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(54) **Wellbore electrical heater**

Elektrisches Bohrlochheizgerät

Appareil de chauffage de fond de puits

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Description

FIELD OF THE INVENTION

[0001] This invention relates to a electrical heating method and apparatus useful in a borehole.

BACKGROUND TO THE INVENTION

[0002] U.S. Patent Nos. 4,640,352 and 4,886,118 disclose conductive heating of subterranean formations of low permeability that contain oil to recover oil therefrom. Low permeability formations include diatomites, lipid coals, and oil shales. Formations of low permeability are not amiable to secondary oil recovery methods such as steam, carbon dioxide, or fire flooding. Flooding materials tend to penetrate formations that have low permeabilities preferentially through fractures. The injected materials bypass most of the formation hydrocarbons. In contrast, conductive heating does not require fluid transport into the formation. Oil within the formation is therefore not bypassed as in a flooding process. Heat injection wells are utilized to provide the heat for such processes.

[0003] Heat injection wells can also be useful in decontamination of soils. U.S. patents 5,318,116 and 5,244,310, for example, disclose methods for decontamination of soils wherein heat is injected below the surface of the soil in order to vaporize the contaminates. The heaters of patent '310 utilize electrical resistance of spikes, with electricity passing through the spikes to the earth. Patent '116 discloses heater elements passing through the wellbore to the bottom of the formation to be heated. The wellbore surrounding the heater includes a catalyst bed, which is heated by the heater elements. Heat conductively passes through the catalyst bed to a casing surrounding the catalyst bed, and then radiantly from the casing to the soil surrounding the wellbore. Typical alumina based catalysts have very low thermal conductivities, and a significant temperature gradient will exist through the catalyst bed. This significant temperature gradient will result in decreased heat transfer to the earth being heated at a limited heater element temperature.

[0004] U.S. patent no. 5,065,818 discloses a heater well with sheathed and mineral insulated ("MI") heater cables cemented directly into the wellbore. The MI cables includes a heating element surrounded by, for example, magnesium oxide insulation and a relatively thin sheathing around the insulation. The outside diameter of the heater cable is typically less than one half of an inch (1.25 cm). The heater well optionally includes a channel for lowering a thermocouple through the cemented wellbore for logging a temperature profile of the heater well. Being cemented directly into the wellbore, a need for a casing (other than the sheathing of the cable) is eliminated, but the outside diameter of the cable is relatively small. The small diameter of the heater cable limits the amount of heat that can be transferred to the formation from the heater cable because the area through which heat must pass at the surface of the cable is limited. A cement will have a relatively low thermal conductivity, and therefore, a greater heat flux at the surface of the cable would result in an unacceptably high heater cable temperature. Multiple heater cables may be cemented into the wellbore to increase the heat transfer to the formation above that which would be possible with only one cable, but it would be desirable to further increase the heat that can be transferred into earth surrounding the heaters.

[0005] U.S. patent 2,732,195 discloses an electrical heater well wherein an "electrically resistant pulverulent" substance, preferably quartz sand or crushed quartz gravel, is placed both inside and outside of a casing of a wellbore heater, and around an electrical heating element inside of the casing. The quartz is placed there to reinforce the casing against external pressures, and a casing that is sealed against the formation is required. The casing adds considerable expense to the installation.

[0006] The wellbore heater and heating method according to the preamble of claims 1 and 9 are known from the aforementioned US patent No. 5,065,818. The relatively small surface area of the known heater cable limits the amount of heat that is transmitted into the surrounding formation.

[0007] US patent No. 2,500,513 discloses an array of electrical heating rods in a downhole cage to crush and melt wax lumps in produced well fluids. Also this patent discloses the features in the preamble of claims 1 and 9.

[0008] US patent No. 2,350,429 discloses a downhole steam boiler vessel in which water is heated by an electromagnetic field transmitted by uninsulated annular electrodes.

[0009] It is therefore an object of the present invention to provide a wellbore heater wherein the heater has a greater surface area at the temperature of the electrical resistance element than those of the prior art, and in which a substantial casing is not required. This heater is useful as a well heater for such purposes as thermal recovery of hydrocarbons and soil remediation.

SUMMARY OF THE INVENTION

[0010] These and other objects are accomplished by a wellbore heater comprising an electrical insulating material surrounding an annular electrical resistance heating element configuration selected from the group consisting of an annular porous metal sheet, one or more rounded and/or expanded metal plates and a wire mesh, the wellbore heater having no metal casing located between the heating element configuration and the earth surrounding the borehole to be heated.

[0011] The casingless design of the present heater significantly reduces the cost of a heat injection well, which is significant in an application such as heat injec-

tors for recovery of hydrocarbons from, for example, oil shales, tar sands, or diatomites. Heat injection can also be used to remove many contaminates.

[0012] In accordance with another aspect of the invention there is provided a method to heat a portion of the earth, the method comprising the steps of:

providing a borehole within the portion of the earth to be heated;
placing a tubular electrical resistance heating element configuration which is selected from the group consisting of an annular porous metal sheet, one or more rounded and/or expanded metal plates and a wire mesh within the borehole; and
supporting the heating element configuration within the borehole with electrically insulating material, wherein a metal casing is not provided between the heating element configuration and the earth to be heated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

FIG. 1 shows first embodiment of a heater according to the present invention within a wellbore.
FIGS. 2A, 2B, and 2C show details of an electrical cable attached to the top of a heater according to the present invention.
FIG. 3 shows an apparatus for installing the heater of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Optionally the annular heater of the present invention has a mesh heating element which can be formed to conform to a wall of a wellbore to maximize the surface of the heating element which is provided and to maximize the heat flux leaving the wellbore. An electrically insulating filler is placed around and inside of the heating element to essentially eliminate electrical shorting of the element to the formation. This electrically insulating material could be a material that is initially wet, and therefore electrically conducting until it is dried. The drying step could be accomplished by passing electricity through the heating element and into the wet material, and heat generated by the electrical energy would gradually heat the soil and eventually vaporize liquid water initially present. The remaining dry sand is an acceptable electrical insulator. Optionally, a hydraulic cement could be used in place of the sand. Hydration of the cement reduces free liquid water, and the cured cement can be an acceptable electrical insulator. Other materials could be used as the insulating material. Preferred materials are easily placed and inexpensive. An ideal material would also either be or readily become an electrically nonconducting material. A material such as sand could be placed pneumatically or as a slurry.

[0015] A plurality of electrical heating elements are preferably placed in the wellbore to form the heater, with the elements connected at the lower portion of the wellbore, and different phases of alternating electrical power applied to each of the elements. Two or three elements are preferred.

[0016] The heating elements can be expanded metal, or another porous metal element such as a wire screen or wire mesh. A porosity of between about forty percent and about eighty percent is preferred, where porosity is defined as the percent of open area looking at the surface of the sheet of material. Providing this open area considerably increases the total area contacted by the element, without reducing the thickness of the element. A thicker element provided greater allowances for corrosion. Thickness of the element is chosen to result in a voltage requirement at the targeted heat flux which is not excessively low or high. For example, a voltage differential of about 120 to about 960 volts of alternating current between the upper ends of two elements within a wellbore which have connected lower ends would be preferred. Generally, for longer lengths of meter (100 to 700 meters) from 480 to 960 volts is preferred and for shorter meters (2 to 200 meters) from 120 to 480 volts is preferred. To accommodate greater thicknesses of elements, multiple heaters could be provided in series, but the extent to which this can be done is limited by the expense of the cables leading to the heater elements. Power is preferably applied between two symmetrical heater elements wherein the net voltage is zero. Thus the voltage applied at one time to one electrode is the negative with respect to ground of the voltage applied to the other heater element.

[0017] The elements are preferably formed into a curved shape either at the surface or within the borehole to conform to the walls of the wellbore. The curved shape could be provided at the surface by a die through which the metal is passed as it is passed into the wellbore. The curved shape could be provided within the wellbore by passing a mandrel past the element. The mandrel could, for example, be provided as a part of an apparatus which spreads the elements and places the electrical insulating material around and between the elements. When the elements are formed into a curved shape at the surface, centralizers and spacers can be added to the elements to keep the elements separated within the wellbore. Use of the mandrel as described above is preferred because centralizers and spacers can be eliminated, reducing the cost of materials. Flat mesh elements could be provided. The advantage of providing curved elements is that heat could be transferred from almost the entire circumference of the borehole, with two flat elements, heat could be transferred from a surface area of only about twice the diameter of the wellbore, but installation of the flat elements could be simplified compared to the semicircular shaped elements.

[0018] Generally, heater elements of stainless steel

of, for example, grades 304 or 316 are preferred. INCLOY 600 could also be useful (INCLOY is a trademark). 316 stainless steel is preferred when the elements will be exposed to brines because of the greater resistance of 316 stainless steel to chloride stress corrosion. Stainless steels are not excessively expensive, and would withstand exposure to elements that may be present during start-up phases for long enough to get the elements up to elevated temperatures, and sufficiently low corrosion rates when exposed to most borehole environments for extend periods of time at elevated temperatures. Typically, stainless steels are not utilized as heater elements because of limited high temperature corrosion resistance, but because of the relatively large surface area from which heat is transferred in the heater of the present invention, the elements surface temperature can be suitable for stainless steels. Carbon steels could also be used as heater elements for applications where high levels of heat do not have to be provided for extended periods of time.

[0019] Although in a preferred embodiment of the present invention includes the use of stainless steel as the heater element material, higher alloys could be useful in some applications of the present invention. For example, when the heater is applied in a relatively deep wellbore, the costs of providing the well could be much greater than the costs of the heater element material, and therefore a higher alloy could reduce total costs by permitting operation at higher temperatures and thus reducing the number of wells required for the same total heat duty.

[0020] Alternatively, the heating elements could be coated with a more corrosion restive metal surface, or a refractor surface to provide additional electrical insulation and protection.

[0021] Thermocouples for control of the heaters could be provided within the wellbore, either inside of curved heater elements, outside of the elements, or attached to the heater elements (through an electrically insulating connection). The thermocouple could be used to monitor the operation, or to control electrical power applied to the heater element. When thermocouples are used to control the electrical power, multiple thermocouples could be provided and the a control temperature selected from the thermocouples. The selection could be based on a maximum temperature, an average temperature, or a combination such as an average of the highest two or three temperatures.

[0022] The heat elements of the present invention can be made to a wide variety of lengths because of the flexibility to select different combinations of voltages and porosities of the heater elements. Heaters as short as two to six meters can be used, and as long as two hundred to seven hundred meters could be provided.

[0023] A borehole within which the heater of the present invention is placed may be cased and cemented for at least a portion of the borehole above the heater, to ensure isolation of the formation to be heated. In a shallow well, the borehole may be filled with sand to the surface.

[0024] Referring now to FIG. 1, a schematic drawing of the annular heater of the present invention is shown. A mesh heater element 1 is shown as two semicircular expanded metal plates within a wellbore 2. An electrically insulating filler 3 such as sand is shown surrounding and between the heating elements. The borehole is within a portion of the earth to be heated 4, such as a formation of oil containing diatomite, tar sands or oil shale. Alternatively, the earth to be heated 4 could be contaminated soil in a thermal desorption remediation process. Electrical leads 5 extend to each of the heater elements and the heater elements are electrically connected at the lower portion of the elements by connector 6. Alternatively, the elements could all be grounded at the base of the borehole. Electrical leads extend through the portion of the overburden which is not to be heated 7 through sheathed cables 8, the sheathed cables separated by spacers 9. A transition portion of the wellbore will be heated by the heater elements, but not to the temperatures that result in the portion of the borehole which contains the heater elements. This transition portion of the borehole is shown as cased by a casing 10, which may be of a metal such as stainless steel, which will have an acceptably long useful life when exposed to elevated temperatures. The corrosion environment within this transition volume may be more sever than the corrosion environment near the heaters because of the dew point temperature being within this region. Above the transition zone, the casing could be a carbon steel casing 11. The casing within the transition zone and the overburden 7 could be filled with a filler 12 such as sand or cement, or left void.

[0025] Referring now to FIG. 2A, 2B, and 2C, three views with partial cutaways are shown of fittings for electrical cables and connections to the heater element of the present invention. The top of the heater element 21 is connected to a high temperature lead cable 22 by a weld connection 33. A waterproof interface between the cable and heater A is within a transition zone. Above the transition zone, an inexpensive cable such as a polyethylene coated copper wire could be used. An electrically insulated high temperature section B extends from the waterproof interface to the heater element. A stiffener 24 provides support for the electrical connection to the heater element. The stiffener is attached to the cable by a collar 25. The collar is an electrically insulating collar. The water proof interface includes a coupling 26 around a soldered connection 27, the soldered connection providing continuity between the high temperature lead cable 22 and a low temperature lead cable 28. The coupling is threaded to swedge fittings 30, which may be brass fittings, and which provide a friction fitting to each of the high temperature lead sheath 31 and the low temperature lead sheath 23. Cable 23 goes from the surface to just above the top of the heater and cam be a copper core-copper sheathed mineral insulated cable. This

type of cable is preferred because of its ability to carry very large amounts of electrical power, and because it is waterproof. Although the cable can withstand high temperatures, it is used at temperatures below the boiling point of water due to corrosion rates. A waterproof splice (A) terminates the mineral insulated cable 23 and forms a transition to a nickel or nichrome clad-nickel electrode 22 that is welded 33 to the upper part of the heater 21. The nickel hot electrode 22 can be insulated with a TEFLON sleeve 31 to prevent corrosion of the nickel electrode and provide a waterproof seal at the lower end of the cable transition 30 (TEFLON is a trademark). Stiffening arm 24 provides support to the TEFLON sleeved nickel electrode 22 during installation of the heater into a wellbore. The waterproof splice A can be about two to twenty feet above the top of the heater element. The water proof splice is far enough away from the heater so that the water proof splice remains at a temperature below the boiling point of water. The TEFLON coated high temperature lead is, at one point, exposed to the boiling point of water, and is easily capable of handling this environment. The lower (hotter) portion of the high temperature lead sheath 31 will eventually melt away, leaving exposed high temperature lead. Providing the TEFLON coating to this point ensures that the TEFLON extends past the point where the temperature is at the boiling point of water.

[0026] The high temperature lead sheathing could be any coating which would protect the high temperature lead from corrosion at temperatures of the boiling point of water or less, and would either withstand higher temperatures or melt away and not cause any corrosion at higher temperatures. Heat resistant resins are preferred because they provide a greater length of protected high temperature lead which could be helpful if the point at which the temperature is the boiling point of water moves. Acceptable high temperature resins include polyimide, polyamide-imide, and polyetheretherketone.

[0027] The high temperature lead sheath is separated from the high temperature lead by mineral insulation such as magnesium oxide. Copper leads are acceptable and effective for the low temperature leads, but nickel or nickel-chromium clad nickel are preferred for the high temperature leads.

[0028] Alternatively a plurality of elongate electrical heating elements are placed in the wellbore to form the heater, with the elements connected at the lower portion of the wellbore, and different phases of alternating electrical power applied the elements. At least six elements are preferred in order to provide heat around the entire circumference of the wellbore.

[0029] The heating elements can be, for example, stainless steel wire, nickel-chrome alloy wire or carbon fiber elements. The wires are preferably between about 0.2 and about 0.8 mm in diameter and more preferably about 0.3 mm in diameter. Thicker elements provided greater allowances for corrosion, but at the expense of greater current requirements and greater material costs. Thickness of the element is chosen to result in a voltage requirement at the targeted heat flux which is not excessively low or high. For example, a voltage differential of about 60 to about 960 volts AC between the upper ends of two elements within a wellbore which have connected lower ends would be preferred. For shorter heaters (2 to 200 meters), voltages of 60 to 480 volts AC are preferred, and for longer heaters (100 to 700 meters) a voltage of 480 to 960 volts AC is preferred. To accommodate greater thicknesses of elements, multiple heaters could be provided in series, but the extent to which this can be done is limited by the expense of the cables leading to the heater elements.

[0030] Generally, heater elements of stainless steel of, for example, grades 304, 316, or 310 are preferred. Stainless steels are not excessively expensive, and would withstand exposure to elements that may be present during start-up phases for long enough to get the elements up to elevated temperatures, and sufficiently low corrosion rates when exposed to most borehole environments for extend periods of time at elevated temperatures. Carbon steels could be used as heater elements for applications where heat does not have to be provided for extended periods of time. For shallow applications such as soil remediation, nichrome 80 is preferred.

[0031] Thermocouples for control of the heaters could be provided within the wellbore, either inside of the ring of heater elements, outside of the elements, or attached to the heater elements. The thermocouples could be, for example, secured to one of the electrically insulating spacers. The thermocouple could be used to monitor the operation, or to control electrical power applied to the heater element. When thermocouples are used to control the electrical power, multiple thermocouples could be provided and the control temperature selected from the thermocouples. The selection could be based on a maximum temperature, an average temperature, or a combination such as an average of the highest two or three temperatures.

[0032] The heater elements of the present invention can be made to a wide variety of lengths because of the flexibility to select different combinations of voltages and diameters of the heater elements. Heaters as short as two meters can be used, and as long as 700 meters could be provided.

[0033] A borehole within which the heater of the present invention is placed may be cased and cemented for at least a portion of the borehole above the heater, to ensure isolation of the formation to be heated. In a shallow well, the borehole may be filled with sand or a bentonite slurry to the surface. The bentonite slurry prevents water ingress from above.

[0034] Referring now to FIG. 3, an apparatus which can be used to place the heater of the present system into a wellbore is shown. Heater elements 101 (two shown) are strung over pullies 301, the pullies mounted on brackets 302 which are set on a flange 303. The

flange 303 is mounted on the casing 103, which is equipped with a mating flange. The heater elements 101 are rolling off spools (not shown) and can be maintained in slight tension to prevent entanglement of the heater elements within the borehole. A coiled tubing 304 is shown extending into the borehole. The coiled tubing can be used to place the heater elements and electrical leads within the borehole, and then used to fill the borehole with the electrically insulating filler as it is removed.

[0035] The heating elements can be of a wide variety of lengths and a wide variety of distances down a borehole. For example, for heating an oil shale formation, the heater may be 400 meters long. For remediation of contaminated soil, the heater may be only two or three meters long, although longer heater elements are more advantageously provided by the present invention. The heaters may be provided an extended distance down the borehole. For example, an oil shale formation may be heated which lies under 400 meters of overburden. As the length of the heater and electrical leads become very long, the heater elements and/or electrical leads may be required to be of larger diameter or may need to be made of a material which has greater strength because these elements must be self supporting until the electrically insulating filler is placed around the elements. The heater elements therefore do not have to be self supporting at operating temperatures because friction with the electrically insulating filler will provide vertical support for the elements.

Claims

1. A wellbore heater comprising:

a heating element configuration (1); and
an electrical insulating material (3) surrounding the heating element configuration (1);
the wellbore heater having no metal casing located between the heating element configuration (1) and the earth surrounding the borehole to be heated;

characterized in that the heating element configuration (1) is annular and comprises electrical resistance heating elements selected from the group consisting of an annular porous metal sheet, one or more rounded and/or expanded metal plates and a wire mesh.

2. The heater of claim 1 wherein the annular heating element configuration (1) comprises at least one expanded sheet which is rounded to essentially comply with a portion of a wall of a wellbore.

3. The heater of claim 2 wherein a plurality of expanded slotted metal sheet heating elements (1) are provided and each expanded slotted metal sheet is separated from the other expanded slotted metal sheets.

4. The heater of claim 3 wherein the plurality of expanded metal sheets (1) are electrically connected at a lower extremity (6).

5. The heater of claim 4 further comprising a power supply (5) to each of the expanded metal sheets at an upper extremity, and wherein each of the power supplies is a different phase of electrical power.

6. The heater of claim 1 wherein the electrical insulating material (3) comprises sand.

7. The heater of claim 1 wherein the electrical insulating material (3) comprises cement.

8. The heater of claim 1 wherein a plurality of expanded metal heating elements (1) are provided and the plurality of heating elements are electrically connected to different phases of alternating electrical power at a powered end and electrically connected to a common ground at a ground end.

9. A method to heat a portion of the earth, the method comprising the steps of:

providing a borehole within the portion of the earth to be heated;
placing a heating element configuration (1) within the borehole; and
supporting the heating element configuration within the borehole with electrically insulating material, wherein a metal casing is not provided between the heating element configuration and the earth to be heated;

characterized in that the heating element configuration is annular, and comprises electrical resistance heating elements selected from the group consisting of an annular porous metal sheet, one or more rounded and/or expanded metal plates and a wire mesh.

10. The method of claim 9 further comprising the step of initiating electrical flow through the heating element configuration by passing electrical current from the heating element to the portion of the earth to be heated at a current effective to remove liquid water from the electrical insulating material; and increasing voltage applied to the heating element configuration as a resistance increases through the electrical heating element configuration.

11. The method of claim 10 wherein a plurality of heating elements are provided; the heating elements are all electrically connected at a lower extremity of

the heating elements; and different phases of electrical power are applied to the heating elements at an upper extremity of the heating elements.

Patentansprüche

1. Bohrlochheizeinrichtung, mit:

einer Heizelementkonfiguration (1); und

einem elektrisch isolierenden Material (3), welches die Heizelementkonfiguration (1) umgibt;

wobei die Bohrlochheizeinrichtung keine Metallauskleidung aufweist, die zwischen der Heizelementkonfiguration (1) und der das Bohrloch umgebenden, zu erhitzenden Erde angeordnet ist;
dadurch gekennzeichnet, daß die Heizelementkonfiguration (1) ringförmig ist und elektrische Widerstandsheizelemente aufweist, die aus der Gruppe gewählt sind, welche ein ringförmiges poröses Metallblech, eine oder mehrere gerundete und/oder expandierte Metallplatten und ein Drahtgitter umfaßt.

2. Heizeinrichtung nach Anspruch 1, bei welcher die ringförmige Heizelementkonfiguration (1) zumindest ein expandiertes Blech aufweist, welches gerundet ist, um mit einem Teil der Wand des Bohrloches im wesentlichen übereinzustimmen.

3. Heizeinrichtung nach Anspruch 2, bei welcher eine Vielzahl von expandierten geschlitzten Metallblech-Heizelementen (1) vorgesehen ist, und jedes expandierte geschlitzte Metallblech von den anderen expandierten geschlitzten Metallblechen getrennt ist.

4. Heizeinrichtung nach Anspruch 3, bei welcher die Vielzahl von expandierten Metallblechen (1) am unteren Ende (6) elektrisch miteinander verbunden ist.

5. Heizeinrichtung nach Anspruch 4, die ferner eine Energieversorgung (5) zu jedem der expandierten Metallbleche an einem oberen Ende aufweist, und bei welcher jede der Energieversorgungen elektrische Energie mit einer unterschiedlichen Phase zuführt.

6. Heizeinrichtung nach Anspruch 1, bei welcher das elektrisch isolierende Material (3) Sand umfaßt.

7. Heizeinrichtung nach Anspruch 1, bei welcher das elektrisch isolierende Material (3) Zement umfaßt.

8. Heizeinrichtung nach Anspruch 1, bei welcher eine Vielzahl von expandierten Metallheizelementen (1) vorgesehen ist, und die Vielzahl von Heizelementen an dem Zuführende elektrisch an unterschiedliche Phasen elektrischer Wechselstromenergie angeschlossen ist, und am Erdungsende elektrisch an eine gemeinsame Erdung angeschlossen ist.

9. Verfahren zum Erhitzen eines Teiles der Erde, wobei das Verfahren die Schritte aufweist:

Vorsehen eines Bohrloches innerhalb des zu erhitzenden Erdteiles;

Anordnung einer Heizelementkonfiguration (1) innerhalb des Bohrloches; und

Abstützen der Heizelementkonfiguration (1) innerhalb des Bohrloches mit elektrisch isolierendem Material, wobei eine Metallauskleidung zwischen der Heizelementkonfiguration und der zu erhitzenden Erde nicht vorgesehen ist;

dadurch gekennzeichnet, daß die Heizelementkonfiguration ringförmig ist und sie elektrische Widerstandsheizelemente aufweist, die aus der Gruppe gewählt sind, welche aus einem ringförmigen porösen Metallblech, einer oder mehreren gerundeten und/oder expandierten Metallplatten und einem Drahtgitter besteht.

10. Verfahren nach Anspruch 9, welches ferner den Schritt aufweist, daß ein elektrischer Strom durch die Heizelementkonfiguration geleitet wird, indem der elektrische Strom von dem Heizelement zu dem Teil der zu erhitzenden Erde mit einer Stromstärke geleitet wird, die ausreicht, um flüssiges Wasser von dem elektrischen Isoliermaterial zu entfernen; und daß die an die Heizelementkonfiguration angelegte Spannung erhöht wird, wenn der Widerstand durch die elektrische Heizelementkonfiguration zunimmt.

11. Verfahren nach Anspruch 10, bei welchem eine Vielzahl von Heizelementen vorgesehen ist; wobei alle Heizelemente am unteren Ende der Heizelemente elektrisch miteinander verbunden sind; und am oberen Ende der Heizelemente unterschiedliche Phasen elektrischer Energie an die Heizelemente angelegt werden.

Revendications

1. Dispositif de chauffage pour puits de forage, qui comprend:

une configuration (1) d'éléments de chauffage et

un matériau (3) électriquement isolant qui entoure la configuration (1) d'éléments de chauffage,

le dispositif de chauffage du puits de forage ne présentant pas de coffrage métallique entre la configuration (1) d'éléments de chauffage et le terrain qui entoure le trou de forage et qui doit être chauffé,

caractérisé en ce que la configuration (1) d'éléments de chauffage est annulaire et présente des éléments de chauffage à résistance électrique sélectionnés dans le groupe constitué d'une feuille annulaire poreuse de métal, d'une ou plusieurs plaques en métal déployé et/ou arrondies et d'un treillis.

2. Dispositif de chauffage selon la revendication 1, **caractérisé en ce que** la configuration annulaire (1) d'éléments de chauffage présente au moins une feuille déployée qui est arrondie de façon à correspondre essentiellement à une portion d'une paroi d'un trou de forage.

3. Dispositif de chauffage selon la revendication 2, **caractérisé en ce qu'**il présente plusieurs éléments chauffants (1) en plaques de métal déployé dotées d'évidements et **en ce que** chaque plaque de métal déployé dotée d'évidements est séparée des autres plaques de métal déployé dotées d'évidements.

4. Dispositif de chauffage selon la revendication 3, **caractérisé en ce qu'**à une extrémité inférieure (6), les plaques (1) de métal déployé sont reliées électriquement.

5. Dispositif de chauffage selon la revendication 4, **caractérisé en ce que** chacune des plaques de métal déployé est en outre dotée à une extrémité supérieure d'une alimentation en énergie (5) et **en ce que** chacune des alimentations en énergie est raccordée à une phase d'énergie électrique différente.

6. Dispositif de chauffage selon la revendication 1, dans lequel le matériau (3) électriquement isolant comprend du sable.

7. Dispositif de chauffage selon la revendication 1, dans lequel le matériau (3) électriquement isolant comprend du ciment.

8. Dispositif de chauffage selon la revendication 1, **caractérisé en ce qu'**il présente plusieurs éléments de chauffage (1) en métal déployé et **en ce que** ces éléments de chauffage sont reliés électriquement à différentes phases d'alimentation électrique alternative à une extrémité à laquelle l'électricité est apportée et sont reliés électriquement à un raccordement commun à la masse à une extrémité de mise à la masse.

9. Procédé pour chauffer une portion de terrain, **caractérisé en ce qu'**il comprend les étapes qui consistent à:

réaliser un trou de forage dans la portion de terrain qui doit être chauffée,

agencer une configuration (1) d'éléments de chauffage dans le trou de forage et

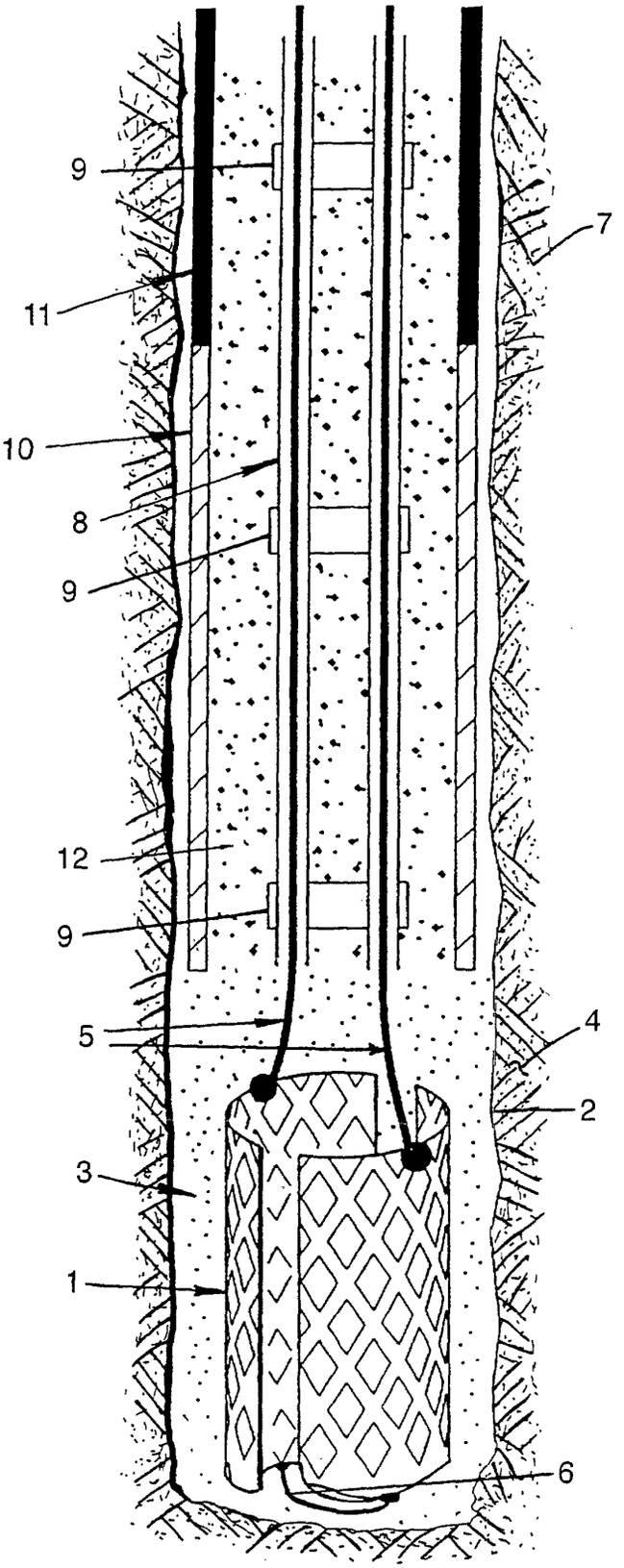
soutenir la configuration d'éléments de chauffage dans le trou de forage par un matériau électriquement isolant sans prévoir un coffrage métallique entre la configuration d'éléments de chauffage et le terrain qui doit être chauffé,

caractérisé en ce que la configuration d'éléments de chauffage est annulaire et présente des éléments de chauffage à résistance électrique sélectionnés dans le groupe constitué d'une feuille annulaire poreuse de métal, d'une ou plusieurs plaques en métal déployé et/ou arrondies et d'un treillis.

10. Procédé selon la revendication 9, **caractérisé en ce qu'**il comprend en outre les étapes qui consistent à lancer un flux électrique à travers la configuration d'éléments de chauffage en faisant passer de l'élément de chauffage à la portion du terrain qui doit être chauffée un courant électrique dont l'effet est d'évacuer l'eau liquide du matériau électriquement isolant et à augmenter la tension électrique appliquée sur la configuration d'éléments de chauffage au fur et à mesure que la résistance croît dans la configuration d'éléments de chauffage électrique.

11. Procédé selon la revendication 10, **caractérisé en ce qu'**il présente plusieurs éléments de chauffage qui sont reliés électriquement entre eux par une extrémité inférieure et **en ce que** différentes phases de courant électrique sont appliquées sur une extrémité supérieure des éléments de chauffage.

Fig.1.



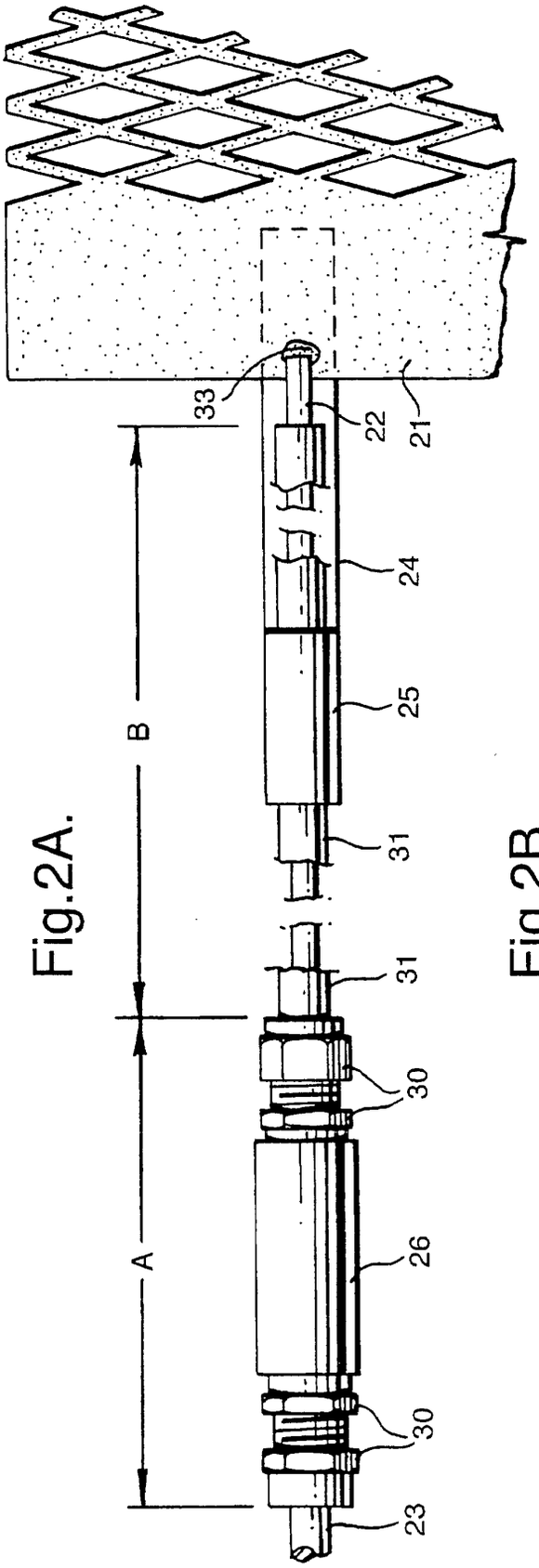


Fig.2A.

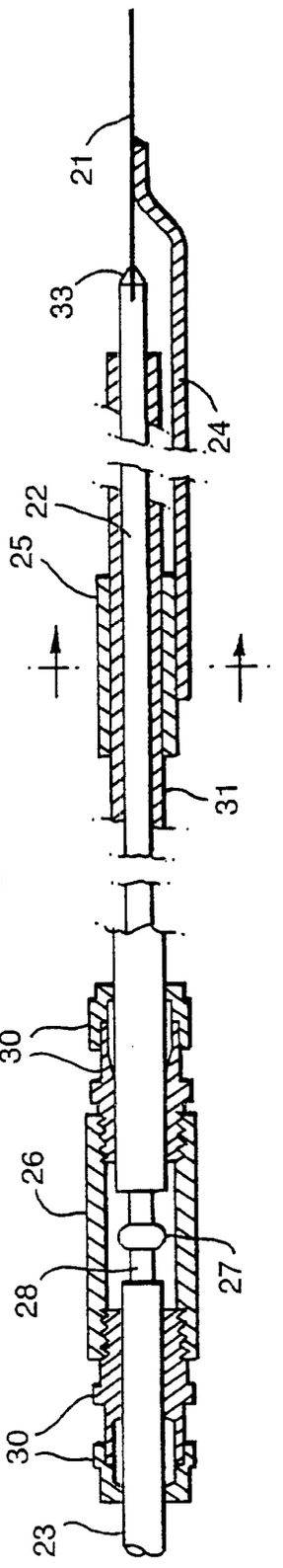


Fig.2B.

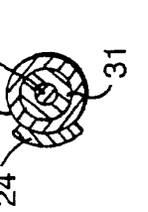


Fig.2C.

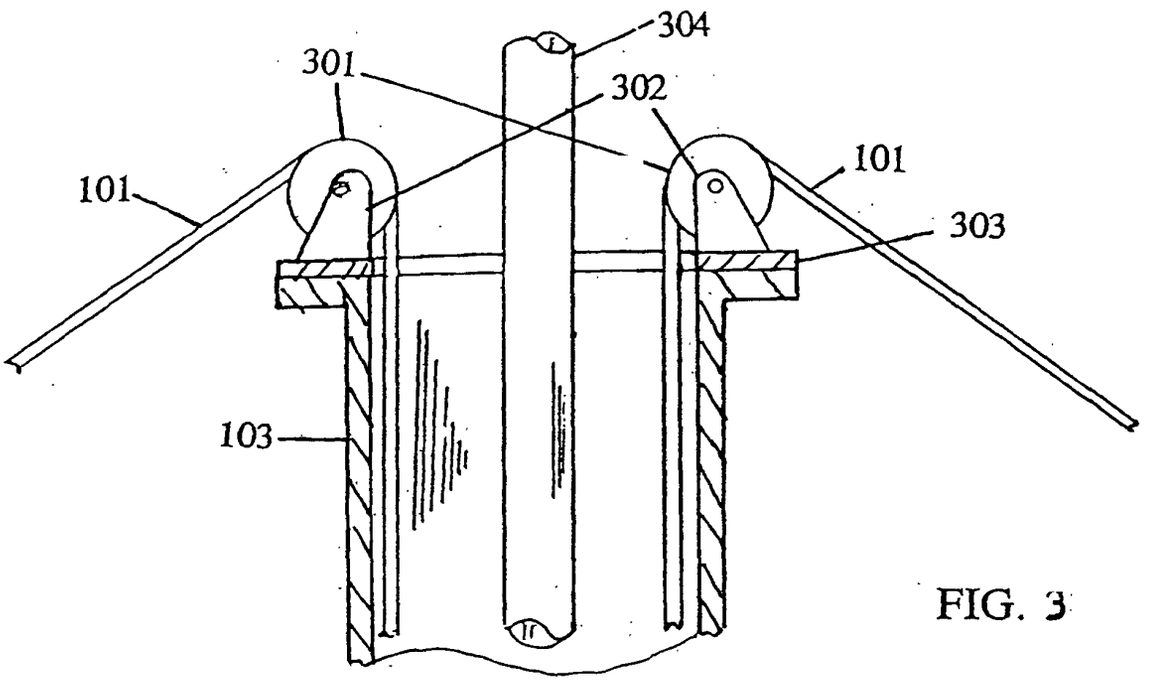


FIG. 3