United States Patent [19]

Kern

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[45] **Oct. 23, 1973**

[54] **PERMAFROST AND WELL PROTECTION**

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[21] Appl. No.: **278,552**

[52] **U.S. Cl.** .... **166/248,** 61/36 A, 166/57, 166/60, 166/65, 166/DIG. 1

[51] **Int. Cl.** **E21b 43/00**

[58] **Field of Search** .... 166/57, 60, 65, 248, 166/302, DIG. 1; 219/277, 278; 65/36 A

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Assistant Examiner—Jack E. Ebel
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[57] **ABSTRACT**

A method for protecting a permafrost zone and a well passing through that permafrost zone wherein a pipe string is placed in said well so as to extend through at least part of said permafrost zone and is heated over its length in said permafrost zone using electrical energy thereby avoiding alternate freezing and thawing of the permafrost and sloughing of the permafrost due to thermal cycling and preventing freeze up of the well itself.

7 Claims, 3 Drawing Figures

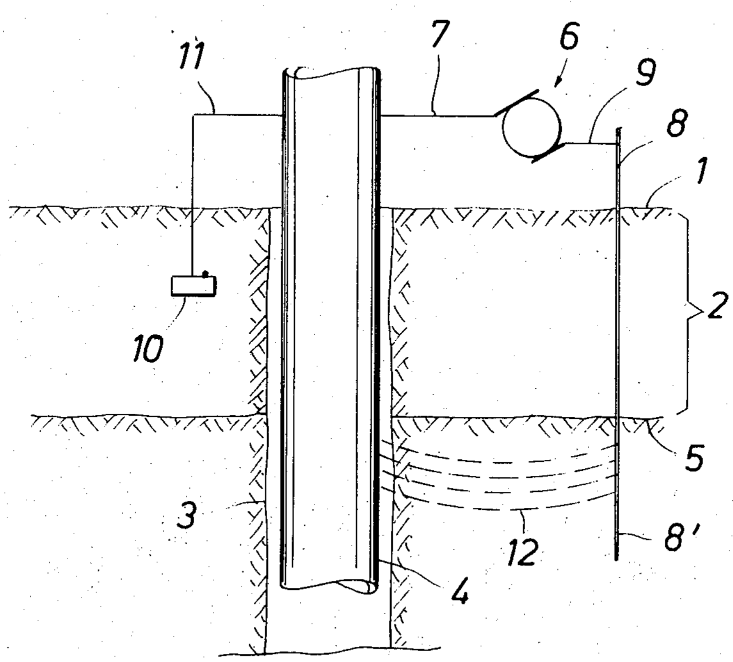

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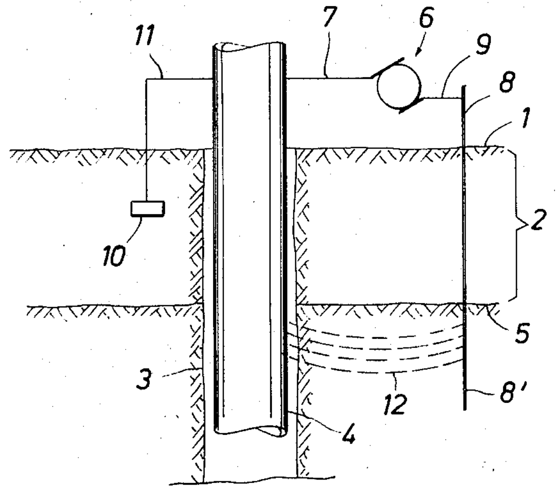
FIG. 1



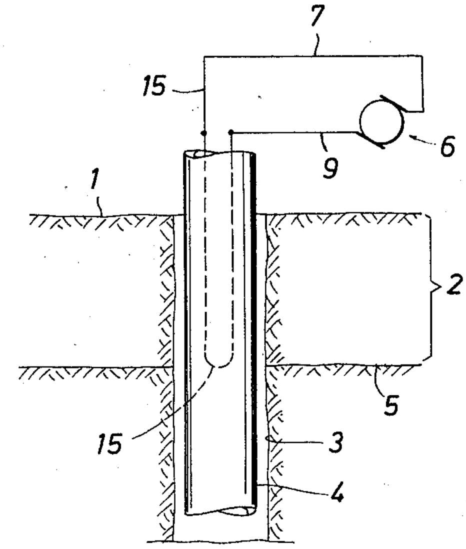


FIG. 2

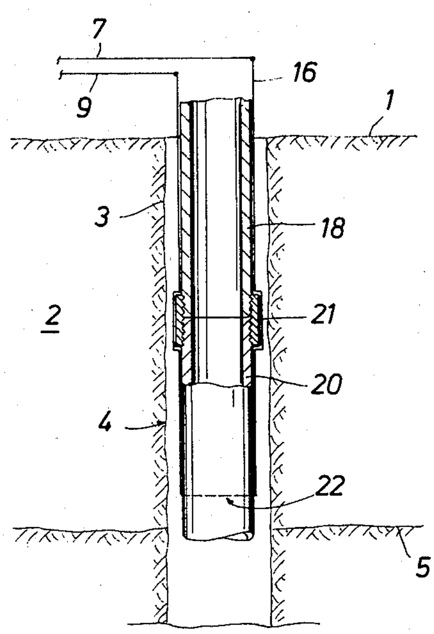


FIG. 3

PERMAFROST AND WELL PROTECTION

BACKGROUND OF THE INVENTION

Heretofore, wells such as oil and gas wells have been successfully drilled through a permafrost zone without causing substantial damage to the permafrost itself. During the drilling of a well, relatively warm fluid is circulated through the well in the permafrost zone. After drilling a well, relatively warm fluid such as a mixture of oil and gas is produced through the well to the earth's surface. Warm fluid, used during drilling or production of the well, when passing through the permafrost zone establishes a temperature equilibrium between the well and the permafrost itself. If after drilling, the well is shut in or if after some production has taken place the well is shut in or its production rate substantially reduced, this equilibrium between the well and surrounding permafrost is altered with the net result that part or all of the affected permafrost refreezes. If any water is entrained in the well in the permafrost zone, the water in the well can also freeze. Thereafter, when production does take place, or resumes, or increases, thawing can again take place and if this thermal cycling is carried on often enough and for a long enough period of time sloughing of permafrost as well as damage to the well itself could occur.

Thus, once a temperature equilibrium is established between the permafrost and the well, e.g., during the drilling of the well, it is preferable to maintain this equilibrium essentially undisturbed for the life of the well even though the production rate of the well may vary considerably and for a substantial period of time even be zero. In this way, a particular well could be shut in for workover or any other desired purpose without fear of harm to the well itself or the permafrost surrounding the well by substantially disturbing the equilibrium previously established between the producing well and the permafrost.

Also, if a well should become frozen up because it passes through a permafrost zone and is shut in or produced at too slow a rate or with too cool a fluid, it must be thawed out before its full productive capacity can be realized.

Further, natural gas or other hydrocarbon containing gas being produced through a wellbore or shut into a wellbore which passes through a permafrost zone can be sufficiently cooled to cause the formation of a hydrate. The hydrate is a solid ice-like material containing both water and hydrocarbon which can form at temperatures substantially above 32° F.

Hydrate can be formed in the produced gas in such quantity that plugging of the tubing through which the gas is produced and/or pipes for carrying the gas over the earth's surface can occur. The plugging is particularly troublesome wherever the flow path of the gas has to change directions such as when passing through valves, T's, and L's in the pipe system.

SUMMARY OF THE INVENTION

According to this invention, a pipe string is established in the wellbore so as to extend through at least part of the permafrost zone and this pipe string is then uniformly heated over its length in the permafrost zone using electrical energy.

The electrical energy can be applied directly to the pipe string or to an electrical conductor associated with the pipe string, but it is important in obtaining the protection required by this invention that the heating of the pipe string be substantially uniform along that length of the pipe which is in the permafrost zone.

Heretofore, downhole heaters have been used in wells to, for example, melt paraffin, but these heaters have not and cannot uniformly heat a length of pipe in a wellbore. On the contrary, these heaters heat only a small localized portion of the wellbore such as the area immediately adjacent where produced fluid leaves an underground geologic formation and flows into the wellbore. By this invention, a substantial length of pipe is heated in a uniform manner to prevent localized overheating which can damage the pipe itself and/or the permafrost. This invention also avoids underheating along the pipe length in the permafrost zone. This invention also avoids disruption of the thermal equilibrium set up between the well and the permafrost anywhere along the heated length of pipe.

By practicing this invention, any length of pipe in the permafrost zone up to and including, but not limited to, the full depth of the permafrost zone, is heated in a controlled manner to prevent freezing of fluids in the wellbore itself, to prevent thawing of the permafrost, and to prevent hydrate formation in the gas produced from the well should a gas well be shut in or otherwise produced at a rate which tends to allow the formation of hydrate before the gas reaches the earth's surface.

Further, if a well has already frozen up due to a lack of production or otherwise, the method of this invention can be employed to thaw out the well without overheating the well piping or permafrost and to reestablish a desired temperature equilibrium between the well and the permafrost.

Accordingly, it is an object of this invention to provide a new and improved method for protecting permafrost. It is another object to provide a new and improved method for producing a well which is completed through a permafrost zone. It is another object to provide a new and improved method for protecting a well which passes through a permafrost zone. It is another object to provide a new and improved method for substantially maintaining a temperature equilibrium set up between a well and surrounding permafrost. It is another object to provide a new and improved method for avoiding substantial thermal cycling of permafrost. It is another object to provide a new and improved method for protecting a well from freeze up when completed through a permafrost zone. It is another object to provide a new and improved method for producing a wall through a permafrost zone at a rate or temperature sufficiently low that freezing of at least part of the produced fluid could occur. It is another object to provide a new and improved method for thawing out a frozen well. It is another object to provide a new and improved method for preventing hydrate formation in a well.

DETAILED DESCRIPTION OF INVENTION

FIG. 1 shows a cross-section of a well employing one embodiment of this invention.

FIG. 2 shows a cross-section of a well employing another embodiment of this invention.

FIG. 3 shows a cross-section of a well employing yet another embodiment of this invention.

More specifically, FIG. 1 shows the earth's surface 1 below which is a permafrost zone 2 and through both of which is drilled a wellbore 3. Emplaced in wellbore 3 is a pipe string 4 which extends from above the earth's surface to below the lower end **5** of the permafrost.

An electric current source **6** has one pole connected by way of electrical wire **7** directly to pipe **4**. An electrical return conduit which can be a metal rod, a pipe string in another wellbore, or any sort of electrical return is situated at **8** so that its lower end **8'** extends below the lower surface **5** of the permafrost to establish an electrical return through element **8** and electrical wire **9** to source **6**, this return being established beneath the zone **2**.

Permafrost zone **2**, being substantially completely frozen, will not conduct substantial amounts of electricity so that the electricity will not leak off from pipe string **4** to any great extent while passing through zone **2**. As soon as electricity reaches the unfrozen earth below zone **2**, i.e., below lower surface **5**, it will migrate toward the electrical return **8**. Thus, it is important to this embodiment of the invention that the electrical return be established beneath the permafrost. In this way, uniform heating over substantially the entire surface of the pipe in zone **2** is achieved. Although it is not required to achieve the results of this invention, it is preferred that the electrical return be another well because by using a pipe string in a second well as a return conduit, that pipe string is also heated and the permafrost around both wells protected at the same time.

Alternating current or direct current can be employed in this embodiment of the invention. If direct current or low frequency alternating current is employed, it may be desirable to utilize a sacrificial anode or some other equipment designed to protect pipe **4** for electrolytic corrosion. For example, a sacrificial anode comprising a zine block **10** can be employed in or below the permafrost and electrically connected to pipe **4** by way of electrical conduit **11**. Any known electrolytic corrosion device can be employed.

The voltage employed can be any voltage necessary to obtain a particular desired result. Thus, substantially any current and voltage can be employed. The current and voltage used in specific situations will vary extremely widely since both are affected, not necessarily in the same manner, by the composition of the pipe, the heat treatment history of the pipe, the size and/or weight of the pipe, the resistance and/or impedance of the pipe, the spacing between the well and its electrical return, the particular result desired be it thawing or permafrost protection or hydrate prevention, and the like. However, if voltages greater than about 75 volts, preferably greater than about 50 volts, are employed, special protective measures should be taken for personnel working on or about the well.

In the embodiment of FIG. **1**, for example, at one point of time, when using alternating current, the current will pass down pipe **4** through substantially the entire cross section of the pipe thereby uniformly heating the external and internal surfaces of that pipe through the full depth of zone **2**, leave pipe **4** below zone **2**, pass to conductor **8** and upwardly to the earth's surface and ultimately through wire **9** to source **6**. The path of the electrons from pipe **4** to return **8** will be a field of flow represented by dotted lines **12**.

Although substantially no electrical current will leak off in the permafrost zone, should there be some leak off in this zone, it would not be detrimental to the overall results of this invention. This is so because in an area where permafrost exists, the temperature at the surface of the earth in the winter and near the top of the permafrost in the summer is always much less than the temperature at or near the bottom **5** of the permafrost zone. If there is leak off of electrical current in the permafrost zone, it most likely would occur at various points along the length of that zone. Even if there is some slight loss of current in the zone, the maximum amount of current will be flowing through the upper portion of the zone where more heating is necessary since the upper portion is colder. Thus, should there be any leak off of current so that the magnitude of the current as it reaches the vicinity of bottom **5** of the zone is reduced, this is not critical because the temperature of the permafrost at bottom **5** is close to the freezing point of water and sufficient heating can be achieved in this vicinity with the reduced current, the larger current having already been used in the upper part of the zone where it is needed most. Similar reasoning applies for thawing a well or preventing hydrate formation.

FIG. **2** shows the well of FIG. **1** with an electric source **6** except that the electrical current is not applied directly to pipe **4** but electrical energy is still used to obtain uniform heating of pipe **4** at least in the permafrost zone. This is achieved by employing a loop of electrical conductor **15** which extends in pipe **4** for the depth of zone **2**, one end of conductor **15** being connected to wire **7** and the other end being connected to wire **9** to complete the electrical circuit from the source **6**. In this way an electric current, be it A.C. or D.C. is used to heat conductor **15** which in turn heats pipe **4**. One or more conductors **15** can be employed in a single well and can be employed inside or outside of a pipe string or in an annulus between two pipe strings or both. The loop of conductor **15** can extend for any length in pipe **4**, whether the length is less than, equal to, or greater than the depth of zone **2**.

FIG. **3** shows the well of FIG. **1** wherein electrical conduit **16** is still connected to wires **7** and **9** but conduit **16**, instead of being hung in an open volume somewhere in the well, is physically attached to the wall of pipe string **4**. Conduit **16** as emplaced on the wall of the pipe can be insulated or uninsulated. If the wire is uninsulated it will have some of the heating attributes of FIG. **1** as well as some of the attributes of FIG. **2**. If conduit **16** is insulated it will have the heating attribute of FIG. **2** only except that it will be in much more intimate contact with the pipe for the conduction of heat. More than one conduit **16** can be employed in pipe **4**.

To insure continuity of the electrical circuit from one pipe section to another pipe section in pipe **4**, conduit **16** passes from upper pipe section **18** over coupling **21** to lower pipe section **20** so that when the two pipe sections are made up at the earth's surface and joined by way of a conventional coupling **21**, electrical continuity throughout the length of pipe string **4** is insured. The return loop of the conduit **16** at or near the lower surface **5** of the permafrost zone merely passes laterally around the wall of the pipe section as shown at **22** for its return up the outside of pipe **4** to electrical wire **9**. Wire **16** can be physically attached to the pipe such as by clamps, wire strapping, and the like. More than one wire **16** can be used on pipe **4** on the inside or outside of pipe **4** or both.

A gas, such as natural gas, other hydrocarbon containing gas, carbon dioxide, and the like, can be produced from a gas producing formation (not shown) into, for example, pipe **4** and up the wellbore through zone 2 to the earth's surface for further processing, use, and the like.

The gas passing from pipe 4 at the earth's surface normally passes through a piping system for further processing such as dehydration, sulfur and sulfur compound removal, and the like. Because of this, the gas passes through a large number of pipes and changes direction by way of pipe T's and L's a large number of times shortly after it leaves pipe 4.

The gas containing hydrate forming water and hydrocarbon can initially be above the temperature and pressure at which substantial amounts of hydrate form. By "initially" it is meant the gas as produced from the formation into the lower portion of wellbore 3.

The substantially hydrate-free gas is produced upwardly through wellbore 3 and if the gas is not heated while passing through zone 2, or if the well is shut in and gas trapped in zone 2 of the wellbore, the gas will be cooled sufficiently to cause substantial hydrate formation.

The hydrate itself is a complex combination of hydrocarbons and water. The chemical composition of the hydrate is presently unknown. The hydrate is formed through the mechanism of water vapor in the gas condensing and freezing in a manner which ties hydrocarbon molecules in with the frozen water. The hydrate is solid like ice but has a substantial hydrocarbon content. The hydrate forms at temperatures above 32° F. and can form at temperatures up to about 80° F. and higher in some situations.

Any water present in the gas produced is a potential hydrate former so that there is substantially no minimum amount of water in a hydrocarbon containing gas below which the hydrate formation potential is nonexistent. Normally, the gas produced from a formation is saturated with water so that there is a very substantial potential for the formation of large amounts of hydrate.

The formation of a hydrate and its pipe plugging propensities are especially significant in the production of gas wells through a permafrost zone. The problem of hydrate formation is not presently considered significant in the production of oil wells. This is so because there is a smaller amount of gas associated with the liquid oil and the liquid oil flowing through the conduits and pipes carries the hydrate out rather than allowing the hydrate to build up in the piping as was discovered to be the case with gas wells.

In an exemplary situation, the gas, as initially produced, is above about 80° F. and above about 100 psig. In this situation the hydrate normally forms in the gas at less than 80° F. and less than 10,000 psig. In this situation the gas in pipe 4 is heated to maintain a temperature of that gas greater than 80° F. while in zone 2. Of course, pressure plays some role in the determination at which temperature hydrate formation will occur. Generally, however, there is a temperature such as 80° F. for most natural gases, above which substantially no hydrate will form at any practical pressure, i.e., less than about 10,000 psig.

Electrical energy can be used in accordance with this invention (including any of the embodiments of FIGS. 1 through 3) at any time during the drilling and/or production of a well (or wells if one or more wells are to serve as a return conduit) or can be used only when the production rate of one or more affected wells is decreased or stopped altogether, or combinations thereof.

EXAMPLE

Apparatus is employed substantially as that shown in FIG. 1 wherein the depth of zone 2 is 2,000 feet and pipe 4 is casing which extends to 2,600 feet so that casing 4 extends about 600 feet below the bottom level 5 of zone 2. Casing 4 is conventional 13⅜ inch O.D., 0.514 inch wall thickness, API grade N80 oil well casing.

Direct current is applied to pipe 4. The resistance of 2,000 feet of pipe 4 is about 0.0071 ohms and about 993 amps of direct current provide 7 kilowatts in permafrost zone 2. The total input voltage and power for the well is 11 volts and 11 kilowatts, respectively.

Reasonable variations and modifications are possible within the scope of this disclosure without departing from the spirit and scope of this invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of protecting a permafrost zone around a well and the well which passes through said permafrost zone comprising emplacing a pipe string in said well which extends through at least part of said permafrost zone, and heating said pipe string uniformly over its length in said permafrost zone using electrical energy.

2. A method according to claim 1 wherein said pipe string is heated by applying an electrical current directly to an upper portion of said pipe string, and returning said current from beneath said permafrost zone.

3. A method according to claim 1 wherein said current is alternating current.

4. A method according to claim 2 wherein said current is direct current.

5. A method according to claim 4 wherein said pipe string is protected from electrolytic corrosion by connecting to said pipe string a sacrifical anode.

6. A method according to claim 1 wherein said pipe string is heated by placing at least one electrical conductor in said well along at least part of the length of said permafrost zone and near said pipe string, and passing electrical current through said conductor to heat same and in turn heat said pipe string.

7. A method according to claim 1 wherein said pipe string is heated by employing at least one electric conductor physically attached to at least one wall of said pipe string, and passing electrical current through said conductor to heat same and in turn heat said pipe string.

* * * * *

PO-1050
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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,766,980 Dated October 23, 1973

Inventor(s) Loyd R. Kern

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 41, "claim 1" should read ---claim 2---.

Signed and sealed this 2nd day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents