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[54] **WELL HEATING**

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[58] **Field of Search**..... 166/302, 248, DIG. 1, 166/250, 57, 65

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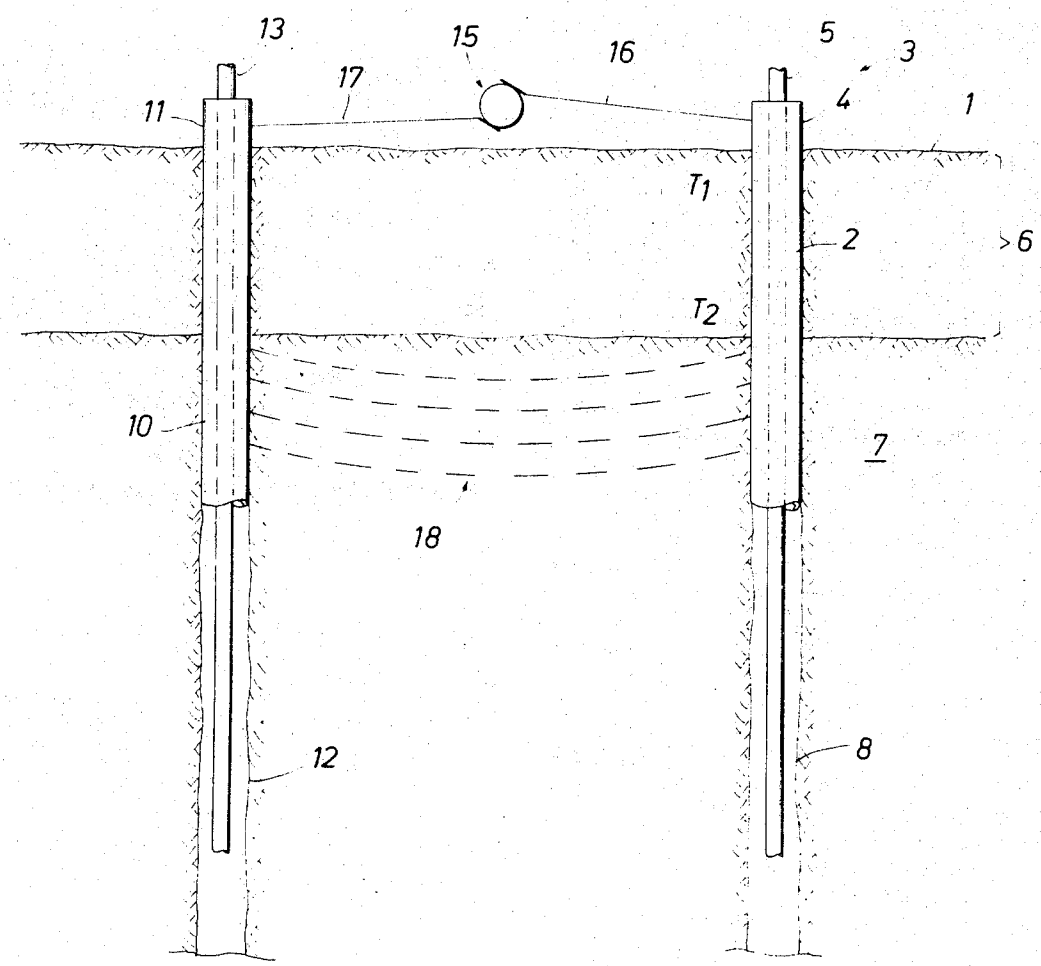
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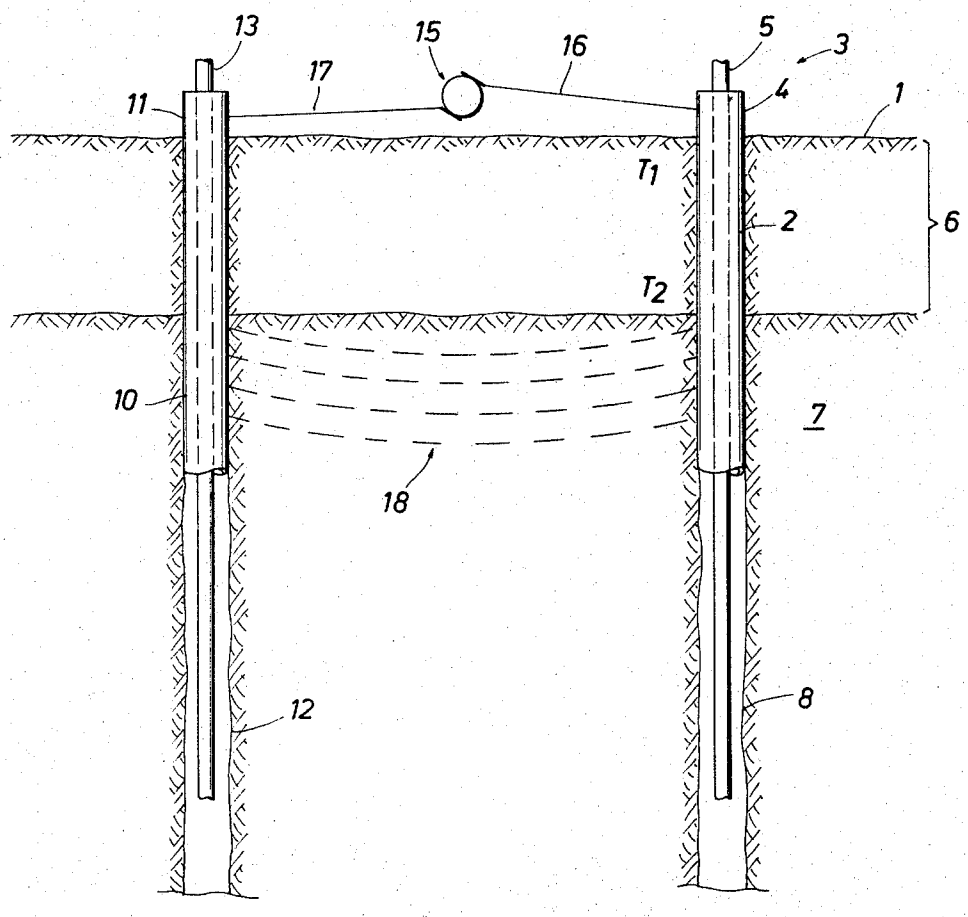
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[57] **ABSTRACT**

A method for heating a well to thaw out a frozen portion of the well or to protect permafrost surrounding the well from thermal cycling due to variations in production rate from the well. Also, a method for improving the pumpability of fluid which is produced from a well which does or does not pass through a permafrost zone. Further, a method for preventing the formation of hydrates in a gas well which is in or out of permafrost. In this invention, an alternating current is applied to at least one pipe in the well and maintained at a desired voltage level, the frequency of the alternating current is varied and controlled to cause a skin effect and to increase the effective electrical impedance of said pipe, and an electrical return is established from beneath the portion of the well to be heated, e.g., from beneath a permafrost zone. By this method the pipe is uniformly heated on its outer surface throughout the portion of the well to be heated to a temperature which prevents hydrate formation, or reduces the viscosity of liquid produced through the wellbore, or causes thawing of ice, or prevents freezing of water present to eliminate alternate freezing and thawing of the permafrost and sloughing of permafrost due to such thermal cycling.

22 Claims, 1 Drawing Figure




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T2
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WELL HEATING

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 drilling a warm fluid is circulated through the wellbore thereby establishing a temperature equilibrium between the well piping and the permafrost itself and sometimes melting some permafrost. So long as warm fluid is produced from the well, some permafrost may not refreeze near the wellbore. The temperature equilibrium established is a function of the flow rate and of the temperature and thermal properties of the produced fluid. If the well is shut in or if the well's production rate is restricted for a substantial time period either initially after drilling or at any time during the productive life of the well, the temperature equilibrium between the well and the permafrost would be altered and as a result part or all of any affected permafrost would refreeze. If any water is entrained in the well in the permafrost zone, the water in the well can also freeze and may cause damage to the well. Thereafter, when production of the well 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.

To substantially maintain the equilibrium between the well and the permafrost means to maintain the well in a heated state even though warm fluid is no longer circulated or produced through the well or is produced through the well at such a low rate that freezing could occur anyway. However, heating a producing well or a well that is to be worked over is not a simple matter if the heating is to be done safely, without obstructing the wellbore itself, or without hindering the production rate of the well or any of the operations that are normally carried out in a wellbore. It is even more difficult to do this with an efficient rate of energy consumption so that the process is also economically feasible. For example, a downhole heater could be set in the wellbore in the permafrost zone but this would be a localized type of heating which could cause overheating at that point and insufficient heating at a point further removed from the source. Downhole heaters can also take up a substantial part of or even block the entire wellbore so that normal production, workover and other operations could not take place. A loop of wire could be passed down into the wellbore or down into an annulus between two pipes of the wellbore to act as an electrical resistance heater. But again this somewhat localized heating obstructs some part of the interior of the wellbore and, like the downhole heater, requires extra equipment and takes up rig time for emplacement and removal. Electrical conduits could be built into the pipe that extends into the wellbore itself but electrically connecting a wire in one pipe to the next adjacent pipe through the coupling is difficult, expensive, and can consume rig time in just making sure that each pipe joint is made up in a manner which preserves the desired electrical continuity.

If a well should become frozen up because it passes through a permafrost zone or for any other reason, it must be thawed out in a safe manner before it can be put on production again.

Also, natural gas or other hydrocarbon containing gas which is shut into or produced through a wellbore (whether the wellbore does or does not pass through a permafrost zone) can be sufficiently cooled while passing through at least a portion of the well 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. so that hydrate can form in a wellbore that does not pass through any permafrost zone.

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.

Further, the fluid produced from a well is sometimes quite viscous and it is helpful to heat the fluid in the wellbore to reduce its viscosity and generally to improve its pumpability for easier production from the well. This applies to wells whether they pass through a permafrost zone or not.

SUMMARY OF THE INVENTION

According to this invention, an alternating electrical current is applied directly to a pipe which extends longitudinally into the wellbore, preferably to the outermost pipe in the well. According to this invention, sufficient heating of the well pipe to maintain at least the outer surface of the well pipe to which the alternating current is applied at a temperature which causes thawing of ice or which prevents freezing of the water adjacent said pipe, or which prevents hydrate formation, or which reduces the viscosity of the liquid produced, can be achieved by controlling the frequency of the alternating current to cause a skin effect, as hereinafter defined, and to increase the effective electrical impedance of the pipe to the alternating current, and returning said electrical current beneath the portion of the well to be heated to the earth's surface.

By following the method of this invention, sufficient heating of the pipe at least in a limited zone, e.g., a permafrost zone, is achieved to prevent hydrate formation, to cause thawing, to prevent thermal cycling above and below the freezing point of water, or to render produced liquid more fluid while still using a safe voltage. In this way, expensive and complicated electrical insulating devices and equipment are not required but a commercially acceptable consumption rate of electricity is maintained. The heating achieved by this invention is uniform over the entire surface of the pipe and therefore not localized in any way so that there is substantially no risk of overheating in one part of the well and underheating in another part. Also, extraneous wires and heaters which take up space in and obstruct

operations in the well are avoided. Further, wires or electrical conductors carried internally of a pipe wall which necessitate special electrical connections through the coupling to maintain electrical continuity are avoided.

The heating achieved by this invention is normally no greater than the heating effected by normal production of warm fluid through the well so that any permafrost that may be present is not subjected to any greater degree of heat than that which is normal for the producing well. Where the flow rate, temperature and thermal properties of the produced fluid are such that the permafrost would refreeze, then heating by the method of this invention can be employed to prevent thermal cycling. In wells that do not pass through a permafrost zone more heating can be tolerated and can be provided by this invention to, for example, reduce hydrate formation or render produced fluid more pumpable.

By employing the skin effect, as defined hereinafter, a loss of current and short-circuiting problems are minimized because by utilizing the skin effect the results of this invention are achieved even if another pipe is touching or otherwise electrically connected to the pipe which is carrying the alternating current according to this invention. Also, by employing the skin effect, where an inner pipe is touching the outer pipe or at other similar points of contact along the outer pipe severe local heating and even welding of the two pipes together is avoided. The avoidance of local heating at any such point of contact is important to avoid damage to the pipes or permafrost or both.

By this invention adequate heating of the well at moderate current consumption rates is realized while at the same time minimizing the electrical power lost during operation of the invention. This is achieved by use of the skin effect to increase the alternating current resistance and impedance in the well pipe but the skin effect does not significantly increase the resistance and impedance from one well to an electrical return below the heated area of the well.

By practicing this invention, a well can be thermally protected without heating permafrost or other heat susceptible material in the well to any greater extent than that caused by normal production of the well.

If the well has already frozen up due to a lack of production or otherwise, the method of this invention can be employed to slowly or rapidly thaw out the well and to establish a desired temperature equilibrium between the well and any permafrost present.

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 substantially maintaining the equilibrium set up between a producing well and surrounding permafrost. It is another object to provide a new and improved method for avoiding substantial thermal cycling of permafrost without inhibiting desired production rate variances. It is another object to provide a new and improved method for protecting the well from freeze up when completed through a permafrost zone. It is another object to provide a new and improved method for producing a well through a permafrost zone. 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. It is another object to provide a new and improved method for improving the pumpability of fluid produced from a well. It is another object to provide a new and improved method for decreasing the viscosity of fluid in a wellbore.

Other aspects, objects, and advantages of this invention will be apparent to those skilled in the art from this disclosure and the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

The drawing shows one embodiment within this invention.

More specifically, the drawing shows the earth's surface **1** having a first well **2** completed therein. Well **2**, for sake of simplicity, shows a simplified wellhead **3** composed of an outer longitudinally extending pipe or casing **4** having substantially concentric therein a longitudinally extending inner pipe or tubing **5**, both pipes extending through permafrost zone **6** into unfrozen earth **7**. For clarity, the invention will be described in reference to a permafrost zone **6**. However, it should be understood that this invention is not limited to permafrost and that zone **6** could also be a portion or region of a well which is desirably heated but in which there is no permafrost. Wellbore **8** extends down to one or more geologic producing zones (not shown).

The drawing shows a second similar well **10** composed of outer casing **11** which extends longitudinally into wellbore **12** with longitudinally extending tubing **13** also extending into wellbore **12**.

When one or both wells **2** and **10** are produced in a normal manner, warm fluid such as natural gas or crude oil with or without entrained natural gas and the like flows or is pumped from a subterranean producing geological formation or formations either through tubing **5** or **13**, or in the annulus between the exteriors of tubings **5** and **13** and the interiors of casings **4** and **11**, or both, in any of which cases some heat will be transferred from the well to the surrounding earth, e.g., permafrost in permafrost zone **6** of the well. When the well is produced for a substantial period of time, a temperature equilibrium will be set up between the relatively warm well and the surrounding permafrost and once this equilibrium is established it is preferable to maintain it as such even if production of oil from either well is substantially reduced or even stopped. If, for example, either or both wells in the drawing is shut in and not produced after drilling of same or production of either or both wells in the drawing is stopped, or the production of either or both wells is low or of relatively cool fluid, the wells and the tubing and casing therein will cool thereby causing a substantial change in the equilibrium set up between the producing well and the permafrost and causing refreezing of part of the permafrost as well as, possibly, causing freezing of water that might be left in the wellbore or pipes in permafrost zone **6**. Thereafter, when warm oil is again circulated through or produced from the well melting of various components will necessarily occur. If this thermal cycling is carried out a number of times, it could cause sloughing or other physical deterioration of the well and/or permafrost which would not occur if the equilibrium initially achieved between the producing well and the permafrost is substantially maintained irrespective of the production rate of oil from that well.

By this invention, an alternating current generator 15 is employed on the earth's surface and connected to casings 4 and 11 by electrical wire 16 so that the alternating current passes, for example, at one point of time, down casing 4 across the earth below permafrost zone 6 between casings 4 and 11 and up casing 11 back to generator 15 by way of electrical wire 17. In this example, the path of electrons from casing 4 to casing 11 in earth 7 will be a field of flow represented by dotted lines 18.

The permafrost, being substantially completely frozen, will not conduct substantial amounts of electricity so that the electricity will not leak off to any great extent while passing through the permafrost portion of the well. As soon as the electricity reaches unfrozen earth below permafrost zone 6, it will migrate toward the electrical return casing 11. Thus, it is important to the results of this invention to return electricity from beneath the permafrost zone. The electrical return need not be another well but rather can be any electrically conductive element which extends below permafrost zone 6 or below the zone of the well to be heated if no permafrost is present. It is preferred that the electrical return be another well because by utilizing casing 11 as a return conduit that well is also heated so that the permafrost around both wells 2 and 10 is protected at the same time. It is emphasized, however, that this invention does not require a minimum of two wells. One well with a suitable electrical return is sufficient.

Alternating current is employed to avoid setting up an electrolytic corrosion cell on one of the wells thereby avoiding corroding the casing of either well. An economic advantage is thereby achieved in that in transmitting electricity to a particular well or plurality of wells a high voltage is employed for efficiency of transmission, but at the site of actual use it is preferred that the electricity received from the power line have its voltage stepped down and its current stepped up, a result which is more readily achieved with alternating current. Also, even though direct current might be usable with sacrificial anodes, substantially higher current would be required for the same power level.

The voltage employed with the alternating current is preferably that which is substantially harmless to personnel working around the well and is generally no greater than 75 volts, preferably no greater than about 50 volts as initially applied to the wellhead. With voltages no greater than 75 volts, slow thawing of a frozen well can be achieved. Faster thawing can be achieved with voltages greater than 75 volts but additional personnel safety features should be used with these higher voltages. Any oil and gas gatherin lines attached to the wellhead at the surface of the earth should be electrically insulated from the wellhead but other than this insulation no other electrical insulation or safety devices are necessary when no more than 75 volts are used. Even the low voltages of this invention are at a sufficiently efficient level of voltage to keep the desired heating result commercially feasible. Similar voltages can be employed for hydrate prevention and well fluid pumpability improvement.

Another important reason for the use of alternating current is that with the alternation of the current through the electrical circuit there comes an inductance effect which causes the current, for example, passing through casing 4, to tend to flow along the surface of the casing rather than through the interior of the casing. This inductance effect is often termed a "skin effect." An additional result that accompanies the skin effect is that the effective electrical impedance of the casing to the alternating current being applied thereto increases above the normal impedance value of that pipe.

The skin effect and the magnitude to which the electrical impedance of the pipe increases can be controlled by the frequency of the alternating current. Generally, as the frequency increases, the skin effect and the electrical impedance increases so that by proper use of the frequency of the alternating current employed, the normal impedance of the pipe can be sufficiently increased to obtain adequate but economical heating of the pipe even at low voltages. Adequate heating is that necessary to prevent the temperature of the well from falling below the freezing point of the water adjacent the pipe or to thaw ice around or in the pipe, or to prevent hydrate formation in the pipe, or to render a fluid in the pipe more flowable.

By this invention, the frequency of the alternating current applied to the well is controlled to cause the above-described skin effect and to increase the effective electrical impedance of the pipe to at least about two times, preferably at least about five times, that of the normal electrical impedance value of the pipe. When this is accomplished, sufficient heating of the well is achieved at a commercially acceptable electrical consumption rate. All this can be accomplished even when low voltages are used without making the well dangerous to personnel even though a minimum of electrical insulation is employed on the well.

The particular frequency used on a particular well to achieve any of the results of this invention will vary extremely widely because the frequency is dependent upon the chemical composition of the pipe, the heat treatment history of the pipe, the size and/or weight of the pipe, the specific voltage employed, the depth of permafrost zone 6 or other zone to be heated, the spacing between the well and its electrical return, whether thawing or permafrost protection or hydrate prevention or liquid pumpability is desired, and the like. Thus, it is impossible to quantify for all possible cases the range of frequencies employed or employable to achieve the desired results of this invention. However, generally the frequency will be at least about 25, preferably from about 25 to about 70, cycles per second.

Essentially all pipes in a well, be they tubing or casing and be they of any type of steel, have too low a resistance to get sufficient heating with moderate currents. Put another way, to achieve adequate heating of pipes in a well, very high currents are required if the teachings of this invention are not followed. Furthermore, with these high currents comes the danger of severe localized heating at points of contact as mentioned before. Thus, by controlling the frequency and using the resulting skin effect and increased impedance as a tool, electrical heating of the well can be economically achieved even with safely low voltages and without danger of severe localized heating in the well pipes.

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 the 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, i.e., T_1 in the drawing, is always

much less than the temperature at or near the bottom of the permafrost zone, T_2 in the drawing. If there is leak off of electrical current in the permafrost zone, it most likely would occur at various points along the length of the zone. Even though there may be some slight loss of current in the permafrost zone, the maximum amount of current will be flowing through the upper portion of the permafrost zone where more heating is necessary since the upper portion is colder than the lower portion. Thus, should there be leak off of current so that the magnitude of the current as it reaches the vicinity of T_2 is reduced, this is not critical because temperature T_2 is close to the freezing point of water and sufficient heating can be achieved in the vicinity of T_2 with a reduced current, the larger current having already been used in the vicinity of T_1 where it is needed most. Similar reasoning applies for the prevention of hydrate formation and the improvement of fluid pumpability where permafrost is or is not present in the well.

Below the lower surface of permafrost zone **6** the current density in pipe **4** will decrease rapidly as the current leaves casing **4** for its return trip by way of casing **11** and wire **17** to generator **15.**

Current can be applied to wells **2** and **10** during drilling or production of either or both wells if desired or can be employed only when one or both wells' production rate is decreased or stopped altogether.

A gas, such as natural gas, other hydrocarbon containing gas, carbon dioxide, and the like, can be produced from a gas producing geologic formation (not shown) into, for example, tubing **5** and up the wellbore through a permafrost zone **6** (or through an unfrozen but cool earth zone) to the earth's surface for further processing, use, and the like.

The gas passing from tubing **5** 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 tubing **5.**

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 geologic formation into the lower portion of wellbore **8.**

The substantially hydrate free gas is produced upwardly through wellbore **8** and if the gas is not heated while passing through zone **6** or if the well is shut in and gas trapped in zone **6** of the wellbore, the gas will be cooled sufficiently to cause substantial hydrate formation. This can occur even if zone **6** is not a permafrost zone but is sufficiently cool to cause hydrate formation since, due to their composition, hydrates can form at temperatures above 32°F. as well as below.

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 or shut in of gas wells through or in 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.

When the portion of the wellbore to be heated by this invention is not highly resistive to electrical current, e.g., the portion is not permafrost, current leak off along the portion of the pipe to be heated will be greater causing a current and heating gradient along the piping. In this situation, the current and heating gradients along the piping can be altered by varying the frequency of the current. This way the heat along the piping can be concentrated near the top of the piping to whatever extent desired or needed.

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 tubing **8** is heated to maintain a temperature of that gas greater than 80°F. while in permafrost zone **6.** 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.

In some wells permafrost may or may not be present but the fluid produced into the wellbore is so viscous that it approaches or acts like tar as far as its flowability and pumpability is concerned. To decrease the viscosity of such a fluid or liquid to improve its flowability and render it more easily pumpable through a downhole or surface pipe, it is helpful to heat the produced fluid or liquid in the wellbore before or while pumping same toward the earth's surface. This invention is well suited for such a task by following the teachings set forth hereinabove with respect to the invention as applied to permafrost and hydrate prevention.

EXAMPLE

Apparatus substantially the same as that shown in the drawing is employed wherein the depth of permafrost zone **6** is 2,000 feet and the length of casings **4** and **11** is 2,600 feet so that casings **4** and **11** extend about 600 feet below the bottom of zone **6.** Casings **4** and **11** are conventional 13⅜ inch O.D., 0.514 inch wall thickness, API grade **N80** oil well casing, while tubings **5** and **13** are conventional 4½ inch O.D., 0.271 inch wall thickness, API N80 oil well tubing.

An alternating current of 250 amps is impressed on the outer surface of casings **4** and **11** using 45.7 volts each and 52 cycles per second frequency. The effective electrical resistance and impedance of each of casings **4** and **11** under the impressed alternating current are 0.112 ohms and 0.183 ohms, respectively. The distance between casings **4** and **11** is 5,200 feet.

By following the above procedure the outer surface of casings 4 and 11 is kept at a temperature of at least about 32°F. using 9 kilowatts of power per well of which 7 kilowatts is absorbed in the permafrost surrounding each well.

For comparison purposes, if direct current were used, the resistance of 2,000 feet of the same casing would be about 0.0071 ohms requiring about 993 amps of direct current to put 7 kilowatts per well into the permafrost zone. The total input voltage and input power per well would be 11 volts and 11 kilowatts, respectively. The efficiency of the direct current would be reduced by greater uphole losses resulting from the higher current required. Capital costs would be greater and there would be risks of hot spots at points of contact between the casing and tubing.

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 heating at least a portion of a first well in the earth comprising applying to at least one string of pipe in said first well an alternating current, varying the frequency of said alternating current to cause a skin effect and to increase the effective electrical impedance of said pipe to said alternating current to at least about two times that of the normal electrical impedance value of said pipe, controlling said frequency to substantially maintain said impedance increase, and returning said electrical current from beneath said portion of said well to be heated.

2. A method according to claim **1** wherein said electrical return is a pipe string in a second well which is spaced from said first well, whereby both said first and second wells are protected at the same time.

3. A method according to claim **1** wherein said portion of said first well to be heated is in a permafrost zone, said heating is to thaw out said first well from a frozen state or to protect said permafrost from thermal cycling, and returning said electrical current from beneath said permafrost zone.

4. A method according to claim **3** wherein said voltage is not substantially greater than 75 volts.

5. A method according to claim **3** wherein said voltage is not substantially greater than 50 volts.

6. A method according to claim **3** wherein said well is initially frozen up and is thawed out by said method.

7. A method according to claim **6** wherein said voltage is at least about 75 volts for fast thawing of said well.

8. A method according to claim **3** wherein said well is not initially frozen up and is protected from freezing up during production of the well by said method.

9. A method according to claim **3** wherein said well is shut in after drilling of same and without production of same and is protected from freezing up by said method.

10. A method according to claim **3** wherein said frequency is varied sufficiently to cause said effective electrical resistance to be at least about five times the normal electrical resistance value.

11. A method according to claim **3** wherein said frequency is at least about 25 cycles per second.

12. A method according to claim **3** wherein said frequency is from about 25 to about 70 cycles per second.

13. A method according to claim **1** wherein said frequency is varied sufficiently to cause said effective electrical resistance to be at least about five times the normal electrical resistance value.

14. A method according to claim **1** wherein said frequency is at least about 25 cycles per second.

15. A method according to claim **1** wherein said frequency is from about 25 to about 70 cycles per second.

16. A method according to claim **1** wherein said first well produces natural gas wherein said gas contains hydrate forming water and hydrocarbons, hydrate tends to form in said portion of said first well which is to be heated, said heating being carried out to prevent the formation of hydrates, and returning said electrical current from beneath said hydrate forming portion of said first well.

17. A method according to claim **16** wherein said hydrate forming portion of said first well is in a permafrost zone.

18. A method according to claim **16** wherein said hydrate forming portion of said first well is not in a permafrost zone but is at temperature and pressure conditions which promote the formation of hydrate in the gas produced from said first well.

19. A method according to claim **16** wherein said voltage is not substantially greater than **75** volts.

20. A method according to claim **16** wherein said frequency is varied sufficiently to cause said effective electrical resistance to be at least about five times the normal electrical resistance value.

21. A method according to claim **16** wherein said frequency is at least about 25 cycles per second.

22. A method according to claim **16** wherein said frequency is from about 25 to about 70 cycles per second.

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