United States Patent

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[54] **APPARATUS FOR OIL PRODUCTION AMPLIFICATION BY SPONTANEOUS EMISSION OF RADIATION**
8 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **166/52,** 166/60, 166/272, 166/303
[51] **Int. Cl.** **E21b 43/24**
[50] **Field of Search** ..... 166/11, 39, 40, 57, 60, 177, 52; 175/16; 219/121P, 277, 278; 331/94.5 Inq; 166/272, 302, 303

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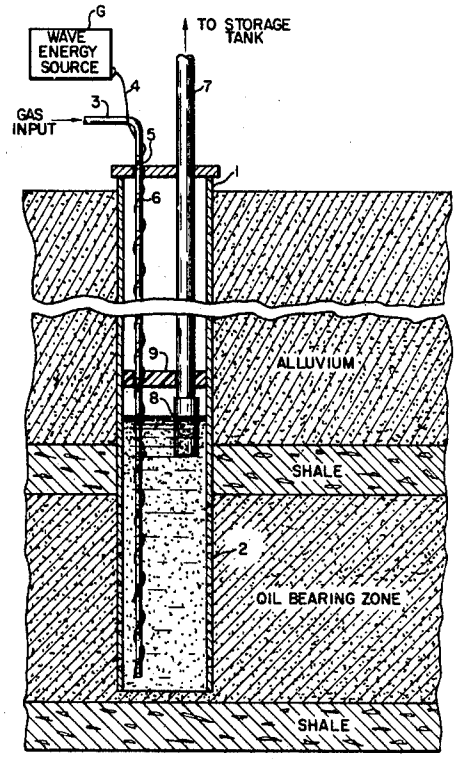
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ABSTRACT: Apparatus for the recovery of viscous crude petroleum from a natural reservoir by use of heat by utilizing gases herein set forth of suitable energy levels, and an electromagnetic wave transducer for exciting the atoms and molecules of the gas or gas mixtures or causing interaction between them and the transducer discharged electromagnetic waves (i.e., "population inversion" or "collision, second kind") that will emit radiation in the infrared sector of the electromagnetic spectrum.



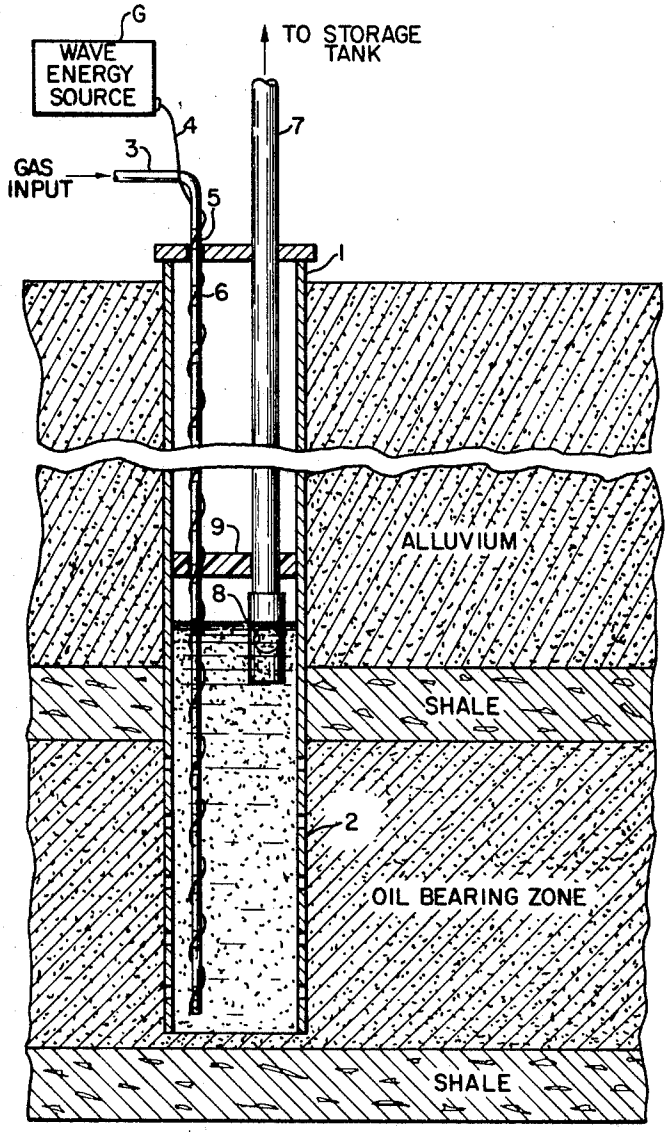


FIG. 1



FIG. 2

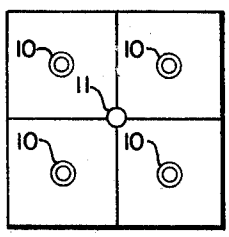


FIG. 6

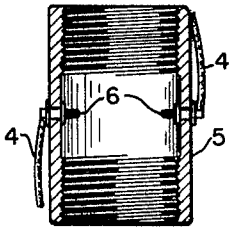


FIG. 3

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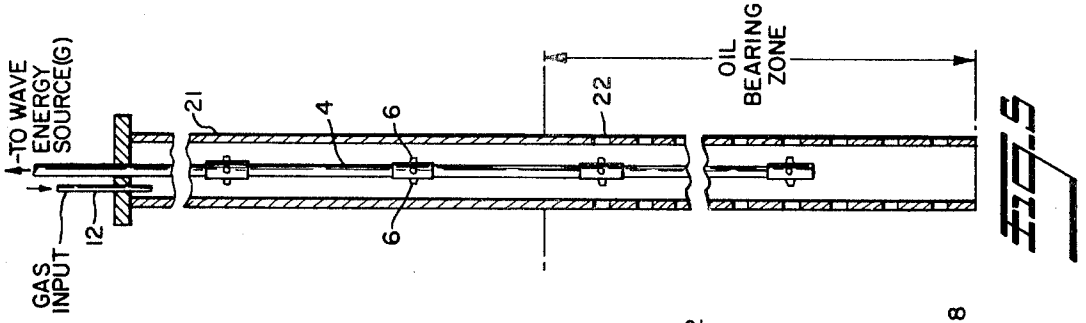


FIG. 5

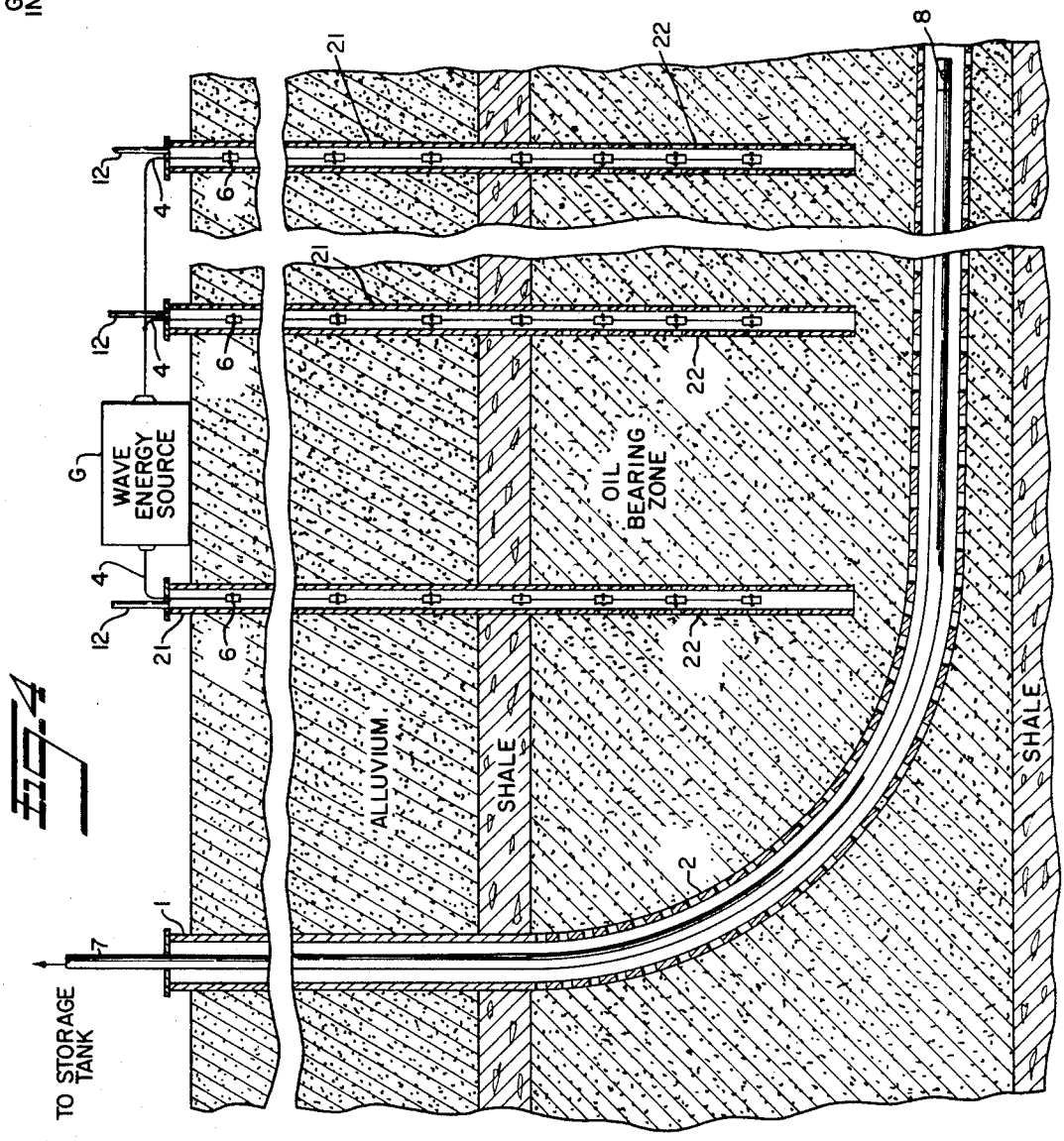


FIG. 4

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U.S. PATENT 3,522,842

APPARATUS FOR OIL PRODUCTION AMPLIFICATION BY SPONTANEOUS EMISSION OF RADIATION

BACKGROUND OF THE INVENTION

The subject invention concerns new, novel, efficient and economical apparatus for use in recovering viscous hydrocarbon oil from porous and permeable natural reservoirs in the earth, and further concerns new and unique designs of certain apparatus to materially assist in the same.

Viscous hydrocarbon oil usually occurs in natural reservoirs of porous and permeable matrix, the oil existing within the interstices of such matrix. The matrix usually consists of quarzitic or dolomitic sand grains or of limestone. The interstices vary in size and continuity as the size and shape of the solid formation particles of the matrix vary from reservoir to reservoir, indeed even from place to place within a single reservoir. Numerous fine fractures interlace the matrix, being interstices themselves. Viscous hydrocarbon oil is restricted in its flow from its position within such interstices because of the properties of cohesion which are the very essence of viscosity; at natural reservoir temperatures such oil is too thick and cohesive to flow through the openings of the matrix and thence into a drilled well to be produced.

It is well known in the petroleum sciences that heat reduces the viscosity of hydrocarbon oil in spectacular fashion, that the application to high viscosity hydrocarbon oil of even a modest amount of heat can produce a reduction of viscosity that can approach **100/1** or even **1000/1**. Such viscosity reduction is now being undertaken, among prior art methods, by the introduction of steam into such natural oil reservoirs for heating purposes.

SUMMARY OF THE INVENTION

My invention utilizes the introduction into an oil bearing natural reservoir containing viscous hydrocarbon oil of heated gas selected from the noble gases (i.e., helium, neon, argon, krypton, xenon, radon) and in addition also nitrogen and carbon dioxide, and/or mixtures of two or more thereof, and causing such gases to be excited by electromagnetic waves, in a manner to emit infra-red radiation.

An important object of my invention is to provide new, novel, economical and efficient apparatus to create heat energy within natural reservoirs containing high viscosity oil, and to impart flowability to such oil.

An important object of my invention is to provide means of applying, reenforcing and controlling the transducer discharged electromagnetic wave energy to be applied to the mixture of gases herein provided for.

An important object of my invention is to provide new, novel, simplified, efficient and economical apparatus (notably transducer) to carry out this invention.

A most important object of my invention is to utilize the energy levels of one or a mixture of two or more of the gases herein set forth to continuously emit infra-red (heat) radiation when excited by the action of electromagnetic waves as herein described. Mixtures of certain of these gases of suitable energy levels (such as Helium and Neon, or Carbon Dioxide and Argon, or Carbon Dioxide and Nitrogen and Helium) will emit infra-red radiation when mixed in proper proportion and the mixtures excited by application of optimum electromagnetic wave energy.

An important object of my invention is to provide an efficient, simple and economical transducer apparatus comprised of several joints of tubing connected by threaded couplings forming a continuous conduit and an electrical cable spiralled thereabout and connected to eletrodes at pre-selected locations in the conduit to impact electromagnetic wave discharges into the gas to cause ionization of the gas as it descends through said conduit.

Another important object of my invention is to provide as an alternate transducer apparatus a small diameter casing

which both cases a bore-hole amd serves also as a continuous conduit to introduce selected gas into a natural oil bearing reservoir and an electrical cable hanging therein and mounting electrodes at pre-selected locations to impact electromagnetic wave discharges into the gas to cause ionization thereof as the gas descends through the casing.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects of the invention will appear from the following description and appended claims when read in connection with the accompanying drawings wherein:

FIGURE 1 illustrates schematically in partial cross-section a conventionally completed well in a natural oil bearing reservoir fitted with suitable apparatus for practicing this invention;

FIGURE 2 is an enlarged schematic elevational view of the conduit provided by the apparatus of **FIGURE** 1 to introduce gas into the natural oil bearing reservoir and the electrical cable and electrodes all of which together form an electromagnetic wave transducer suitable for practicing this invention;

FIGURE 3 is a detailed sectional view on an enlarged scale of one of the threaded couplings employed in the conduit of **FIGURE** 2 to join the lengths of tubing and create a continuous conduit with electrical cable and electrodes by which electromagnetic wave discharges are impacted into the gas conducted to the natural reservoir through the tubing;

FIGURE **4** illustrates schematically in partial cross-section a directionally drilled well employing perforated casing in the lower portion of the natural oil bearing reservoir positioned approaching the horizontal for a relatively long distance and cooperating with vertical bore holes cased to conduct gas to the natural reservoir and house the necessary cable and electrodes to form an alternate type of transducer and form suitable apparatus for practicing this invention;

FIGURE 5 is an enlarged sectional view of one of the vertical bore holes of **FIGURE** 4 illustrating the relatively small diameter casing that may be used to introduce gas into said reservoir and house the electrical cable and electrodes exposed to the gas to impact electromagnetic wave discharges thereinto and practice this invention;

FIGURE 6 schematically illustrates a "**5** spot" application of this invention useful in recovering petroleum from a finite area of a reservoir within the effective range of a single bore hole fitted to practice this invention.

DESCRIPTION OF PREFERRED EMBODIMENT

With continued reference to the drawings wherein the same reference numerals are employed throughout to indicate the same parts, the apparatus of this invention is useful in practicing the production amplification methods disclosed and claimed in my copending application Serial No. **765,052** which can be practiced with a wide variation in apparatus utilizing a conventionally completed well as illustrated in **FIGURE** 1 and the "huff-and-puff" system in which the well is subjected to a cycle of heating the oil in place followed by a cycle of producing the oil and delivering it to a storage tank. **FIGURE** 1 illustrates a preferred adaptation of the invention to such a conventionally completed well suitably equipped to apply the invention. In such a well adaptation, the solid casing **1** extends from the surface to the top of the oil bearing zone, perforated casing **2** extends through the oil bearing zone, and a continuous conduit **3**, made up of joints of tubing (each joint usually **20'** long) the several joints of which are connected by threaded couplings **5**, is introduced to apply this invention. Gas, which may be an optimum mixture of helium and neon, or carbon dioxide and argon, or carbon dioxide and nitrogen and helium, or other suitable mixtures, is pumped into tubing **3** at the surface and is conducted therethrough and exuded into perforated casing **2** below packer **9** which is set at the bottom of solid casing **1**, and thence through the perforations of perforated casing **2** into the oil bearing zone. Inserted through couplings **5** are electrodes **6** the output of which impacts into

the gas mixture ionizing electromagnetic waves, which waves are generated on the surface by a wave energy source generator G of conventional well known design, conducted therefrom to electrodes **6** by means of electrical cable **4**.

As the gas mixture moves down through tubing **3** it is subjected to a series of repeated electron impacts at each preselected location of electrodes **6**. Assuming for this example that the upper limit of the oil bearing zone is **500'** deep and the lower limit **600'** deep as many as thirty electrodes **6** energized through electrical cable **4** may be employed if desired to successfully practice this invention. As the gas moves through tubing **3** each successive electrode **6** reenforces the impact effect thus intensifying the interaction of the transducer discharged electromagnetic waves and the atoms and molecules of the gas or mixture of gases resulting in tremendous emissions of radiation in the infra-red sector of the electromagnetic spectrum (in the order of **10** trillion electrical impulses per second) and heating of the gas to be introduced into the natural oil bearing reservoir.

Specifications and characteristics may be determined, in conventional ways forming no part of this invention, to reach a determination of the physical characteristics and fluid content of the oil bearing zone. Dependent upon this ascertainable information, and a knowledge of the specifications of the mixtures, volume, pressure, and input velocity of the gas or mixture of gases to be used, and the temperature desired (perhaps **300°** F.) to be achieved in the oil bearing zone to greatly reduce the viscosity of the fluid content and impart flowability to such fluid content of the reservoir, mathematical computation can be made to determine the length of time this in-put heating cycle should be extended to achieve the optimum heating result.

The following cycle of producing the oil and delivering it to a storage tank is entirely conventional; the in-put of gas through tubing **3** is stopped and the in-put of electromagnetic wave impacts through electrodes **6** is stopped. The oil enters production tubing **7** through pump **8** and is thence pumped to the surface by conventional means, that are not part of this invention, thence to an oil storage tank.

The cycles may be repeated.

As the heated gases physically combine into a homogenous mass with the hydrocarbon molecules, individual grains of the matrix and hydrocarbon molecules become surrounded by a thin but continuous layer of gas, i.e. "gas wet". It is well known in the sciences that these gases can be in physical continuity even when reduced to a thickness of no more than one millionth of an inch. Yet, such thin-layer gases display the characteristics needed for maintaining gas wet conditions in the reservoir, and for maintaining heat radiation, thus increasing oil flowability. The transducer of this invention is designed to apply to such gases a series of repeated electromagnetic wave impacts at pre-selected intervals, each successive impact reenforcing the excitation effect upon said gases to effect maximum radiation in the infra-red (heat) sector of the electromagnetic spectrum. Thus the transducer subjects the gas or mixture of gases to electromagnetic wave impacts which cause out-put radiation emissions at frequencies millions of times greater than the in-put frequencies.

The emissions herein provided for would, of necessity, be less coherent and intense than the emissions of a laser of the pulsed ruby type, and desirably so. Pulsed ruby type emissions last for only a very small fraction of a second and generate heat up to thousands of degrees F. Any sizeable fraction of such heat would carbonize the oil in place. Emissions as here described would cause less coherence than the pulsed ruby type laser but, coherence of the laser may be a secondary consideration unless focusing at a long distance is desired. And, the subject type is continuous, not pulsed.

As the temperature rise required in the hydrocarbon oil in place is relatively moderate and, the oil-matrix mass is relatively large, the co-efficient of heat transfer of the oil negates any cooling equipment as in a laser instrument. As the hydrocarbon oil and in turn the reservoir matrix (lower temperature bodies), absorb the radiation (infra-red emissions) from the entering superheat gas (warm temperature body) the total purpose of the emissions is accomplished; the viscosity of the oil is greatly reduced, cohesion between the hydrocarbon molecules themselves, and between the hydrocarbon molecules and the solid formation particles of the matrix, becomes greatly reduced and the oil flows through the interstices of the matrix and thence into a drilled well to be pumped to the surface and captured.

Of utmost importance to the present invention, simultaneous with the passage of the gas or mixture of gases down the tubing from the surface to the point or points of injection into the said reservoir, the gas or mixture of gases is subjected to ionizing electromagnetic wave impacts at one or a multiplicity of times and places as it travels through the tubing to cause excitation of the atoms and molecules of said gas or mixture of gases, thus creating stimulated emission of radiation in the infra-red sector of the electromagnetic spectrum (heat). In this way the transducer can be made to operate so as to control the frequency and intensity and to reenforce the molecule-atom-electromagnetic wave interaction by preselecting the placement of the electrodes along the tubing to impact the mixture of gases.

As an example, the upper limit of the oil impregnated reservoir is here assumed to be at a depth of **500'** and the lower limit at the depth of **600'** the oil impregnated reservoir **100'** thick, with ascertainable specifications and characteristics of the matrix thereof and of the fluid content thereof. The total length of the tubing through which the mixture of gases is conducted approaches **600'**. According to the above said ascertainables, and to the specifications of the mixture of gases and the volume, pressure and velocity thereof, and the temperature desired to be achieved in the oil bearing formation by means of the method hereof, mathematical computation can be made of the desired number of points of electromagnetic wave impact upon the mixture of gas, and the nature and intensity of each such impact. In this example one or a multiplicity of points of electromagnetic wave impact may be utilized (perhaps as many as thirty). Each of such impacts may be of the same frequency or intensity, or some or all may be different, as desired to achieve the optimum of emission radiation. Series of impacts may even be applied intermittently. The atoms and molecules of the gases are thus brought to an optimum state of excitation and radiation.

DESCRIPTION OF ALTERNATE APPARATUS

Example **2** represents adaptation of this invention to the gravity flow of oil into a well to be there accumulated and pumped to a surface oil storage tank. Gravity flow of oil from a natural subsurface oil bearing reservoir into a well is known to be exceedingly efficient and economical; however, such flow is greatly retarded by high viscosity of oil, by the cohesion and capillarity of the hydrocarbon molecules to each other and to the reservoir matrix. The contact of the hot gases materially reduces viscosity and imparts the necessary flowability to the oil content of the reservoir.

FIGURE 4 of the drawings illustrates a directionally drilled well in which solid pipe **1** extends from the surface to the top of the oil bearing reservoir, perforated casing **2** assumes in the lower portion of such oil bearing zone a position approaching the horizontal and continues approximately horizontally for a relatively long distance in order to present a maximum drainage area for the gravity flow of the oil into such perforated casing **2**. The horizontal extension of perforated casing **2** may be as much as **1,000** feet, or even more. Such directionally drilled well is equipped with production tubing **7** and pump **8** only, as it is utilized only to accumulate the oil and pump it to the surface.

FIGURE 4 also illustrates three vertically drilled cased holes further illustrated in detail in **FIGURE** 5. Each consists of solid casing **21** extending from the surface to the top of the oil bearing reservoir, and a perforated casing **22** perforated

within the oil bearing reservoir. Electrical cable 4 hangs vertically within said solid casing 21 and perforated casing 22 with electrodes 6 at pre-selected locations upon electrical cable 4. Gas in-put pipe 12 extends only into the very top of the cavity of solid casing 21. Parts 7 and 8 as illustrated in FIGURE 1 are not included in these wells since they are not utilized to accumulate oil or to pump it to the surface, these only function as is hereinafter set forth.

In FIGURE 5 the diameter of solid casing 21 and perforated casing 22 is relatively small, probably no more than that of continuous conduit 3 as illustrated in FIGURE 1; it may consist of joints of 2 1/2" tubing with regular tubing couplings. The gas or mixture of gases as selected and used in this invention is introduced into the top of solid casing 21 through gas in-put pipe 12, and thus solid casing 21 and perforated casing 22 function not only as casing of bore-hole but also as tubing 3 functions in Example 1 illustrated by FIGURE 1. This alternate transducer structure may be substituted for tubing 3 and its electrical cable 4 and electrodes 6 as illustrated in FIGURE 1, if desired.

FIGURE 4 illustrates only three such wells, but any suitable number of same may be utilized in conjunction with this Example 2. Assuming that the horizontal perforated casing 2 of the directionally drilled well extends laterally for 1,000 feet it may be to best advantage in the practice of this invention to have as many as ten such vertical wells above, and along the path of or in reasonable proximity to, the extension of horizontal perforated casing 2 of the directionally drilled well to materially reduce viscosity and impart flowability to the oil content of the reservoir.

In these vertically drilled wells the gas or mixture of gases moves down through solid casing 21 and perforated casing 22 and in passing therethrough is subjected to electromagnetic wave impacts at each electrode 6, and then passes into the natural reservoir. The effect is precisely identical as is described in Example 1 hereof.

As the oil in the reservoir is acted upon as therein described it flows by gravity into perforated casing 2 of the directionally drilled well and is accumulated and pumped to the surface oil storage tank by pump 8 through production tubing 7.

DESCRIPTION OF FURTHER ALTERNATE APPARATUS

Example 3 represents the adaptation of this invention to the "5 spot" system. FIGURE 6 illustrates a field pattern in which 4 conventionally completed wells 10 are spaced in relatively equal distance from each other. Each of wells 10 is according to the detail of FIGURE 1 except that parts 3, 4, 5 and 6 thereof are not included as each well 10 is utilized only to accumulate and pump oil to the surface through tubing 7. Well 11 is spaced relatively equal distance from all wells 10 and is precisely to the detail of FIGURE 5 and is continuously operated in the same manner and for the same purpose as a FIGURE 5 well as above described in Example 2, that is to cause significant reduction of the viscosity and flowability of the oil so it may be accumulated in and produced through wells 10.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

I claim:

1. Apparatus for recovering oil from a natural reservoir comprising:

a) pipe means extending from the surface into said reservoir for conveying gas, that is chemically inactive as to the hydrocarbon constituents of the reservoir and capable of emitting infra-red,into a well bore in fluid communication with said reservoir, said pipe means within said reservoir being perforated to permit ready egress of the conveyed gas into the well bore and reservoir;

b) electromagnetic wave energy transducer means operatively associated with said pipe means for applying ionizing impacts to the conveyed gas in a manner to effect an interaction between the electromagnetic waves and the gas atoms and molecules causing a resultant emission of infra-red radiation heating the gas conveyed into the well bore thereby heating the reservoir to a temperature sufficiently high to reduce the viscosity of the contained oil and free it to flow to a subsurface collection point; and

c) a conventionally completed well having its lower cased end formed and disposed in said reservoir at said subsurface collection point to receive and convey the collected oil to a surface storage area.

2. The apparatus of Claim 1 wherein the pipe means comprises lengths of small diameter pipe coupled together in end-to-end relation by pipe couplings and the electromagnetic wave energy transducer means comprises a plurality of electrodes respectively mounted successively in the pipe and a supply cable connected to said electrodes and to a source of electrical energy to selectively maintain an electromagnetic wave impact from said electrodes upon the supplied gas for a predetermined time interval to assure optimum heating of the reservoir area.

3. The apparatus of Claim 2 wherein the pipe means and electromagnetic wave energy means is mounted within the conventionally completed well.

4. The apparatus of Claim 1 wherein the pipe means comprises lengths of small diameter bore-hole casing conventionally coupled in end-to-end relation and the electromagnetic wave energy transducer means comprises a plurality of electrodes connected at predetermined spaced intervals to a supply cable extending from a source of electrical energy lengthwise of said bore-hole casing to selectively maintain an electromagnetic wave impact from said electrodes upon the supplied gas for a predetermined time interval to assure optimum heating of the reservoir area.

5. The apparatus of Claim 4 wherein the small diameter bore hole casing and the electromagnetic wave energy transducer means is mounted within the conventionally completed well.

6. The apparatus of Claim 1 wherein the conventionally completed well comprises a well casing having an annularly perforated section extending vertically through the reservoir area and said pipe means forms a portion of the electromagnetic wave energy transducer means and extends axially within the casing of said conventionally completed well.

7. The apparatus of Claim 1 wherein the conventionally completed well comprises a directionally drilled well having a casing section formed with a perforated wall portion and adapted to be disposed along the lower portion of a subsurface oil bearing reservoir, said pipe means comprises respective lengths of small diameter bore-hole casing conventionally coupled in end-to-end relation in a series of vertical drill holes arranged in alternating laterally spaced relation to said perforated well casing section, and said electromagnetic wave energy transducer means includes said respective lengths of small diameter bore hole casing and respective lengths of electric cable supported by said casing and having electrodes connected thereto at predetermined spaced intervals and arranged to maintain an electromagnetic wave impact upon the supplied gas in each drill hole for a predetermined time interval to assure optimum heating of the reservoir area.

8. The apparatus of Claim 1 wherein the conventionally completed well comprises a well casing having an annularly perforated section extending substantially vertically through the reservoir area, and said pipe means comprises respective lengths of small diameter bore hole casing conventionally coupled in end-to-end relation in a series of vertical drill holes arranged in radial outward angularly spaced relation to said conventionally completed well, and said electromagnetic wave

energy transducer means includes said respective lengths of small diameter bore hole casing and respective lengths of electric cable supported by said casing and having electrodes connected thereto at predetermined spaced intervals and ar-

ranged to maintain an electromagnetic wave impact upon the supplied gas in each drill hole for a predetermined time interval to assure optimum heating of the reservoir area.