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WELL TUBING HEATER SYSTEM

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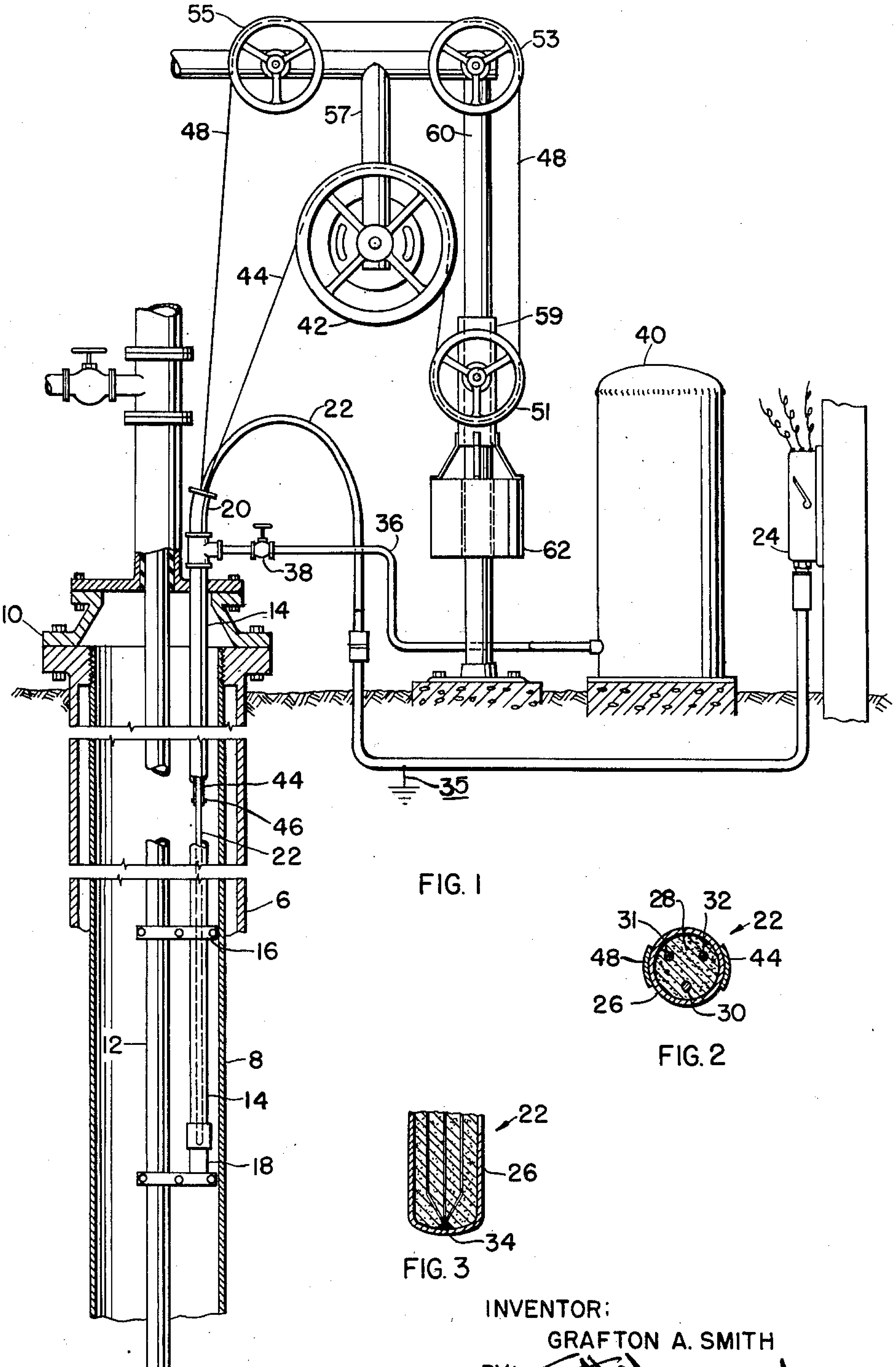

FIG. 1

FIG. 2

FIG. 3

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WELL TUBING HEATER SYSTEM

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This invention pertains to apparatus for heating petroleum wells, and relates more particularly to an electrical resistance heater system adapted to prevent hydrate formation in gas-condensate wells.

Gas-condensate wells, and especially flowing wells located in cold climates, are subject to restriction of flow due to the formation of natural gas hydrates in the tubing string. This condition usually arises when wells are produced at low rates of flow or when production is started after extended shut-in periods in severe winter weather.

A conventional method of preventing the formation of hydrates in the tubing is by circulation of hot diesel oil to a critical depth of about 3,500 feet through the use of an intermediate casing string. Although generally successful, this method substantially increases the investment for completing a well. For example, the cost of installing an additional string of intermediate 5 inch casing, a surface oil heating unit, a circulating pump system, etc., amounts to an expenditure of over thirty thousand dollars per well. Moreover, a heating system of this type constitutes a potential fire hazard, and the fact that the system must be housed in a heat-insulated building, where sour natural gas tends to accumulate, creates additional health and safety hazards for the personnel.

Systems have been proposed to effect the heating of wells by electrical means. These systems have not, however, achieved a conspicuous practical success. In particular, it has not been found readily feasible to distribute electrical heating evenly throughout the total depth, or at least the desired depth interval, instead of positioning individual heaters, or bunching groups of such heaters, at a particular point or level, or at a plurality of relatively widely spaced points or levels within a well. This failure is believed attributable to a lack of electrical conductor means having a resistance sufficienty low to permit the handling of relatively large currents at relatively low potentials, an insulation sufficiently rugged to withstand severe operating conditions under relatively high well temperatures, and a mechanical strength competent to meet the stress of the conductor's own weight.

It is therefore a general object of this invention to provide a system for heating oil and gas wells by the employment of electrical energy.

It is also an object of this invention to provide for said purpose a system wherein electric heat is generated, if desired, evenly throughout the whole depth of the well, but more particularly throughout a desired interval thereof, such as the critical interval of the upper 3,500 feet in gas condensate wells, said heat generation being effected by means of a continuous heater conductor positioned within the well, said conductor having a low resistance permitting operation at low voltages and being provided with an insulation competent to eliminate life and fire hazards due to short circuits, power losses due to leakage, and the like.

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It is also an object of this invention to increase the mechanical strength in tension of a heater conductor such as defined hereinabove to a safe value through the use of special bracing means coupled to said cable, said heater, conductor and bracing means being connected to a counterbalance system providing compensation for unequal length variations due to temperature effects within the well.

These and other objects of this invention will be understood from the following description taken with reference to the attached drawings, wherein:

Fig. 1 is a diagrammatic view of a well head installation according to the present invention;

Fig. 2 is a horizontal cross-section view of cable **22** of Fig. 1;

Fig. 3 is a diagrammatic vertical cross-section view of the lower end terminal of said cable.

Referring to the drawings, Fig. 1 shows a well having an outer casing **6** and an inner concentric casing string **8** of any suitable diameter such for example as 7 inches. The well is closed at the surface by a casing head diagrammatically indicated at **10** and normally provided with conventional devices such as master and gate valves, blowout preventors, lubricators, etc., which are not shown to simplify the drawing, and through which a production tubing string **12** and a parallel string of so-called "macaroni" tubing **14** extends into the well. The production tubing **12** may have a diameter such for example as 2⅞ in. O. D., and the tubing **14** a diameter of 1$\frac{5}{16}$ in. O. D. The two strings of tubing are held together by means such as clamps **16** connecting them preferably at every joint. The string **12** extends to a depth determined by the operating conditions of the well, while the string **14** extends to a depth considered necessary for supplying uniform heat to a critical well interval, such, in the case of gas-condensate wells, as a depth of 3,500 ft., at which depth the string **14** is terminated by a special tubing connector shown at **18**, which is of conventional design.

Connected to the tubing **14** above the casing head **10** is a lubricator device **20** for introducing into the well a heater conductor **22** suitably connected to a current source diagrammatically indicated at **24**, preferably such as a three-phase power supply line, generator, transformer, etc. The lubricator device **20** may be of a type such as described in U. S. Letters Patent 2,670,225, issued to H. E. McKinney for a "Lubricator Device."

The heater cable **22** extends into the tubing **14** throughout its total depth, that is, substantially to the level of the connector **13**. The cable **22** is preferably a cable such as commercially known under the trade name of Pyrotenax. As shown in greater detail in cross-section in Fig. 2, this cable comprises an outer copper sheath **26**, filled with a granular insulating material such as compressed magnesium oxide, as shown at **28**. Embedded in this insulating material are conductor means such as, in case three-phase current is used, three copper conductors **30**, **31** and **32** extending throughout the length of the cable. At the bottom end of the cable, the three conductors are brought together and welded or otherwise electrically connected to the outside copper sheath **26**, as shown at **34** in Fig. 3, the sheath itself being suitably grounded as diagrammatically shown at **35**. This terminal Y-connection of the cable conductors, used in combination with suitable electrical connections at the surface, provides for a balanced resistive electrical load, a condition which is very desirable for the present installation.

The high temperature characteristics of the compressed magnesium oxide insulation permit continuous operation of the heater cable at a temperature of 250° C. which is adequate for the desired purposes. The use of copper wires 30, 31 and 32 (which use, as will be shown below, is mechanically possible only in combination with that of a reinforcing steel tape) permits the supply of the required power at considerably lower applied voltages than with the usual nickel-chrome heater wires, whose resistance is considerably greater than that of the copper wires. The heating of a 3,500 ft. upper interval of a well having a 7 in. casing requires a power consumption of from 30 to 75 kilowatts 50 kw. being an average figure.

Connected to the tubing 14 through a pipe 36 controlled by a valve 38 is a reservoir 40 or other sources of non-inflammable high dielectric strength liquid, preferably a synthetic insulating fluid such as the fluids commercially known under the name of Pyranols (see U. S. Patent 2,277,689 to Clark) or a suitable transformer oil, for example, a highly refined mineral oil comprising sulfonated aromatic compounds. Filling the tubing 14 with such oil serves, first, to minimize losses or hazards due to cable short-circuits, and, second, to protect the copper-clad cable 22 from attack by highly corrosive sulphur-containing gases normally produced in petroleum wells.

Although the conductor cable described hereinabove has very desirable electrical characteristics, its mechanical strength is relatively low so that excessively long stretches of said cable cannot be lowered into a well without failing in tension under the stress of their own weight. According to the present invention, the conductor cable is strengthened by clamping or otherwise exteriorly attaching thereto a reinforcing steel line or tape. A preferred arrangement may be briefly described as follows with regard to a typical well to be heated throughout its upper interval of 3,500 feet.

A steel tape, having a width such as ¼ inch and a thickness of about 1/16 inch has its two ends unwound from a sheave or drum 42. One end 44 is led into the tubing 14 through the lubricator 20 and is clamped at suitable intervals such as 20 feet, to one side of the cable 22 (as shown at 44 in Fig. 2). The steel tape 44 extends into the well to a depth equal to approximately one third of the length of the cable 22; thus for a cable 3,500 ft. long, the steel tape 44 terminates at a depth of approximately 1,160 feet by a lowermost clamp 46 attaching it to the cable.

The other end 48 of the steel tape from drum 42 is led over sheaves 51, 53 and 55 and through lubricator 20, being clamped to the cable 22 in a manner similar and on the side opposite to that of tape 44, as shown at 48 in Fig. 2. The tape 48 extends into the well to a depth equal to about two-thirds of the cable 22: that is, for the example given, to a depth of about 2,320 feet, where it is attached to the cable 22 by a lowermost clamp, similar to clamp 46 and not shown in the drawing. Thus only the last third of the length of cable 22 is unsupported, and must rely on its own mechanical strength, which is, however, entirely adequate for dimensions such as mentioned above.

The sheaves 53 and 55 are fixedly supported on a suitable well head structure diagrammatically indicated at 57. The sheave 51 is supported on a tubular sleeve 59, free to travel up and down over an upright 60, which may form a part of the structure 57. Attached to the sleeve 59 is a relatively heavy weight 62, such as a block of concrete, pig iron, etc. It will be seen that this arrangement serves to apply tension to the two ends or halves 44 and 48 of the reinforcing tape in such a manner that the vertical up and down motion of the sheave 51 acts to compensate for unequal length variations due to the effect of well temperature changes on the copper-sheathed cable and the reinforcing steel tape, having different coefficients of expansion. The above description is purely illustrative, since it is obvious that tension can be applied to tapes 44 and 48 by separate weights acting over the sheaves 42 and 53, and further variations will occur to those skilled in the art.

The operation of the present system is believed clear from the preceding description. A suitable current is supplied to the cable 22 from the source 24 at relatively low voltages, such as 440 volts, which is made possible by the low resistance of the cable 22. The cable is uniformly heated throughout its whole length to a desired temperature, preferably not exceeding 250° C. the heat being dissipated in the well to maintain the producing string 12 at a temperature sufficiently high to prevent the formation of natural gas hydrates. No harm is done to the magnesium oxide insulation of the cable by operation at this temperature. The fluid in the tubing 14 minimizes fire hazard and prevents corrosive well gases from attacking the copper-sheathed cable 22, while the counter-balance arrangement at the surface provides compensation for unequal thermal expansion of the cable and the reinforcing tape as the temperature of the well is raised by heating.

I claim as my invention:

1. Heating apparatus for a well containing a production string of tubing, said apparatus comprising a second tubing string parallel to the production string, an insulated conductor cable extending within said second string substantially throughout the length thereof, said second string being filled with a dielectric fluid, and means for supplying a heating current to said conductor cable.

2. Heating apparatus for a well containing a production string of tubing, said apparatus comprising a second tubing string of smaller diameter, means clamping said two strings together in parallel relationship to each other, an insulated conductor cable extending within said second string substantially throughout the length thereof, said second string being filled with a dielectric fluid, and means for supplying a heating current to said conductor cable.

3. Heating apparatus for a well containing a production string of tubing, said apparatus comprising an insulated conductor cable extending into the well throughout a predetermined vertical interval thereof, means maintaining said cable in parallel relationship with said tubing string throughout substantially the whole length of said cable, longitudinal reinforcing means exteriorly carried by said insulated cable throughout a major upper portion thereof, said reinforcing means being clamped to said cable at the lower end of said reinforcing means and being fixedly supported at the upper end thereof to increase the mechanical strength of said cable, and means for supplying a heating current to said cable.

4. Heating apparatus for a well containing a production string of tubing, said apparatus comprising a second tubing string parallel to the production string, said second string being filled with a dielectric fluid, an insulated conductor cable extending within said second string substantially throughout the length thereof, longitudinal reinforcing means exteriorly carried by said insulated cable throughout a major upper portion thereof, said reinforcing means being clamped to said cable at the lower end of said reinforcing means, and supported in tension at the upper end thereof outside said second tubing string, said reinforcing means serving to increase the mechanical strength of said cable, and means for supplying a heating current to said cable.

5. Heating apparatus for a well containing a production string of tubing, said apparatus comprising a second tubing string of smaller diameter extending into the well to a predetermined depth, said second string being filled with a dielectric fluid, means clamping said two strings together in parallel relationship to each other, an insulated conductor cable extending within said second string substantially throughout the length thereof, said cable comprising a metallic sheath, a heat-resistant insulating material filling said sheath, and electrical conductor means embedded in said insulating material, steel tape means exteriorly affixed to said insulated cable throughout a major upper portion thereof, said steel tape means being clamped to the sheath of said cable at the lower end of said tape

means a counterweight clamped to the upper end of said tape means outside of said second tubing string, whereby a tension force is applied to said tape means and the mechanical strength of said cable is increased and unequal expansion rates of said cable and said tape means are compensated for, and means for supplying a heating current to the conductors within said cable.

6. The apparatus of claim 5, wherein the sheath and the conductors of said cable are of copper, and the insulating material within said sheath is compressed magnesium oxide.

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