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[54] **OIL WELL AND METHOD FOR PRODUCTION OF OIL THROUGH PERMAFROST ZONE**
24 Claims, 4 Drawing Figs.

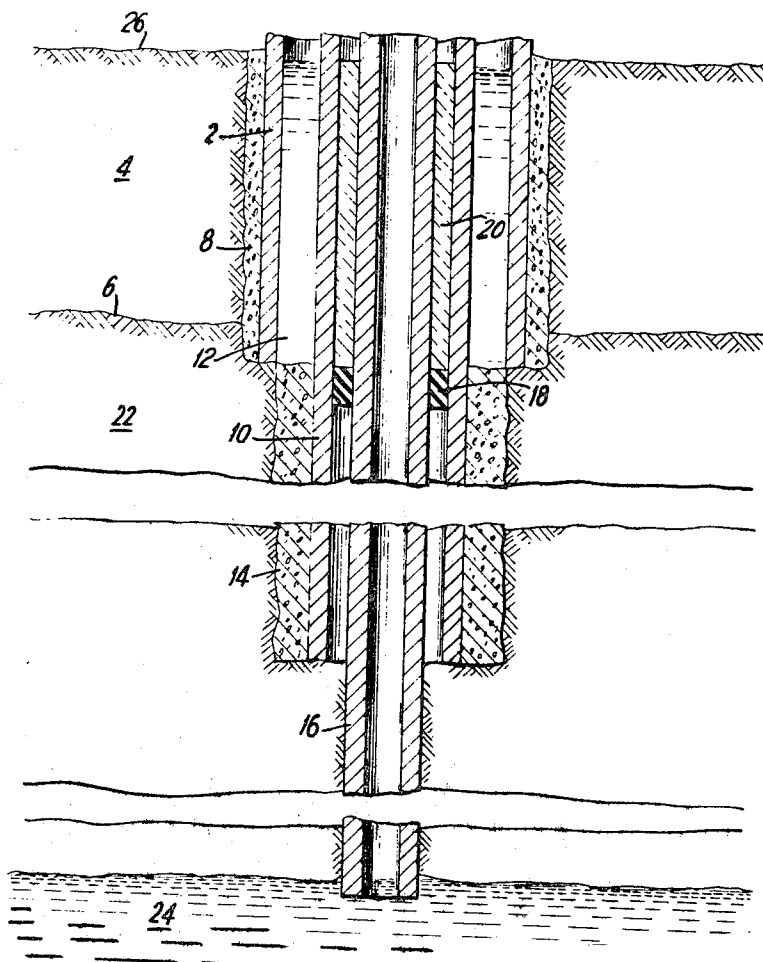
[52] U.S. Cl. **166/315,**
166/57, 166/DIG. 1
 [51] Int. Cl. **E21b 43/00**
 [50] Field of Search **166/302,**
303, 315, 57, DIG. 1

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ABSTRACT: Production oil wells for extracting warm oil from ground containing a permafrost zone without causing the oil to melt the permafrost comprise a pipe extending down into the oil pool, an inner casing surrounding the pipe and running down through the permafrost zone, an outer casing running down through the permafrost zone, surrounding the inner casing and spaced to define an airgap or annulus with the inner casing and means, such as a liquid heat exchange fluid or a refrigerating boiling liquid, in the annulus to inhibit heat transfer from the pipe to the ground surrounding the outer casing. In preferred embodiments a second annulus or airgap, optionally filled with insulation, is provided between the inner casing and the pipe.



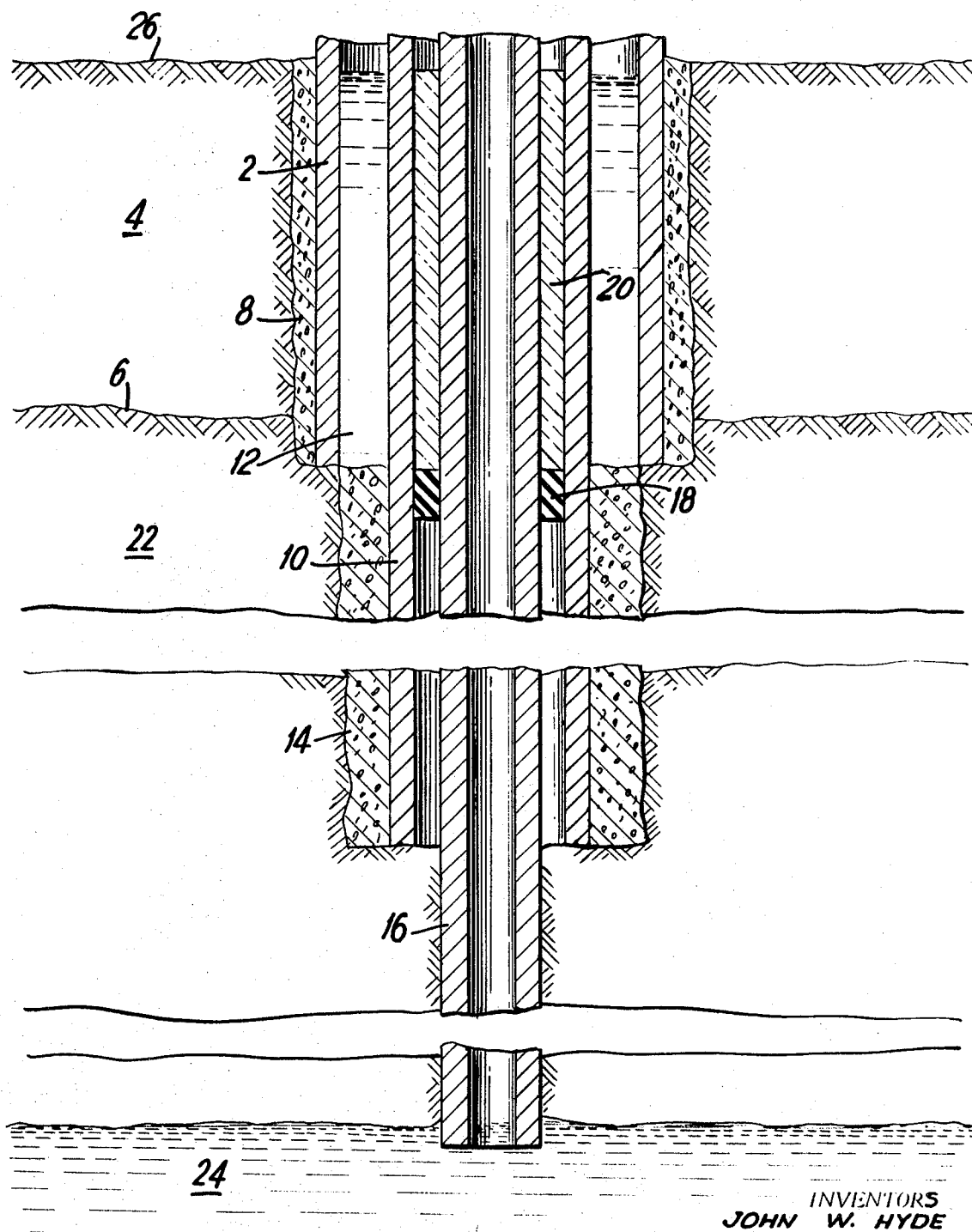


FIG. 1

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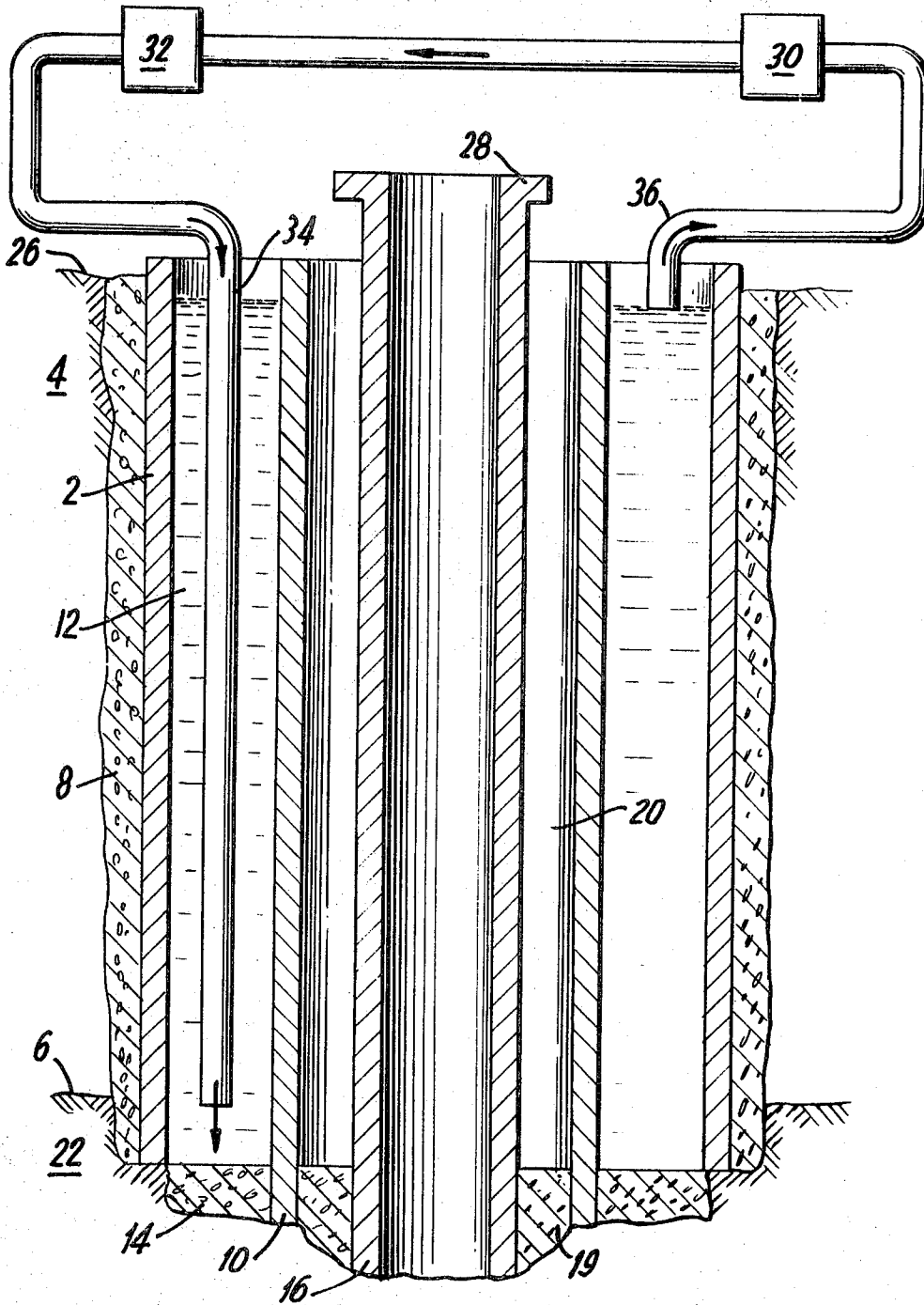


FIG. 2

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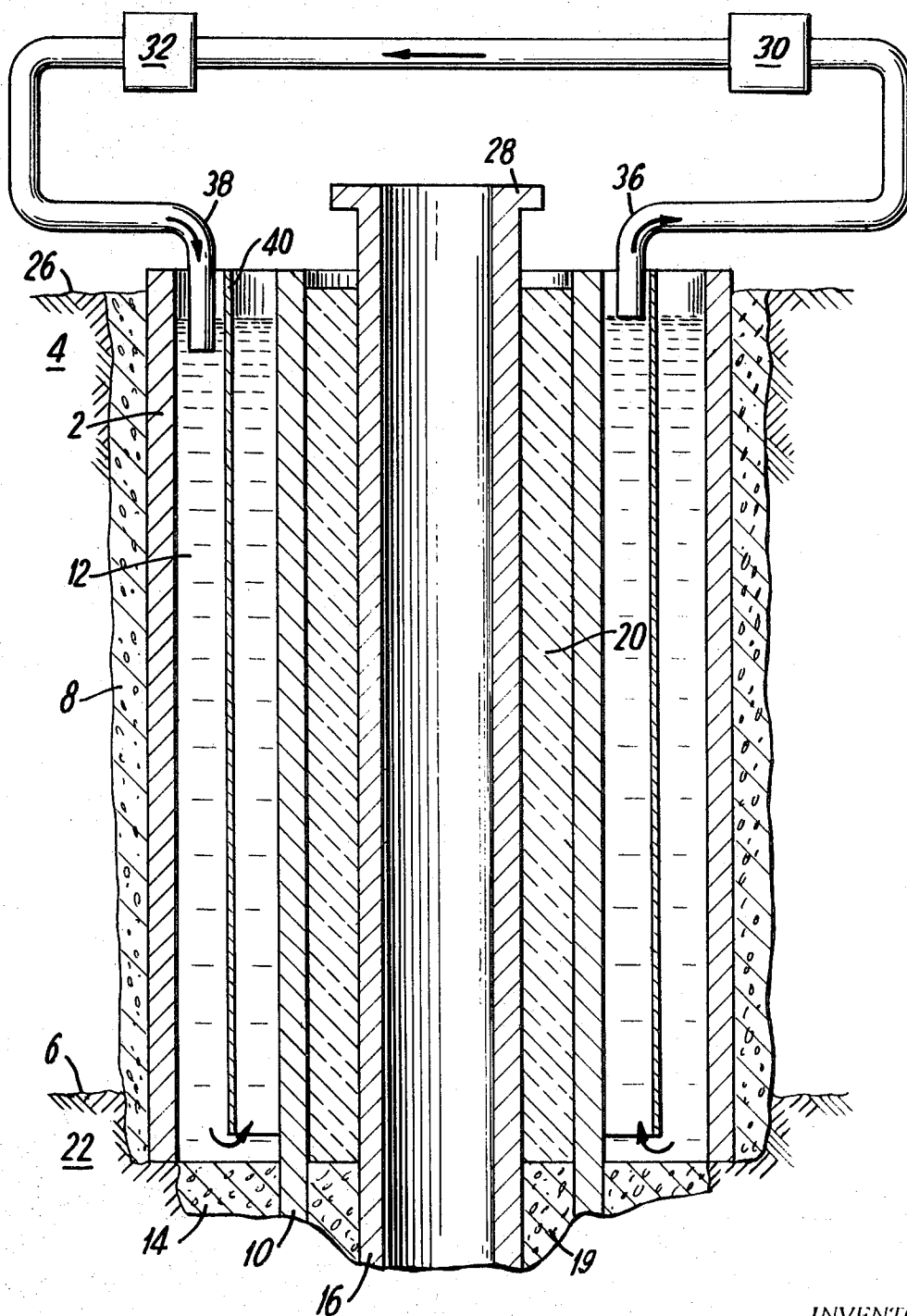


FIG. 3

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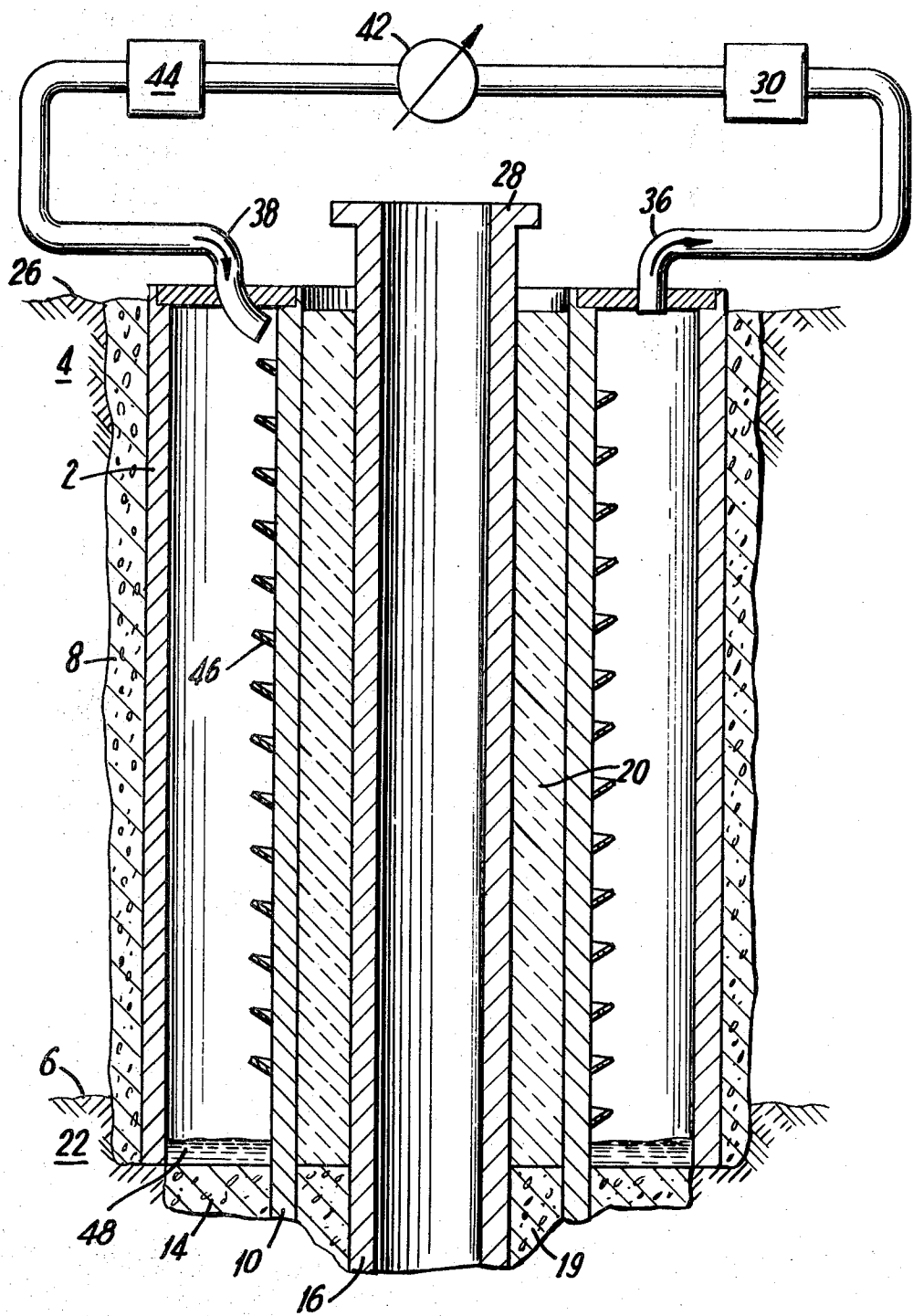


FIG. 4

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OIL WELL AND METHOD FOR PRODUCTION OF OIL THROUGH PERMAFROST ZONE

This invention relates to an oil well and to methods for producing oil. More particularly, it concerns wells for extracting oil from ground containing a permafrost zone.

BACKGROUND OF THE INVENTION

Oil has recently been found under the north slope of Alaska and in this location (and also in other locations) below the earth's surface is a zone consisting of a material usually known as permafrost. In this specification the term "permafrost" will be used to denote a geological formation which contains ice in such quantities that the mechanical properties of the formation depend on the ice so that there would be a substantial change in the mechanical properties should the formation heat to a temperature at which the ice melts and this definition extends to a formation which consists solely of ice. In Alaska the permafrost consists of a mixture of rock, gravel and ice in which the ice content varies with location and depth but 90 percent ice is often encountered at the surface. Permafrost can extend to 2,000-foot depths.

Oil usually issues from a production well at a temperature above 32° F. (in Alaska the oil will be at 170°-175° F., for example) and there is danger of melting the ice in the permafrost which surrounds a production well. Melting of ice in the permafrost will cause subsidence. This subsidence can impose compressive and/or tension loads high enough to fracture the well casing and hence allow the escape of oil. Moreover, unless suitable measures are taken, the producing completed oil well will become surrounded by a crater lake and the soil area will become very unstable.

It is a primary object of this invention to provide a well for recovering oil from ground containing permafrost.

It is another object of this invention to reduce the contamination risk of an oil production well passing through permafrost.

Still another object of this invention is to provide a means to prevent the soil area surrounding an oil well drilled through permafrost to become unstable.

DESCRIPTION OF THE INVENTION

According to this invention an oil production well which passes through permafrost comprises a pipe extending from the earth's surface down into the oil pool, an inner casing surrounding the pipe extending from the earth's surface down to a point between the lower level of the permafrost but above the oil pool, and an outer casing in contact with the permafrost zone and extending to the base thereof, surrounding the inner casing and separated therefrom so as to form an annular space or airgap into which is introduced a means to inhibit transfer of heat from the pipe to the ground containing the permafrost.

In a preferred embodiment the inner casing is in a space relationship with the pipe so as to create an insulating airgap or annulus optionally adapted to contain thermal insulation.

The invention also contemplates a method of producing oil at a temperature above the freezing point from a well which passes through permafrost. The method comprises drilling a first hole down through the permafrost and putting down an outer casing, drilling a second hole smaller in diameter than the first down from the bottom of the first hole to a point above the oil pool and putting down an inner casing in spaced relationship with the outer casing to provide an airgap or annulus, drilling a third hole smaller than the second from the bottom of the second down into the oil pool and putting down a pipe extending from the pool to the earth's surface, and then introducing into the airgap or annular zone between the inner and outer casing means for inhibiting heat transfer from the pipe to the permafrost.

When used herein and in the appended claims the term "means for inhibiting (or "to inhibit") heat transfer" contemplates materials introduced into the airgap or gaps which function to impede the movement of heat from the oil to the

ground containing permafrost. Broadly, these will be fluids, liquid or gaseous, and solids of varying densities. They will comprise a class of materials of limits well understood by those skilled in the art of engineering thermodynamics. See, for example, the disclosure in Perry's Chemical Engineer's Handbook, 4th Edition, McGraw-Hill, Sections 9 through 13, which is incorporated herein by reference. More particularly, suitable means will comprise heat transport fluids, e.g., liquids and vapors, and insulating liquids, gases and solids of low thermal conductivity. The heat transport fluids can comprise liquid heat exchange fluids and refrigerating boiling liquids. Illustrative of the liquid heat exchange fluids are water, oils of low pour point, alcohols, e.g., methanol, ethanol, i-propanol and the like, glycols, e.g., ethylene glycol, propylene glycol, glycerine, and the like, and mixtures thereof, as well as brines, e.g., calcium or sodium chloride brines, and other aqueous solutions, inhibited if desired by addition of conventional additives to minimize corrosion of the equipment. It has been found that very suitable liquid heat exchange fluids comprise brine, inhibited aqueous ethylene glycol and mixtures of methanol and water. Illustrative of the refrigerating boiling liquids are ammonia, carbon dioxide, halogenated liquid hydrocarbons, such as methyl chloride, methylene chloride, trichloroethylene; a class of nonflammable liquid fluorinated hydrocarbons known as the "Freons," e.g., Freon 114, Freon 21, Freon 11 and Freon 12, the latter being, for example, dichlorodifluoromethane, hydrocarbons, such as propane, butane, and the like; ethers, such as methyl ethyl ether, diethyl ether, ethyl n-propyl ether, and the like; esters, such as methyl formate; amines, such as methyl amine; and other refrigerating liquids, e.g., sulfur dioxide, nitrous oxide, carbon disulfide, mixtures thereof, and the like. It has been found that very suitable refrigerating boiling liquids comprise propane, ammonia or a nonflammable gaseous or liquid fluorinated hydrocarbons, i.e., Freons. Such refrigerating boiling liquids are also denoted "refrigerants" by those skilled in the art; see Perry's Chemical Engineers' Handbook, 4th Edition, 1963, Section 12-3, particularly, FIG. 12-2.

Illustrative of thermally insulating liquids, gases and solids of low thermal conductivity are air, cork, balsa wood, reflective foils, e.g., aluminum foil, especially in multipliers, fiber mats, e.g., fiber glass mats or papers, nylon net, aluminized plastic films, powders, particularly evacuated powders, such as perlite, silica aerogel, phenolic spheres, lampblack, diatomaceous earth, alumina, and the like; foamed plastics such as polystyrene, epoxy resin, polyurethane, foamed rubber, silica and cellular glass, and the like; and insulating minerals such as vermiculite, mineral wool, and the like. It has been found that in addition to the use of an airgap, heat transfer is inhibited especially conveniently with expanded plastics such as polyurethane and polystyrene, and with minerals, such as vermiculite.

A number of ways to introduce the means to inhibit heat transfer into the annular zone or zones can be used. Several that will work especially well are shown in the drawings and will be described in detail hereinafter.

DESCRIPTION OF THE DRAWINGS

The invention will now be described by way of examples with reference to the accompanying drawings in which, in cross section:

FIG. 1 shows diagrammatically a production well according to this invention.

FIGS. 2 and 3 illustrate the upper portion of wells according to this invention in embodiments wherein two different means are used to introduce a liquid heat exchange fluid into the airgap between the casings. FIG. 4 illustrates an oil well in another embodiment which includes a means to introduce a refrigerating boiling liquid into the annulus or airgap between the casings.

The well illustrated in FIG. 1 comprises an outer casing 2 of any suitable material, e.g., steel, and diameter, e.g., 20 inches,

which extends from the earth's surface 26, to just below the base 6 of the permafrost 4. In a typical Alaskan production well this casing would normally average about 1,000 feet long but could be as much as about 2,000 feet long. In accord with standard practice it is shown to be cemented to the sides of the hole with a cement layer 8.

An inner casing 10 of suitable diameter, e.g., 13% inches, extends from the surface to a median point between the oil-bearing formation or pool 24 and the bottom of the outer casing. The depth of the median point will be determined by the geological formation and the need, for example, to keep the formation from caving in, and to keep gas and other fluids from becoming uncontrollable during or after the drilling operation, and by other safety and economic reasons. The upper section of casing 10 is situated inside of outer casing 2 so as to create an annular space 12. Below the permafrost the inner casing 10 may also be cemented to the formation with cement layer 14 in accord with standard practice. In a typical Alaskan production well, inner casing 10 could be about 4,000 feet long.

A pipe 16 of suitable diameter, e.g., diameter 9% inches, extends from the surface to the level of the producing formation, i.e., the oil pool or reservoir. In a typical Alaskan production well, pipe 16 would be about 9,000 feet long.

The uppermost section of pipe 16 is situated inside the inner casing 10. In its broadest aspects, the present invention contemplates oil wells wherein the outer wall of pipe 16 and the inner wall of inner casing 10 are together, i.e., there is no air-gap or annulus between the pipe and the inner casing. The lowermost section of pipe 16 preferably is cemented to the formation and to inner casing 10 up to just below the level of the permafrost although, in the oil well illustrated, in FIG. 1 this has not been done. Instead a conventional packer 18 has been located to define an upper insulation chamber in airgap or annulus 20, extending from the surface to just below the base of the permafrost.

The outer annular space 12, which is situated a permafrost level, is adapted to filled with means (described hereinabove) to inhibit the transfer of heat from the pipe 16 to the ground surrounding outer casing 2.

As has been mentioned, broadly, the oil wells according to this invention will comprise only one annular space 12 which is filled with the means to inhibit heat transfer. In the preferred embodiments shown in the drawings, however, there are two annular spaces 12 and 20, 12 being filled with means to inhibit heat transfer and 20 being an empty annular space (as shown in FIG. 2) or preferably (as shown in FIGS. 1, 3 and 4), filled also with means to inhibit heat transfer.

as it issues from the production well the oil is at a temperature of about 170° F. and the means shown in annular space 12 functions to inhibit heat transfer from pipe 16 to the permafrost 4 so that the permafrost does not melt.

In the embodiment shown in FIG. 2, the means in annular space 12 would be a circulating liquid heat exchange fluid of the type illustrated above, e.g., brine, methanol-water, or aqueous ethylene glycol solution, and the like. This is circulated with pump 32 down a dip tube 34, up through the annular space 12, out through exit port 36, to a heat exchanger 30 to remove the heat gained during circulation, then back to pump 32. In accordance with good engineering practice, it is preferred for best efficiency to circulate a cold liquid. The initial temperature and flow rate will be selected to ensure that heat transfer through annular space 12 is impeded to such an extent that the permafrost is not melted. One way to accomplish this is to provide that the liquid emerging from the top of annular space 12 at point 36 remains below about 32° F. A sensing device (not shown) at this location may be used to measure the temperature. The conduction of heat from the hot oil in pipe 16 to the outer wall of inner casing 10 will be reduced if an optional air gap 20 is provided as in shown in FIG. 2. This reduces the power consumption needed to remove heat picked up by the liquid heat transfer fluid circulating in annular space 12. The power will be reduced even

more if air gap 20 is filled with means to inhibit heat transfer (as defined above), especially with thermal insulation of low conductivity, e.g., expanded polyurethane, expanded polystyrene or vermiculite.

In the embodiment shown in FIG. 3, the means circulated through annular space 12 would (as in FIG. 2) be a circulating liquid heat exchange fluid. In this embodiment annular space 12 is divided into two chambers by separator casing 40 to provide a down-up path for circulating the liquid, in the direction shown by the arrows.

In the embodiment shown in FIG. 4, the means in annular space 12 would be a circulating refrigerating boiling liquid of the type illustrated above, e.g., propane, ammonia, a Freon, and the like. This is circulated in a closed system with a pump 30 through a heat exchanger, e.g., a compressor, 42, and a holding tank 44, being introduced as a liquid through port 38 and being distributed by means of spiral guide 46 or other suitable means, such as a perforated dip tube, splash plates, Raschig rings and the like, (not shown) into annular space 12, volatilizing therein and removing the heat being introduced into the chamber by oil in pipe 16, leaving as a vapor at exit port 36 and returning to pump 30. In a preferred manner of operation, a small pool of refrigerating liquid 48, e.g., about 10 feet deep in a 2,000-foot annulus, will be allowed to collect at the bottom of the annulus 12. The level of the pool can be measured with an appropriate sensing device (not shown).

In addition to the features illustrated in the drawings the wells comprise conventional tubing strings and wellhead equipment in accordance with standard practice. The casings, 2 and 10, and pipe 16 are suspended from wellhead equipment so that the upper portions remain in tension. In the embodiments of FIGS. 2, 3 and 4 for example, flange 28 can be fastened to a mating flange in a system of control valves placed at the upper end of the pipe and casings conventionally used to cap a well and known as a Christmas tree.

From the foregoing description and examples, it is obvious that a simple and efficient method for producing oil from permafrost-containing formations has been discovered. Obvious modifications will suggest themselves to those skilled in art. For example, oil strings or production strings can be included in the wells; liners with many holes in them can be used; and conventional modifications will be made to accommodate the different kinds of underground pressure driving the oil to the surface. Of course, the oil can also be pumped from the well.

The invention is not to be limited by the above description but is to be defined only by the appended claims.

What is claimed is:

1. A well for extracting oil from ground containing a permafrost zone comprising:
 - a. a pipe extending downwardly from the surface of the ground to the body of oil;
 - b. an inner casing surrounding the pipe and extending downwardly from the surface of the ground and terminating at a medial point along said pipe below the permafrost zone;
 - c. an outer casing surrounding the inner casing in spaced relationship to define with said inner casing an annulus extending downwardly from the surface of the ground to below the permafrost zone; and
 - d. liquid means in the annulus for inhibiting heat transfer from the interior of the pipe to the ground surrounding the outer casing.
2. A well as defined in claim 1 wherein said means for inhibiting heat transfer is liquid heat exchange fluid.
3. A well as defined in claim 2 wherein said liquid heat exchange fluid is brine, inhibited aqueous ethylene glycol solution or methanol-water.
4. A well as defined in claim 1 wherein said means for inhibiting heat transfer is a refrigerant liquid.
5. A well as defined in claim 4 wherein said refrigerant liquid is propane, ammonia or a nonflammable liquid-fluorinated hydrocarbon.

6. A well as defined in claim 1 wherein said inner casing is in a spaced relationship which defines with said pipe an inner annulus.

7. A well as defined in claim 6 wherein said inner annulus is provided with closure means at a location below the permafrost zone to provide an upper insulation chamber in said annulus.

8. A well as defined in claim 7 including means in said upper insulation chamber for inhibiting heat transfer from the interior of the pipe to the wall of the inner casing.

9. A well as defined in claim 8 wherein said means in the upper insulation chamber for inhibiting heat transfer is solid thermal insulation of low conductivity.

10. A well as defined in claim 7 wherein the annulus between the outer and inner casings contains a liquid heat exchange fluid or a refrigerant liquid.

11. A well as defined in claim 10 wherein the upper insulation chamber in the inner annulus between the inner casing and the pipe contains thermal insulation of low conductivity.

12. A process for completing a well for extracting oil from ground containing a permafrost zone which comprises the steps of:

- a. drilling a first hole from the surface of the ground downwardly at least through the permafrost zone;
- b. putting an outer casing down into said first hole;
- c. drilling a second hole smaller in diameter than said first hole from the bottom of said first hole downwardly into the ground to a medial point between the oil level and the bottom of said first hole;
- d. putting an inner casing down into said second hole to line said second hole, the outer surface of said inner casing and the inner surface of said outer casing defining an annulus;
- e. drilling a third hole smaller in diameter than said second hole downwardly from the bottom of said second hole through the ground into the oil reservoir;
- f. putting a pipe down through said third hole into said oil reservoir, which pipe extends upwardly to the surface of the ground; and
- g. introducing into said annulus liquid means for inhibiting heat transfer from the interior of said pipe to the earth surrounding said outer casing.

13. A process as defined in claim 12 wherein said means for inhibiting heat transfer is a liquid heat exchange fluid.

14. A process as defined in claim 13 wherein said liquid heat exchange fluid is brine, inhibited aqueous ethylene glycol solution or methanol-water.

15. A process as defined in claim 12 wherein said means for inhibiting heat transfer is refrigerant liquid.

16. A process as defined in claim 15 wherein said

refrigerant liquid is propane, ammonia or a nonflammable liquid-fluorinated hydrocarbon.

17. A process as defined in claim 12 wherein the outer surface of the pipe and the inner surface of the inner casing define an inner annulus.

18. A process as DEFINED in claim 17 including providing said inner annulus with closure means at a strategic location to provide an upper insulation chamber in said inner annulus.

19. A process as defined in claim 18 including introducing into said upper insulation chamber means for inhibiting heat transfer from the interior of THE pipe to the wall of the inner casing.

20. A process PROCESS as defined in claim 19 wherein said means in the upper insulation chamber for inhibiting heat transfer is a thermal insulation that has a low conductivity.

21. A process as defined in claim 20 wherein said thermal insulation is expanded polyurethane, expanded polystyrene or vermiculite.

22. A process as defined in claim 18 wherein the means for inhibiting heat transfer introduced into the annulus between the outer and inner casings is a liquid heat transfer fluid or a refrigerant liquid.

23. A process as defined in claim 22 wherein the means for inhibiting heat transfer introduced into the upper insulation chamber in the inner annulus between the inner casing and the pipe is a thermal insulation of low conductivity.

24. A well for extracting oil from ground containing a permafrost zone comprising:

- a. a pipe extending downwardly from the surface of the ground to the body of oil;
- b. an inner casing surrounding the pipe and extending downwardly from the surface of the ground and terminating at a medial point along said pipe below the permafrost zone;
- c. an outer casing surrounding the inner casing in spaced relationship to define with said inner casing an annulus extending downwardly from the surface of the ground to below the permafrost zone;
- d. liquid means in the annulus for inhibiting heat transfer from the interior of the pipe to the ground surrounding the outer casing;
- e. wherein said inner casing is in a spaced relationship which defines with said pipe an inner annulus;
- f. said inner annulus being provided with closure means at a location below the permafrost zone to provide an upper insulation chamber in said annulus; and
- g. said upper insulation chamber contains solid thermal insulation selected from expanded polyurethane, expanded polystyrene or vermiculite.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,613,792 Dated October 19, 1971

Inventor(s) John W. Hyde and William J. George

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 1, delete "21"; line 6, delete
"DEFINED", and insert -- defined --; line 11, delete
"THE" and insert -- the --; and line 13, delete
"PROCESS".

Signed and sealed this 9th day of May 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents