# United States Patent

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Continuation-in-part of Ser. No. 641,825, May 29, 1967


[54] **METHOD AND APPARATUS FOR PRODUCTION AMPLIFICATION BY SPONTANEOUS EMISSION OF RADIATION**
**28 Claims, 9 Drawing Figs.**


[52] **U.S. Cl.** ..... **166/303,** 166/60; 219/277
[51] **Int. Cl.** ..... **E21b 43/24**
[50] **Field of Search** ..... 166/272, 302, 303, 57,60; 175/16; 219/121P, 277, 278; 290/1



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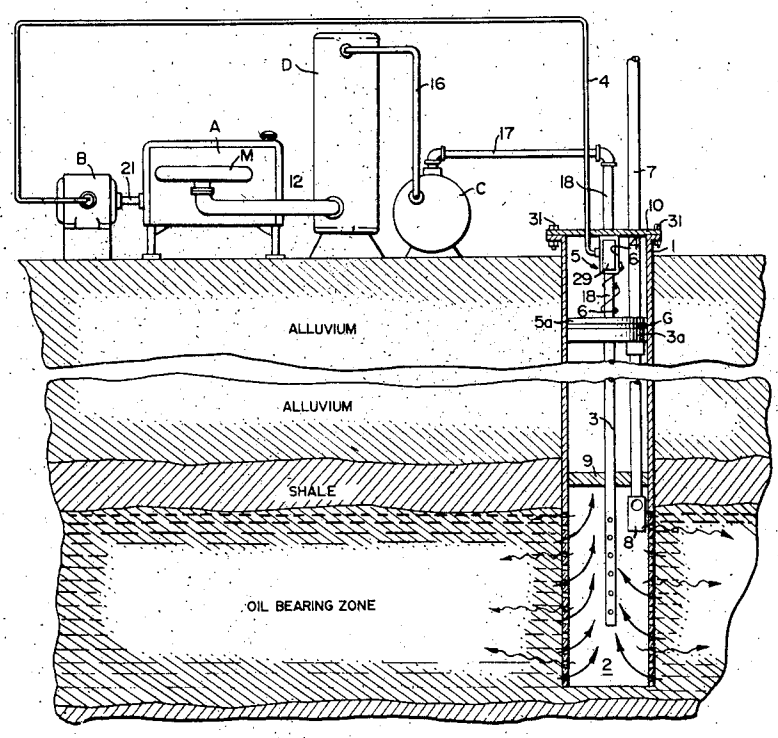
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**ABSTRACT:** A method and variant apparatus for the recovery of crude petroleum from a natural reservoir by introduction through a drilled well-bore of suitably heated inert gas or mixtures of such gases as herein set forth of suitable energy levels, produced by excitation of the atoms and molecules of the introduced gas by "electro-energy" impacts (for the purposes of this application "electro-energy" is used as a generic term and includes electrical current discharges and/or electromagnetic wave discharges) to effect an interaction between said gas and the impacted electro-energy with resultant ionizing excitation of the gas atoms and molecules and emission of radiation in the infrared (heat) sector of the electromagnetic spectrum within the natural reservoir. The apparatus contemplates a source of suitable gas, preferably internal combustion engine exhaust gases, a suitable source of electrical current as herein defined, and transducer means composed of a tube for conducting the gas into the drilled well-bore and extending through the natural reservoir oil bearing zone and discharge elements for injecting electro-energy impacts into the gas or gases to excite the atoms and molecules during their passage through and from the transducer.

Patented Aug. 4, 1970 3,522,846



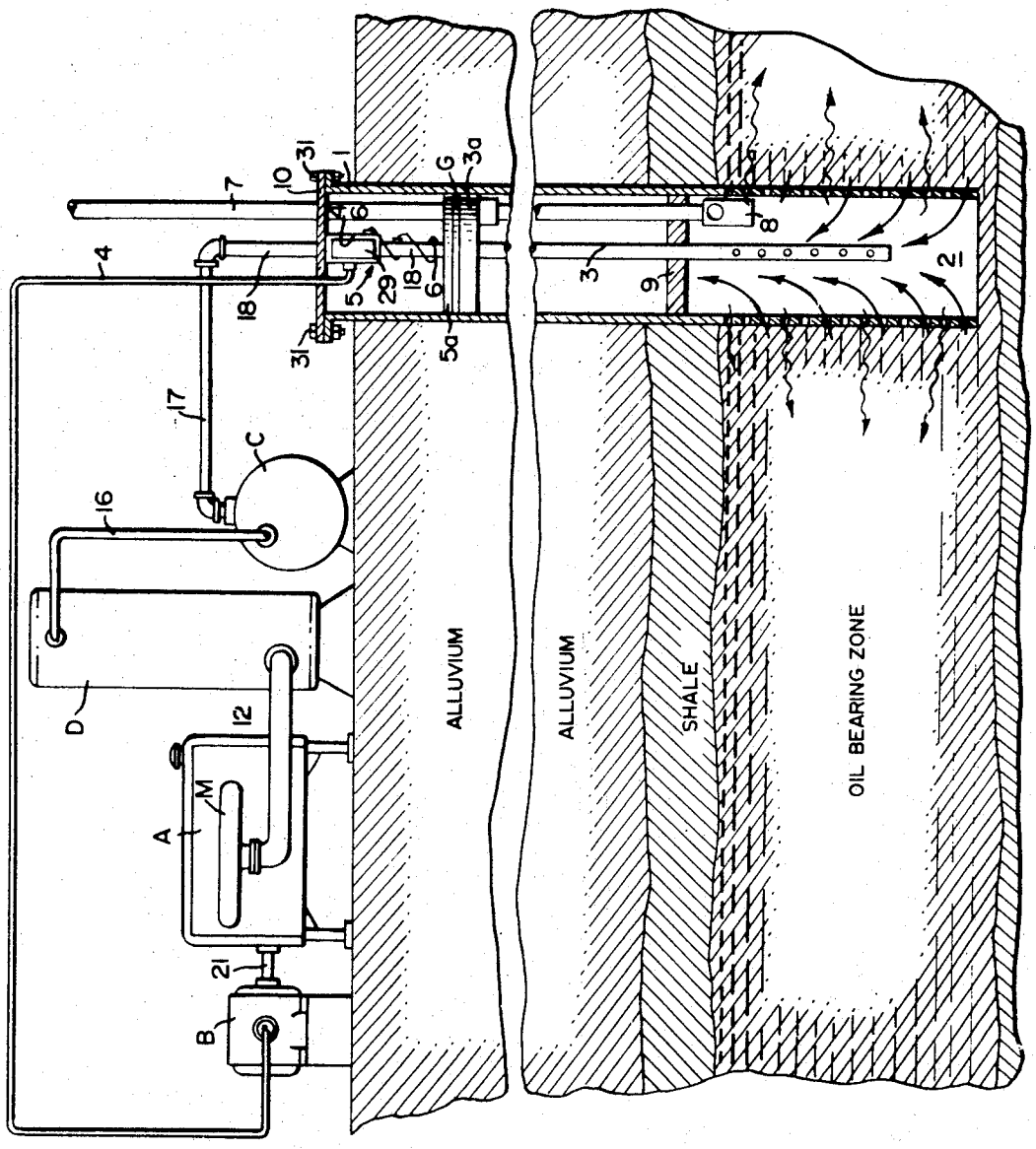



FIG. 1.

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Fig 2.

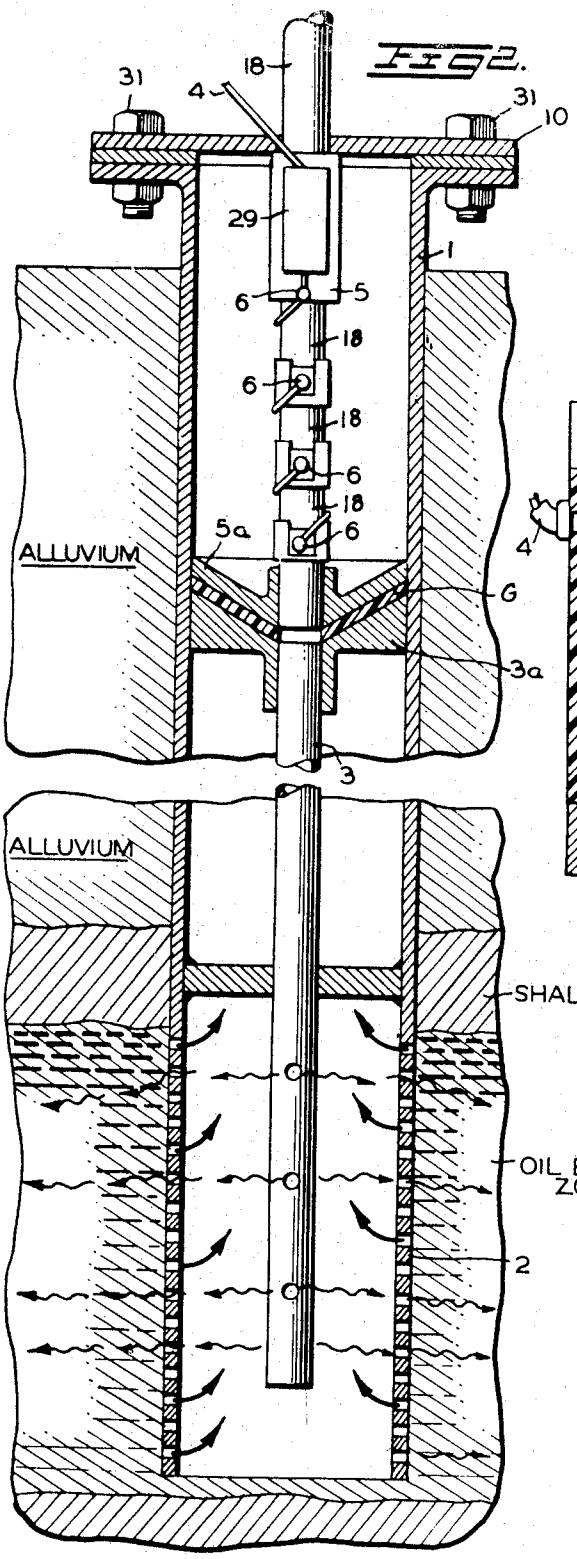
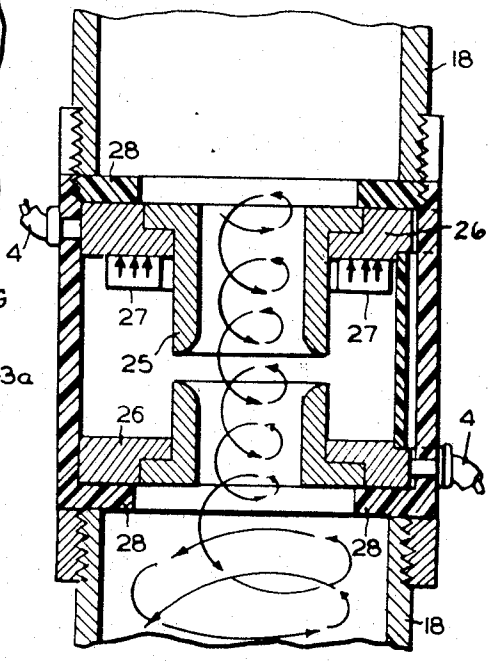



Fig 3.




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Fig 5.

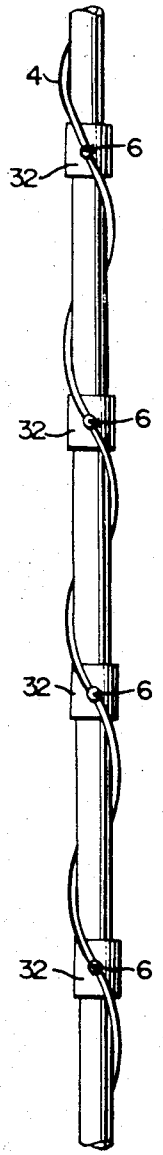



Fig 4.

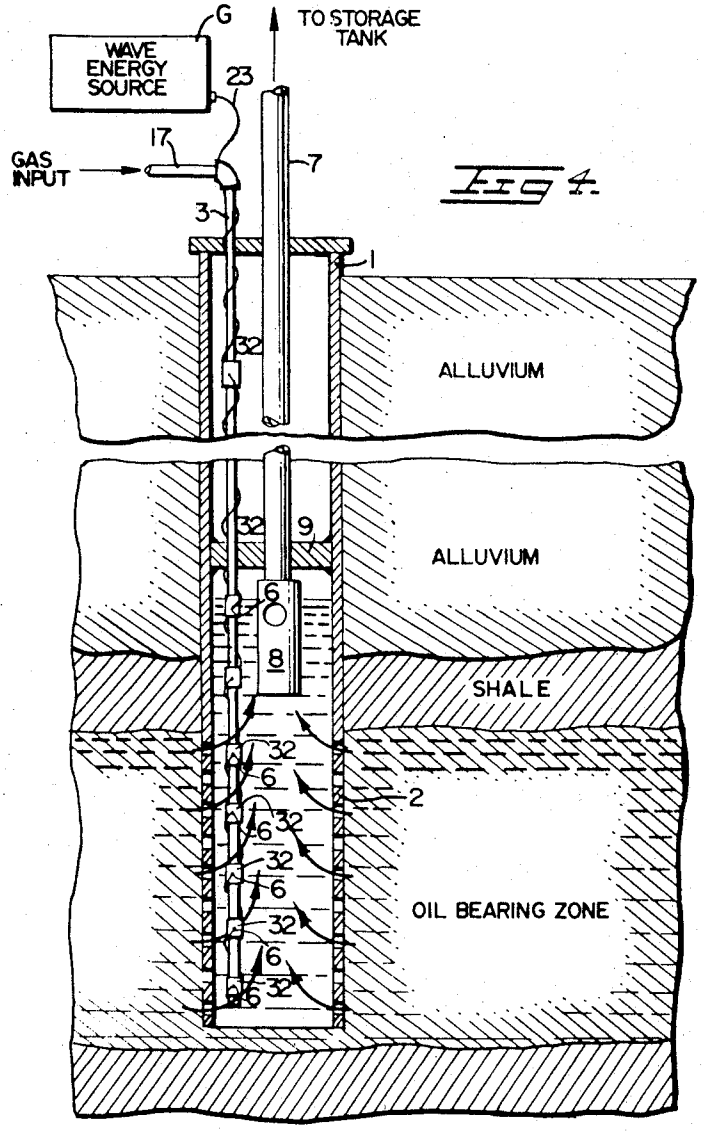



Fig 7

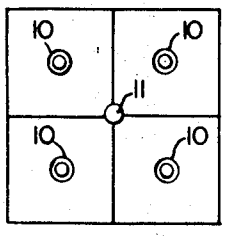
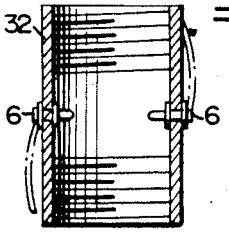



Fig 6.




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FIG 9

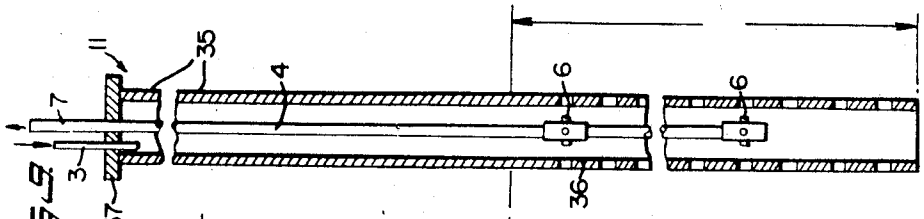
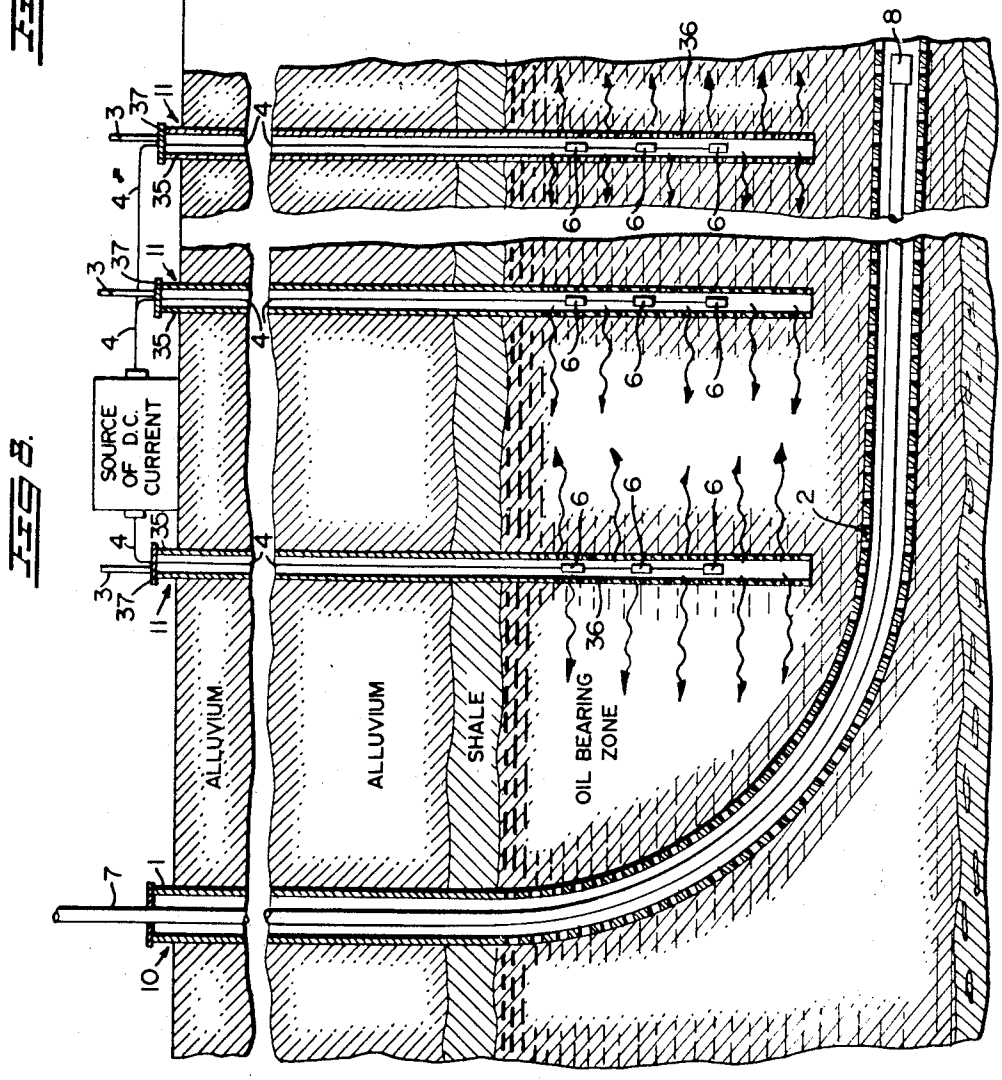



FIG 8.




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U.S. PATENT 3,522,846

# METHOD AND APPARATUS FOR PRODUCTION AMPLIFICATION BY SPONTANEOUS EMISSION OF RADIATION

## CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of my copending application Serial No. 641,825, filed May 29, 1967, entitled Method and Apparatus for Oil Production Amplification by Stimulated Emission of Radiation.

## BACKGROUND OF THE INVENTION

Hydrocarbon oil usually occurs in natural reservoirs of porous and permeable conglomerate matrix, the oil existing within the interstices of such matrix. The interstices vary in size and continuity as the size and shape of the solid formation particles of the matrix vary within the said reservoirs. Numerous fine fractures interlace the matrix, being interstices themselves. Hydrocarbon oil is restricted in its flow from its position within such interstices because of (1) the properties of viscosity, capillarity, cohesion and surface-tension, (2) by lack of the energy often naturally caused by gas expansion or water drive, and/or (3) contamination in or adjacent to the well-bore.

It is well known that heat reduces viscosity of hydrocarbon oil in spectacular fashion, that the application to hydrocarbon oil of even a modest amount of heat can produce a reduction of viscosity that can approach **100/1** or even **1000/1**. Also, it is well known that steam vapor requires about **1400** times the amount of space as does the water from which it is formed, the expansion in volume creating pressure which is the basis for all steam-developed kinetic energy. Also, it is well known that materials and conditions accumulate in well-bores and attendant equipment and in the adjacent formation that inhibit production. It is the purpose of this invention to provide in an improved and simple, economical and novel, way with an apparatus and means of simple novel construction, a method to elevate sufficiently the temperature of a cased well-bore and its attendant equipment and/or the adjacent natural oil-bearing reservoir by introduction of super-heated inert gas or gas mixtures into the reservoir to effect desired reduction in viscosity, capillarity, cohesion and surface-tension of the hydrocarbon oil content, and/or conversion of the interstitial water to steam, and/or removal of accumulated salt, paraffin, asphalt, sludge or emulsions, detrital material, products of metallic oxidation (such as rust), water-block and other production inhibitors.

The method and apparatus variants are respectively useful in accomplishing the teachings and purposes disclosed in my copending application Ser. No. **667,228** filed Sept. **12, 1967,** of the same title now abandoned, by copending applications entitled Apparatus for Production Amplification by Stimulated Emission of Radiation, Ser. No. **641,823** filed May **29, 1967,** and Ser. No. **712,510** filed Mar. **12, 1968,** and my copending application Ser. No. **724,002** filed Apr. **24, 1968** entitled Method and Apparatus for Cleaning Heat Amplification by Stimulated Emission of Radiation.

## SUMMARY OF THE INVENTION

This invention utilizes the introduction into a natural reservoir containing hydrocarbon oil of gas selected from the inert chemically inactive group, i.e., helium, neon, argon, krypton, xenon, radon, and also nitrogen and carbon dioxide, and/or mixtures of two or more thereof, and causing such gases to be excited and heated by electro-energy impacts in a manner to effect emission of radiation in the infrared sector of the electro-magnetic spectrum.

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

Another object of this invention is to extract "shale-oil" from "oil-shale" by injection of infrared (heat) radiation and hot inert gases (at temperatures, for example, up to **1000°F**) into an oil shale reservoir after the same has been highly fractured by nuclear explosion to provide permeability. By such injection of hot inert gases and infra-red radiation created by electro-energy impacts into the said gases to cause excitation of the atoms and molecules thereof, the shale particles become "gas wet" , the shale particles shrink, cohesion is broken, capillarity is overcome, the shale oil tends to vaporize, whence the shale-oil will flow into a collection point for recovery.



Another important object of this invention is to provide means of applying, reenforcing and controlling the electro-energy impacts to be applied to the mixture of gases as herein provided.

A further object of this invention is to provide new, novel, simplified, efficient and economical apparatus (notably transducer means) to effect the excitation of the gas.

A most important object of this invention is to utilize the energy levels of one or more of the gases herein set forth to continuously emit infra-red (heat) radiation when excited by the action of electro-energy impacts 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) will emit infra-red (heat) radiation when mixed in proper proportion and the mixtures are excited by application of optimum impacts of such nature.

Still another object of this invention is to provide an efficient, simple and economical transducer means comprised of tubing forming a continuous conduit and an electrical cable spiraled thereabout and connected to electro-energy discharge elements at pre-selected locations along the transducer designed to inject electro-energy discharges into the gas to cause excitation and a high degree of ionization of the atoms and molecules of the gas as it descends through said conduit.

Another object of this invention is to provide as one form of transducer means a small diameter casing which both cases a bore-hole and serves also as a continuous conduit to introduce selected gas into a natural oil bearing reservoir and an electrical cable hanging therein and mounting electro-energy discharge elements in the form of electrodes or light-emitting injection diodes at pre-selected locations to exert electro-energy impacts upon the gas to cause a high degree of excitation and ionization of the atoms and molecules of the gas as it descends through the casing.

The present invention further provides a new, novel, efficient, and exceedingly economical internal combustion engine driven electrical generating plant supplying engine exhaust gas and also electrical current for activating a transducer means of the preceding objects disposed in a bore-hole in a natural reservoir to cause a high degree of excitation and ionization of the atoms and molecules of the exhaust gas resulting in radiation in the infrared (heat) sector of the electromagnetic spectrum, for heating of the through put gas and of the porous and permeable oil bearing zone of natural reservoirs in the earth thereby causing the oil therein to flow into a completed production well for recovery, and/or to cause removal of materials and conditions that may inhibit maximum and efficient production.

A further object of the invention is to provide exhaust gases and electrical current generator plant equipment and a transducer of an immensely improved and efficient construction for on site operation to produce the oil from a natural reservoir by infrared radiation produced by excitation of the exhaust gases, preferably of an internal combustion engine which engine simultaneously, and at almost no extra cost, drives an electrical generator to provide the required quantities of electrical current to energize the transducer fitted with electro-energy discharge elements (such as electrodes or injection diodes) to cause ionizing excitation of the atoms and molecules of the combustion gases in a manner to effect quantities of radiation emissions in the infrared sector of the electromagnetic spectrum to heat and substantially reduce the

viscosity of the hydrocarbon oil, and/or to vaporize the interstitial water in the natural reservoir, and/or remove production inhibitors within a cased well-bore, its attendant equipment and adjacent formation.

Still another object of this invention is to provide generating equipment that produces both large volumes of nitrogen and carbon dioxide gas and electrical current for effective use under predetermined conditions to provide new, novel, efficient and extremely economical means to create and introduce heat into natural reservoirs containing hydrocarbon oil, and/or hydrocarbon oil and water, and/or into well-bores and attendant equipment and adjacent formations which may be rendered inefficiently productive or non-productive because of the accumulation of production inhibitors.

A still further object of this invention is to provide apparatus that is an assemblage of relatively inexpensive and largely well known components arranged in efficient and economical combination for effective transformation of x quantities of hydrocarbon fuel and ambient atmospheric air into approximately 9 times x quantities of nitrogen and carbon dioxide exhaust (waste) gas, and simultaneously, and at almost no additional cost, generate quantities of suitable electrical current usable to energize a transducer providing an electro-energy feedback into the exhaust gas (and possibly other selected inert gases admixed with said exhaust gas) to produce infrared (heat) emissions by excitation of the gas atoms and molecules.

A further most important object of this invention is to provide as a part of the apparatus hereof an improved efficient, simple, and economical transducer means, comprising tubing arranged to form a conduit through which a suitable gas or mixture of gases is conducted and to mount electro-energy discharge elements, comprising suitable electrodes disposed at one or a multiplicity of pre-selected locations within and along the conduit so that the electric sparks (arcs) emanating from the electrodes as they are energized will cause excitation and ionization of the atoms and molecules of the gas or mixture of gases as it passes through the conduit, and suitable permanent magnets in close proximity to each electrode to create a static field for the purpose of causing a rotational effect in the arcs and also a swirling or rotational effect in the flow of the gas so that all parts and portions of said gas flow will be in ionizing contact with the said electric arcs.

A further important object of this invention is to provide as a part of the apparatus of the preceding object an efficient, simple and economical ignitor to start breakdown and ionization of the gas as it flows through the transducer, thus activating the electrodes into which the electrical current voltage has already been charged and causing the electrodes to emit electrical sparks (arcs) which sparks will thereafter create further and continuous excitation and ionization of the gases.

A most important object of this invention is to provide new, unique and novel apparatus assemblies to apply this invention to a cased well-bore in such a way that the electrical cable, transducer, electrode assembly and ignitor are readily accessable for adjustment, repair or replacement without the necessity of pulling the tubing that serves as the conduit to convey the gas-flow thus effecting maintenance economies contributing to the economical aspects that are so important a part of this invention.

## 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 generator equipment provided by this invention for effective production of electro-energy and the principal gaseous components fitted to a conventionally completed well in a natural oil bearing reservoir for practicing any of the several methods disclosed;

**FIGURE** 2 is an enlarged schematic sectional view of the sub-surface apparatus of **FIGURE** 1 employed to obviate the necessity of pulling the tubing that serves as the conduit for the hot inert gas-flow to the bottom of the well-bore in order that the transducer and its component parts may be readily retrieved for adjustment, repair or replacement;

**FIGURE** 3 illustrates in partial cross-section a schematic cross-sectional view of the continuously operating electrode arrangement of **FIGURES** 1 and 2 for maintaining excitation and ionization;

**FIGURE** 4 illustrates schematically in partial cross-section a conventionally completed well in a natural oil bearing reservoir fitted with an alternate suitable apparatus for practicing this invention;

**FIGURE** 5 is an enlarged schematic elevational view of the conduit provided by the apparatus of **FIGURE** 4 to introduce the hot inert gas into the natural oil bearing reservoir and the electrical cable and electrodes to form an electromagnetic wave transducer suitable for practicing this invention;

**FIGURE** 6 is a detailed sectional view on an enlarged scale of one of the threaded couplings employed in the conduit of **FIGURE** 5 to join the lengths of tubing and create a continuous conduit with electric cable and electrodes by which electro-energy impacts are exerted upon the gas conducted to the natural reservoir through the tubing;

**FIGURE** 7 schematically illustrates a "**5** spot" application of hot inert gas produced in accord with this invention useful in continuously recovering petroleum from an area of a natural reservoir within the effective range of a single bore hole fitted to produce the reservoir area;

**FIGURE** 8 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 a further apparatus arrangement, namely, vertical bore holes cased and fitted to serve as transducers, for applying hot inert gas to the natural reservoir in accord with this invention; and,

**FIGURE** 9 is an enlarged sectional view of one of the vertical bore holes of **FIGURE** 8 illustrating the relatively small diameter casing that may be used to introduce the hot inert gas into said reservoir and house the electrical cable and electro-energy discharge elements for producing the electro-energy impacts into the gas within the oil bearing zone.

## DESCRIPTION OF METHOD

With continued reference to the drawings wherein the same reference numerals are employed throughout to indicate the same parts, the method of heat application provided by this invention can be practiced with a wide variation in apparatus.

**FIGURE** 1 illustrates a preferred adaptation of the invention to a conventionally completed well suitably equipped to apply the invention. In such a well, the conventional well casing is composed of solid well casing **1** extending from the surface down through the alluvium and shale formations to the top of the oil bearing zone of the reservoir where it joins connected sections of perforated well casing **2** which extends down through the oil bearing zone. The usual production tubing **7**, pump **8** and packer **9** set at the bottom of solid casing **1** is provided to pump the oil entering the well bore to the surface and thence to an oil storage tank. The gas employed in carrying out this invention is supplied to the bottom of the well bore through a supply conduit **3** extending through packer **9** and composed of threadedly coupled tubing sections the uppermost section of which terminates within perhaps **10** feet of well-cap **10** (see **FIGURE** 2) in a cupped flange **3a** that is only fractionally smaller in diameter than the inner diameter of solid well casing **1**. Flange **3a** receives in nested relation, a gasket G, preferably of neoprene or asbestos, which is sealingly clamped between flange **3a** and the lower flanged end **5a** of a preferred form of transducer **5** of this invention, which is secured to well-cap **10**, when the latter is conven-

tionally bolted to the upper end of well casing 1. Transducer 5 comprises a main tubular body, which may be a section of tubing like that employed to provide conduit 3, and electro-energy discharge elements 6 connected by suitable electric cable 4 to supply source of electric current, in the present embodiment of the invention an on-site gas and electrical current generating plant of novel construction adapted to supply a flow of exhaust gas under low pressure to and through the tubing section of transducer 5 and conduit 3 to the bottom of the cased well bore.

In operation of this form of the invention, the gas, which may be one or an optimum mixture of two or more of the gases herein set forth, preferably internal combustion engine exhaust gas (carbon dioxide and nitrogen) obtained as hereinafter pointed out, is pumped into the main tubular body of transducer 5 at the surface and flows therethrough and into and along conduit 3 to exude therefrom below packer 9 set below the lower end of solid casing 1 into perforated casing 2 and through the perforations thereof into the oil bearing zone (see wavy shanked arrows).

As the gas or mixture of gases moves down through transducer 5 it is subjected to atom and molecular excitation and ionization from a number of electro-energy discharge elements 6 disposed at preselected locations along transducer 5. As the gas moves through transducer 5 each successive discharge re-enforces the excitation effect thus creating and then intensifying an inter-action of the electro-energy impacts and the atoms and molecules of the gas mixture resulting in tremendous emissions of radiation in the infrared sector of the electromagnetic spectrum (in the order of 10 trillion electrical impulses per second) the radiated heat being effective to super-heat the gas which is then introduced into the natural oil bearing reservoir.

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

In the "huff-and-puff" method (**FIGURES** 1 and 4) the cycle of producing the oil and delivering it to a storage tank is entirely conventional; the input of gas through tubing 3 is stopped and energizing of the electro-energy discharge elements 6 is stopped at the end of the computed heating period. 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.

The transducer means of this invention in its alternate forms is interchangeable and designed to apply to such gases a series of excitation discharges at pre-selected intervals, each successive discharge re-enforcing the ionizing effect upon said gases to affect maximum radiation in the infrared (heat) sector of the electromagnetic spectrum. Thus the transducer means subjects the mixture of gases to excitation stimulation which causes out-put radiation emissions at frequencies in the order of 10 trillion cycles per second (infrared).

As the heated gases physically combine into a homogeneous mass with hydrocarbon molecules, individual grains of the matrix and the 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 distributing the heat throughout the reservoir. As the hydrocarbon oil, and the reservoir matrix and the interstitial water (connate and intrusional) and accumulated production inhibitors absorb the heat under "gas-wet" conditions the total purpose is accomplished; the viscosity of the oil is greatly reduced, cohesion between the hydrocarbon molecules themselves and the cohesion and capillarity between the hydrocarbon molecules and the solid formation particles of the matrix becomes greatly reduced, the interstitial water is converted to steam providing kinetic energy in the form of a pressure drive force acting on the oil and on the production inhibiting contaminants to effect efficient oil flow through the interstices of the matrix and thence into a drilled well to be pumped to the surface and captured (see straight shanked arrows).

Of utmost importance to the present invention, simultaneous with the passage of the mixture of gases down the tubing from the surface to the point or points of injection into the said reservoir, the mixture of gases is subjected in the transducer to ionizing excitation charges, preferably at a multiplicity of times and places as it travels through the transducer, to create radiation in the infrared (heat) sector of the electromagnetic spectrum. In this way the transducer means can be constructed to operate so as to control the interaction and to re-enforce the molecule-atom-electro-energy interaction by pre-selecting the placement of the electro-energy discharge elements 6 along transducer 5.

In the above mentioned example, knowing the ascertainable specifications and characteristics of the matrix and of the fluid content thereof, 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, mathematical computation can be made of the desired number of points to place the ionizing electro-energy discharge elements 6, and the nature and intensity of each electro-energy discharge. In this example one or a multiplicity of points may be utilized.

## DESCRIPTION OF PREFERRED APPARATUS EMBODIMENT

With continued reference to **FIGURE** 1, a combined electrical and gas generating plant, conveniently assembled almost entirely from a wide range of conventional apparatus components obtainable at reasonable cost to efficiently and effectively produce electrical current and exhaust gas at substantially elevated temperatures and relatively low pressure (as distinguished from high pressure "gas-drive"), is combined with a transducer 5 of unique construction to inject ionizing electro-energy discharges into the exhaust gases of the generating plant to interact with and excite the gas atoms and molecules within the transducer to infrared emissivity and introduce the heated emitting gases into the well-bore and the surrounding natural oil bearing reservoir through a supply conduit in carrying out the method of this invention. The introduced gases act on the hydrocarbon oil in a manner to greatly reduce the viscosity, cohesion, capillarity and surface-tension of the hydrocarbon oil, and/or convert the interstitial water to steam providing kinetic energy to impart flowability to the oil content of such reservoir, and/or cause removal of the materials or conditions that inhibit or reduce production.

In this adaptation of the invention, an internal combustion engine A of conventional construction, preferably of a type capable of burning a mixture of natural gas usually present in an oil field and ambient air, exhausts products of combustion (nitrogen and carbon dioxide and a small quantity of water) through exhaust manifold M, preferably to inlet pipe 12 of a desiccator D where the water is removed. The resulting nitrogen and carbon dioxide mixture under the influence of pressure, passes thereafter into and through pipe 16 to compressor C where it is compressed to a relatively low constant pressure (for example 15 to 150 psi) and then delivered through pipe 17 to main body conduit 18 of transducer 5,

hereinafter described in detail, fixed to well cap **10**, as by welding, of a conventionally completed production well to mount transducer **5** suspended in the upper end of solid casing **1**. The lower end of transducer conduit **18** is sealingly connected to gas conduit **3** hereinbefore described by butt engaging its convex faced terminal flange **5a** fitted with gasket G in the mating concave upwardly facing flange **3a** of conduit **3** as cap **10** is bolted to the coupling flange of upper casing section **1**.

The drive shaft **21** of engine A is shown connected to drive a suitable D.C. electrical generator B designed to generate electrical generator B designed to generate electrical current at conventional voltage (perhaps **300** volts). This output current is fed through cable **4** sequentially to a first radio frequency ignitor type electro-energy discharge element **6**, to be hereinafter described in detail, and then to one or more continuously operating electro-energy discharge elements **6** in the form of plasma tube type electrodes to be hereinafter described, all arranged to discharge into the gas mixture conveyed through transducer **5**.

Transducer conduit **18** of **FIGURE** 1 comprises a high temperature resistant material (for example high temperature metal or ceramic) while the conduits **17** and **3** may be made of any suitable inexpensive material for conveying the gas mixture to transducer **5** and from transducer **5** into the well-bore.

Each plasma tube type electrode **6** is designed to transform the conventional direct current energy input into spark (arc) discharges injected into the gases beyond ignitor discharge element **6** in a way to expose all parts and portions of the following gas, to the arcing discharge and maintain the excitation and ionization of the gas atoms and molecules. **FIGURE** 3 hereof shows schematically in partial cross-section the operational parts of such plasma tube type electrodes. As there shown, cable **4** is connected to an electrode assembly **24** mounted in a pipe coupler and made up of suitable opposing tungsten electrodes **25** mounted in electrode holders **26** made of suitable material such as copper and also mounting permanent magnets **27** arranged to create a static field (see arrows) to impart rotation to the arcs bridging electrodes **25** minimizing burning of the electrodes and imparting a swirling or rotational effect to the flow-through of gas assuring that all parts and portions of the gas come in contact with the ionizing sparks. The entire mechanism of electrode assembly **24** here delineated is insulated from undesirable contacts with the coupler by insulation rings **28** made of suitable material such as refractory material.

Radio frequency ignitor discharge element **6** comprises an assembly **29**, containing an R.F. converter, a step-up transformer and automatic switch gear, to change the generated D.C. electrical current to an electro-energy discharge of radio-frequency (in the range of **1** million cycles per second) high voltage (several hundred kilovolts) characteristics capable, upon starting operation of this embodiment of the invention, to shunt the generated D.C. current through assembly **29** to produce a momentary discharge (in the order of one second) of electro-energy of radio-frequency and optimum voltage into the flow of gas, breaking down the gas and initiating ionization thereof. Such ionization in turn reduces the resistance path between and causes the charged plasma tube type electrodes **6** to arc, and from that time on the low voltage direct current energy of cable **4** by-passes assembly **29** and flows directly to continuously operating plasma tube type electrodes **6** energizing them to arc continuously and sustain ionization excitation. The gas pressure is increased automatically through the switch gear of assembly **29** to the desired pressure (perhaps **50** to **150** psi) as the ignitor electrode **6** ceases operation and the operating voltage thereafter remains at its generated amplitude (perhaps **300** volts) of direct current.

The switch-gear to direct the flow of electrical current to ignitor discharge element **6** or to by-pass it is conventional and not part of this invention. Such equipment together with other conventional control equipment also not part of this invention will provide for automatic re-procedure as above in the event the arc of the electrodes should become extinguished.

**FIGURE** 2 illustrates more fully the manner in which electrical cable **4**, transducer **5** and its associated discharge elements **6** are made readily accessible for adjustment, repair or replacement without the necessity of pulling supply tubing **3** that serves as the conduit to convey the gas-flow. To adjust, repair, or replace all or any portion of cable **4**, discharge elements **6** or gasket G requires only removing cap bolts **31** and lifting cap **10** to which transducer **5** is secured to effect separation of the gas flow line at the junction of transducer **5** and supply conduit **3**. Conduit **3** between flange **3a** and packer **9** may or may not be insulated, and to whatever degree of efficiency, as desired.

The construction, installation, adjustment and application of the components and apparatus referred to above are within the knowledge and abilities of one skilled in such arts to put this invention to use.

The operation of the generating equipment and the results obtainable therefrom, are based upon proven scientifc theories, i.e.:

**1**. Internal combustion engines will produce approximately **9X** quantities of nitrogen and carbon dioxide as exhaust gas for each x quantity of natural gas burned as fuel, and will at the same time drive a suitable electrical generator to produce quantities of electro-energy, at almost no extra cost, to be converted to optimum conditions of usability as a feedback to cause excitation of the gas.

**2**. The nitrogen and carbon dioxide content of the exhaust of an internal combustion engine needs only as treatment for the purposes of this invention the drying provided by a conventional type desiccator; experience indicates that at the contemplated pressures exhaust gases cause little or no corrosion of materials used in a well. In this connection, this invention is set forth as one to "heat" (as distinguished from a high pressure "gas-drive" or forced displacement theory) operating at relatively low pressures, the radiated heat and hot gas moves slowly into the well-bore and reservoir so the element of time complements the coefficient of heat transfer.

In the application of the invention a unified fourfold advantage results, in that (**1**) the temperature of the hydrocarbon oil in a natural oil bearing reservoir is elevated to a sufficient degree to greatly reduce viscosity, cohesion and capillarity; (**2**) interstitial water heated sufficiently to create steam; (**3**) salt, paraffin, asphalt, sludge or emulsions, detrital material, products of metallic oxidation (such as rust), scale, etc., may be conditioned for easy removal from a well-bore and its attendant equipment by melting, spalling, erosional or mechanical action, and water-block adjacent to the well-bore vaporized and expelling kinetic energy developed; (**4**) heating is accomplished more efficiently and cheaply than in any heretofore practiced method because of the in situ generation of heat and simplification of equipment achieved in adapting the concept of gas excitation to the heating of a natural reservoir.

## DESCRIPTION OF ALTERNATE APPARATUS EMBODIMENT

The method of this invention can also be practiced utilizing the "huff-and-puff" system and a conventionally completed well equipped as will now be described with reference to **FIGURES** 4 through 6 . 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 **2**, made up of joints of tubing (each joint usually **20'** long) the several joints of which are connected by threaded couplings **32**, 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, 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 32 are electro-energy discharge elements 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 and conducted therefrom to discharge elements 6 by means of electrical cable 23.

As the gas mixture moves down through tubing 3 it is subjected to a series of repeated impacts at each pre-selected location of discharge elements 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 30 discharge elements 6 energized through electrical cable 23 may be employed if desired to successfully practice this invention. As the gas moves through tubing 3 each successive discharge element 6 re-enforces the impact effect thus intensifying the interaction of the electromagnetic waves and the atoms and molecules of the gas mixture resulting in tremendous emissions of radiation in the infrared sector of the electromagnetic spectrum (in the order of 10 trillion electrical impulses per second) the radiated heat being then introduced into the natural oil bearing reservoir as the super-heated gas is exuded thereinto.

Should the internal combustion engine generating plant of FIGURE 1 be used as the combined source of gas and electrical energy, conventional low voltage alternating current could be produced by a suitable generator B and converted in an R.F. converter and then transformed to high voltage (in the order of 1 kilovolt). Such electro-energy, when introduced into the gas by means of electro-energy discharge elements 6 (see FIGURE 5 and 6 ), creates an interaction with the gas resulting in emissions in the infrared sector of the electromagnetic spectrum. The heated gas flows thence into the oil bearing formation through the perforations of perforated casing 2.

Alternatively, electromagnetic wave energy utilizing the internal combustion engine gas and electrical current generating plant to create exhaust gas and electrical energy as in FIGURE 1 (in this case direct current) can be employed to energize semi-conductor crystals (in the nature of light-emitting injection diodes) as the electro-energy discharge elements 6 of a transducer variant as shown in FIGURES 8 and 9. Such discharge elements can also be employed in the transducers in either the well arrangement of FIGURE 1 or FIGURE 4 if desired thus impacting into the gas electromagnetic waves of the frequency of visual light.

## DESCRIPTION OF ALTERNATE METHOD AND REQUIRED APPARATUS

FIGURES 7 and 8 disclose an adaptation of this invention to a method of continuous injection and production involving in the arrangement of FIGURE 8 of the stimulation of 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 radiated heat and "gas-wet" condition of this invention materially reduces viscosity, cohesion and capillarity and imparts the necessary flowability to the oil content of the reservoir.

FIGURE 7 illustrates a method of continuous injection and production wherein wells 10 are conventionally completed wells having pumps 8 and production tubing 7 but contain no apparatus for the injection of gas or radiation. Well 11 (constructed as shown in FIGURE 9) contains the apparatus of this invention for the injection of gas and radiation but contains no production equipment. The injection of gas and radiation by the method of this invention is continuously maintained in well 11 to heat the surrounding reservoir area causing the contained oil to be freed to readily flow to wells 10 where the production of oil is continuously maintained from wells 10.

FIGURE 8 illustrates this invention applied through a method of continuous injection and production wherein a conventional slant drilled production well 10 has a plurality of gas injection and radiation wells 11 spaced along and at opposite sides of its relatively horizontal perforated section 2 for the purpose of heating the reservoir area above casing section 2 and exploiting gravity flow of reservoir fluids into casing section 2. In this apparatus embodiment, directionally drilled well 10 includes solid pipe 1 extending 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.

In the embodiment of FIGURE 8 three or more vertically drilled cased holes, further illustrated in detail in FIGURE 9 , are disposed along the sides of and above the horizontal run of perforated casing 2 to form wells 11 while in FIGURE 7 a single well 11 is centered with respect to wells 10. Each well 11 consists of solid casing 35 extending from the surface to the top of the oil bearing reservoir, and a perforated casing 36 within the oil bearing reservoir. Electrical cable 4 depends vertically within solid casing 35 and perforated casing 36 and is fitted with electro-energy discharge elements 6 of any of the previously described embodiments (semi-conductor crystal injection diodes where a D.C. source is provided may be used) at preselected locations along electrical cable 23, preferably within perforated casing 36. Gas input pipe 3 extends through casing cap 37 into the upper end of the cavity of solid casing 35. These wells are not utilized to accumulate oil or to pump it to the surface, these only function as is hereinafter set forth.

The diameter of solid casing 35 and perforated casing 36 is relatively small, probably no more than joints of 2-1/2" tubing with regular tubing couplings. The mixture of gases as selected and used in this invention is introduced into the top of solid casing 35 through gas input pipe 3, and thus solid casing 35 and perforated casing 36 function not only as the casing of the bore-hole but also as a transducer conduit as in FIGURE 1 . The alternate transducers can be interchanged in practicing the several methods of the invention if desired.

While FIGURE 8 illustrates only three wells 11, any suitable number may be utilized in conjunction with this method application. Assuming that the horizontal perforated casing 36 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 or more 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 the various ways heretofore pointed out.

In these vertically drilled wells 11 the mixture of gases moves down through solid casing 35 and perforated casing 36 and the mixture passing therethrough is subjected to ionizing electro-energy discharges from discharge elements 6 and then passes outwardly into the natural reservoir. The effect thereafter is precisely identical as is described in connection with FIGURE 2 hereof. It follows, therefore, that the overall concept of heating of the natural reservoir is the same irrespective of whether the "huff-puff" or continuous application equipment is used.

As the oil in the reservoir is acted upon as heretofore described it flows by gravity, assisted by any steam generated, into the perforated casing of the vertically or directionally drilled wells 10 and is accumulated and pumped to the surface oil storage tank by pump 8 through production tubing 7.

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

cope 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. A method of recovering hydrocarbons from a natural subsurface reservoir through a completed cased production well comprising: supplying gas that is chemically inactive as to the hydrocarbon constituents of the reservoir and capable of emitting infrared into a well-bore in fluid communication with said reservoir; simultaneously applying ionizing electro-energy impacts to the supplied gas to effect an interaction between the electro-energy discharges and the gas atoms and molecules causing a resultant emission of infrared radiation to heat the gas, the well-bore and the reservoir area selectively to a temperature sufficiently high to accomplish at least one of the following: (a) conversion of the interstitial water in the reservoir to steam thereby imposing the resulting pressure on the contained hydrocarbon constituents forcing them to flow to a subsurface collection point, (b) a melting or spalling of hardened inhibitors, vaporization of the connage and intrusional water, and mechanical disintegration and dissolution of the frangible metallic oxides and scale, and (c) reduction of the viscosity of the contained petroleum hydrocarbons freeing them to flow to a subsurface collection point; and conveying the collected hydrocarbons and fluids and removing the freed inhibitors through the completed cased production well.

2. The method as defined in Claim 1 wherein the gas is selected from the noble gases, (i.e. helium, neon, argon, krypton, xenon, radon) and also nitrogen and carbon dioxide, and mixtures thereof.

3. The method as defined in Claim 1 wherein the ionizing electro-energy impacts comprise a first high (radio) frequency high voltage discharge of short duration followed by a series of sustaining low voltage, direct current, electron discharges.

4. The method as defined in Claim 1 wherein the ionizing electro-energy impacts comprise a series of high (radio) frequency high voltage discharges.

5. The method of Claim 1 wherein the ionizing electro-energy impacts comprise a series of photon discharges.

6. The method as defined in Claim 1 wherein the gas is supplied from the surface through tubing passing downwardly through the conventionally completed well provided to convey the collected oil to a surface storage area and the ionizing electro-energy impacts comprise the output of a plurality of electrodes spaced along said tubing and energized from common source of high (radio) frequency, high voltage electrical energy.

7. The method as defined in Claim 1 wherein the gas is supplied from the surface through tubing passing downwardly through the conventionally completed well provided to convey the collected oil to a surface storage area and the ionizing electro-energy impacts comprise the photon output of a plurality of suitable injection diodes spaced along said tubing and energized from a common source of conventional low voltage D.C. electrical current.

8. The method as defined in Claim 1 wherein the gas is supplied from the surface through tubing passing downwardly through the conventionally completed well provided to convey the collected oil to a surface storage area and the ionizing electro-energy impacts comprise a first high (radio) frequency high voltage discharge of short duration of an electrode assembly including a converter, a transformer and suitable switch gear followed by a series of sustaining low voltage, direct current electron discharges from plasma tube type electrodes spaced along said tubing, said plasma tube electrodes being energized from a common source of conventional D.C. electrical current.

9. The method as defined in Claim 1 wherein the gas is supplied from the surface through one or more cased bore holes adjacently related in said reservoir to at least one conventionally completed well provided to convey the collected oil to a surface storage area and the ionizing electro-energy impacts comprise the output of a first high (radio) frequency high voltage discharge of short duration followed by a series of sustaining low voltage, direct current electron discharges applied at spaced intervals along said cased bore holes and energized by a common source of conventional D.C. electrical current.

10. The method as defined in Claim 9 wherein the completed well is a directionally drilled well having a casing section with a perforated wall portion extending substantially horizontally along the lower portion of the oil reservoir and forming a collection conduit and the gas is supplied from the surface through a plurality of cased bore-holes adjacently related and spaced axially along said perforated casing section.

11. The method as defined in Claim 9 wherein the completed well is a vertically drilled well having a casing section with a perforated wall portion extending substantially vertically through the oil reservoir and forming a collection conduit and the gas is supplied from the surface through a plurality of cased bore-holes adjacently related and spaced along a circle having the completed well as its center.

12. The method as defined in Claim 1 wherein the ionizing electro-energy impacts are applied to the stream of supplied gas at pre-selected intervals along its path of travel so each successive application will have an excitation re-enforcing effect upon the gases to create, maintain and intensify a resultant infrared radiation heating effect in the gas as it passes well out into the reservoir area.

13. The method as defined in Claim 1 wherein the infrared emissions are maintained for a period sufficient to heat the gas sufficiently to convert the interstitial water to steam.

14. The method as defined in Claim 1 wherein the infrared emissions are maintained for a period of time sufficient to heat the gas sufficiently to effect a melting or spalling of hardened inhibitors, vaporization of the connate and intrusional water, and mechanical disintegration and dissolution of frangible metallic oxides and scale.

15. The method as defined in Claim 1 wherein the infrared emissions are maintained for a period of time sufficient to heat the gas sufficiently to reduce the viscosity of the contained oil and free it to flow.

16. The method of Claim 1 wherein the gas is supplied from the surface through tubing passing downwardly through said conventionally completed well provided to convey the collected hydrocarbons to a surface storage area and the ionizing electro-energy impacts comprise the output of a series of high (radio) frequency discharges of a plurality of electrodes spaced along said tubing and powered by a common source of conventional A.C. electrical current.

17. The method of Claim 1 wherein the gas is supplied from the surface through one or more cased bore holes adjacently related to said conventionally completed well provided to convey the collected hydrocarbon to a surface storage area and the ionizing electro-energy impacts comprise the output of a series of high (radio) frequency discharges of a plurality of electrodes spaced along said cased bore holes and powered by a common source of conventional A.C. electrical current.

18. The method of Claim 17 wherein the conventionally completed well is a directionally drilled well having a casing section extending substantially horizontally along the lower portion of the reservoir and having a perforated wall portion forming a collection conduit and the gas is supplied through bore-holes adjacently related and spaced along said perforated casing section.

19. Apparatus for recovering hydrocarbons from a natural subsurface reservoir comprising: conduit means for conveying a gas that is chemically inactive as to the hydrocarbon constituents of the reservoir and capable of emitting infrared into a well bore in fluid communication with said reservoir, said conduit means within the reservoir having passage means providing ready egress of the conveyed gas into the reservoir; transducer means for applying ionizing electro-energy discharges to the conveyed gas to effect an interaction between the electro-energy discharges and the gas atoms and molecules causing a resultant emission of infrared radiation

effectively to heat the gas, the well-bore and the reservoir area selectively to a temperature sufficiently high to accomplish at least one of the following: (a) conversion of the interstitial water in the reservoir to steam thereby imposing the resulting pressure on the contained hydrocarbon constituents forcing them to flow to a subsurface collection point, (b) a melting or spalling of hardened inhibitors, vaporization of the connate and intrusional water, and mechanical disintegration and dissolution of the frangible metallic oxides and scale, and (c) reduction of the viscosity of the contained petroleum hydrocarbons freeing them to flow to a subsurface collection point; and at least one conventionally completed well having its lower cased end perforated and disposed in said reservoir at said sub-surface collection point to receive and convey the collected hydrocarbons and fluids and removing the freed inhibitors to a surface storage area.

**20**. The apparatus of Claim **19** wherein the conduit means comprises lengths of small diameter pipe coupled together in end-to-end relation by pipe couplings and the transducer means comprises a terminal length of said pipe fitted with at least one high (radio) frequency high voltage discharge element connected by a supply cable extending from a suitable source of electrical energy to selectively maintain said discharge element energized to discharge into the supplied gas for a predetermined time interval to assure optimum heating of the reservoir area.

**21**. The apparatus of Claim **19** wherein said conduit means extends axially within said conventionally completed well and said transducer means includes a section of said conduit means disposed immediately adjacent the surface of the ground and provided at its lower end with an abutment flange, the adjacent section of said conduit means is provided at its upper end with a mating abutment flange, a sealing gasket is disposed between said abutment flanges in position to sealingly cooperate with and be clamped between said abutment flanges when said transducer means is lowered upon said sealing gasket and said adjacent section of said conduit means, said connection between said transducer means and said adjacent conduit section assuring a leak proof connection and adapting said transducer means for ready removal for servicing without the need of pulling the entire conduit means.

**22**. The apparatus of Claim **21** wherein said conduit means and said transducer means are disposed within the casing of the conventionally completed well, said conventionally completed well is provided conventionally with a bolt on closure cap and said section of said conduit means included as part of said transducer means is fixed to said closure cap for unitary removal and replacement with said closure cap whereby tightening of said closure cap bolts imparts a clamping force through said transducer means to sealingly clamp said gasket between said abutment flanges.

**23**. The apparatus of Claim **21** wherein said transducer means includes an input electrical cable encircling associated with said section of said conduit means and respective electro-energy discharge elements electrically connected at predetermined spaced intervals to said input electrical cable and fitted to said section of said conduit means to discharge into the gas flow through said section of said conduit means.

**24**. The apparatus of Claim **21** wherein said electro-energy discharge elements comprise a first high (radio) frequency high voltage discharge element energized for a short duration to initiate excitation and ionization of the through flow of gas entering said section of said conduit means and at least one plasma tube type electrode spaced downstream of said section of said conduit means continuously energized to sustain excitation and ionization of the through flow gas after its initial excitation and ionization.

**25**. The apparatus of Claim **19** wherein said conduit means comprises the well casing of a small diameter drill bore adjacently related to said conventionally completed well, said well casing includes a perforated casing section lying within the oil bearing zone of said natural reservoir, and said transducer means comprises a portion of said conduit means and an input electrical cable suspended in axial relation within said conduit means with the portion thereof within said portion of said conduit means fitted with at least one electro-energy discharge element.

**26**. The apparatus of Claim **19** wherein said transducer means comprises a section of said conduit means, a series of electrodes spaced along said section of said conduit means, and cable means interconnecting said series of electrodes and connected to a common source of high (radio) frequency, high voltage electrical energy.

**27**. The apparatus of Claim **19** wherein said transducer means comprises a section of said conduit means, a series of injection diodes spaced along said section of said conduit means, and cable means interconnecting said series of injection diodes and connected to a common source of conventional low voltage D.C. electrical current.

**28**. A generating plant and transducer means for producing a flow of gas that is chemically inactive to petroleum hydrocarbons and electrical energy to be impacted into the flowing gas as electro-energy discharges to excite and ionize the flowing gas to infrared (heat) emissivity and apply the heat output to a source of hydrocarbon oil comprising an internal combustion engine including an output shaft and an exhaust manifold; an electrical current generator drivingly connected to said output shaft; conduit means connected to said exhaust manifold and including a desiccator and a compressor for delivering said exhaust gas to said source of hydrocarbon oil; electro-energy discharge means fixed to a portion of said conduit means downstream from said compressor and arranged to discharge into the through flow of gas in said portion of said conduit means; and cable means connected to the electrical output of said generator and to said electro-energy discharge means to energize said electro-energy discharge means and effect excitation and ionizing discharges into the flow through gases.

# UNITED STATES PATENT OFFICE

# CERTIFICATE OF CORRECTION

Patent No. 3522846 Dated August 4, 1970

Inventor(s) ROBERT V. NEW

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

Column 7, line 12, after "trical" delete --generator B designed to generate electrical--.

Column 7, lines 30 and 31, change "following" to --flowing--.

Column 8, line 67, change "2" to --3--.

Claim 1, Column 11, line 22, change "connage" to --connate--.

Claim 6, Column 11, line 47, after "from" insert --a--.

SIGNED AND SEALED DEC 1 - 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents



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