other than those described above and illustrated by the several figures of the drawing 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 longitudinally therethrough, an electrical resistance heating element disposed within said container between the lateral walls thereof and said conduit, a particulate heat-conducting electrical-insulating solid disposed within said container for conducting heat from said heating element either to the walls of said container or to said conduit or to both, a heat-conducting electrical-insulating fluid filling the spaces between the particles of said solid, and electrically conductive means for supplying electric current to said heating element from a source outside said container. Thus, the electrical resistance heating element may take the form of straight lengths of relatively heavy Nichrome wire or even silicon carbide rods mounted parallel to the central conduit. 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 heater may be of fluted shape or may be fitted with internal or external fins to promote the radiation of heat therefrom. The central oil-conducting 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 oil-conducting conduit. Also, various types of sealing and insulating means may be employed for passing the power cable into the interior of the heater to the heating element, and in addition to the cable-and-tubing system shown the current may be supplied to the heater via two or more flexible conductors or via any of the known tubing-and-casing or other systems which employ various well parts as conductors.

The solid component of the mixture employed for transferring heat from the heating element to one or more of the internal surfaces of the heater may be any particulate solid which is a non-conductor of electricity, a relatively good conductor of heat, and is capable of withstanding elevated temperatures, e. g., finely-divided silica, alumina, glass 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. The fluid which is employed in conjunction with the particulate solid material may be any liquid which is capable of conducting heat and at the same time has good electrical insulating properties, but is preferably the mixture of diphenyl and diphenyloxide which is sold under the name "Dowtherm." Such a fluid fills the interstices between the particles of said solid material and improves heat transfer therethrough, but since the bulk of the space within the heater is occupied by the particulate solid there will not be enough fluid present to require the provision of any great amount of space for the thermal expansion thereof.

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 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 electrical heater for use in oil wells, comprising an imperforate conduit adapted to be coupled to the well tubing; a tubular shell of substantially larger diameter than said conduit; spaced annular closures providing a fluid-tight seal between said conduit and said shell; an

electrical resistance heating element disposed between said spaced closures and within the annular space between the outer surface of said conduit and the inner surface of said shell; a body of a particulate heat-conducting electrical-insulating refractory solid substantially filling said annular space and in contact with the said heating element and at least one of said surfaces defining said annular space; a body of a heat-conducting electrical-insulating liquid filling the spaces between the particles of said solid; and means for conducting electric current to said heating element from an exterior source.

2. A well heater in accordance with claim 1 wherein the said body of particulate heat-conducting electrical-insulating refractory solid is in contact with the said heating element and the inner surface of said shell.

3. A well heater in accordance with claim 1 wherein the said body of particulate heat-conducting electrical-insulating refractory solid is in contact with the said heating element, the outer surface of said conduit, and the inner surface of said shell.

4. A well heater in accordance with claim 1 wherein the said particulate heat-conducting electrical-insulating refractory solid is silica sand.

5. A well heater in accordance with claim 1 wherein the heat-conducting electrical-insulating liquid is a mixture of diphenyl and diphenyloxide.

6. An electric heater for use in oil wells, comprising an imperforate conduit adapted to be coupled to the well tubing; a tubular shell of substantially larger diameter than said conduit; spaced annular closures providing a fluid-tight seal between said conduit and said shell; an electrical resistance heating element disposed substantially parallel to and spaced away from said conduit between the spaced closures and within the annular space between the outer surface of said conduit and the inner surface of said shell; electrical-insulating means for supporting said heating element on said conduit; a body of a particulate heat-conducting electrical-insulating refractory solid substantially filling said annular space and in contact with said heating element and at least one of said surfaces defining said annular space; a body of a particulate electrical-insulating liquid filling the spaces between the particles of said solid; and means for conducting electric current to said heating element from an exterior source.

7. A well heater in accordance with claim 6 wherein the said heat-conducting electrical-insulating refractory solid is silica sand.

8. A well heater in accordance with claim 6 wherein the heat-conducting electrical-insulating 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 tubular shell of substantially larger diameter than said conduit; spaced annular closures providing a fluid-tight seal between said conduit and said shell; a heat-conducting electrical-insulating sheath in direct contact with said conduit between said spaced closures; an electrical resistance heating coil wound on said sheath; a body of a particulate heat-conducting electrical-insulating refractory solid substantially filling the annular space between said sheath and said shell, and in contact with said heating coil and the inner surface of said shell; a body of a heat-conducting electrical-insulating liquid filling the spaces between the particles of said solid; and means for conducting electric current to said heating coil from an exterior source.

10. A well heater in accordance with claim 9 wherein the said sheath is a ferro-enamel coating applied directly to said conduit.

11. An electric heater for use in oil wells, comprising an imperforate conduit adapted to be coupled to the well tubing; a tubular shell of substantially larger diameter than said conduit; spaced annular closures providing a fluid-tight seal between said conduit and said shell; a tubular heat- and electrical-insulating coil-support coaxially disposed within the annular space between the outer surface of said conduit and the inner surface of said shell, said coil-support being spaced away from said conduit; an electrical resistance heating coil wound on the outer surface of said coil-support; a body of a particulate heat-conducting electrical-insulating refractory solid substantially filling the annular space between the outer surface of said coil-support and the inner surface of said shell, and in contact with said heating coil and said shell; a body of a heat-conducting electrical-insulating liquid filling the spaces between the particles of said solid; and means for conducting electric current to said heating coil from an exterior source.

12. A well heater in accordance with claim 11 wherein the lower edge of said coil support is received by a groove in the upper face of the lower of the said spaced annular closures and the upper edge of said coil support is received by a groove in the lower face of an annular plate carried by the said conduit between the said spaced annular closures.

13. A well heater in accordance with claim 11 wherein the particulate solid and liquid are in contact with the said heating element and the inner surface of said shell and are maintained out of contact with the inner surface of said coil-support.

14. An electric heater for use in oil wells, comprising an imperforate conduit adapted to be coupled to the well tubing; a tubular shell of substantially larger diameter than said conduit; spaced annular closures providing a fluid-tight seal between said conduit and said shell; an electrical resistance heating element disposed between said spaced closures and within the annular space between the outer surface of said conduit and the inner surface of said shell; thermal insulation disposed within said annular space and between the outer surface of said conduit and said heating element; a body of a particulate heat-conducting electrical-insulating refractory solid substantially filling said annular space and between said thermal insulation and the inner surface of said shell, said body of particulate solid being in contact with said heating element and the inner surface of said shell; a body of a heat-conducting electrical-insulating fluid filling the spaces between the particles of said solid; and means for conducting electric current to said heating element from an exterior source.

References Cited in the file of this patent

UNITED STATES PATENTS

1,457,690	Brine	June 5, 1923
2,076,669	Redfield et al.	Apr. 13, 1937
2,484,063	Ackley	Oct. 11, 1949
2,647,196	Carpenter et al.	July 28, 1953