(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 307 003 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: 88115385.2

(51) Int. Cl.4: C10G 1/00

(22) Date of filing: 19.04.85

(30) Priority: 20.04.84 US 602399

(43) Date of publication of application: 15.03.89 Bulletin 89/11

(60) Publication number of the earlier application in accordance with Art.76 EPC: 0 180 619

(84) Designated Contracting States: AT BE CH DE FR GB IT LI LU NL SE

(71) Applicant: ELECTROMAGNETIC ENERGY CORPORATION
208A Long Plantation Road
Lafayette, LA 70508(US)

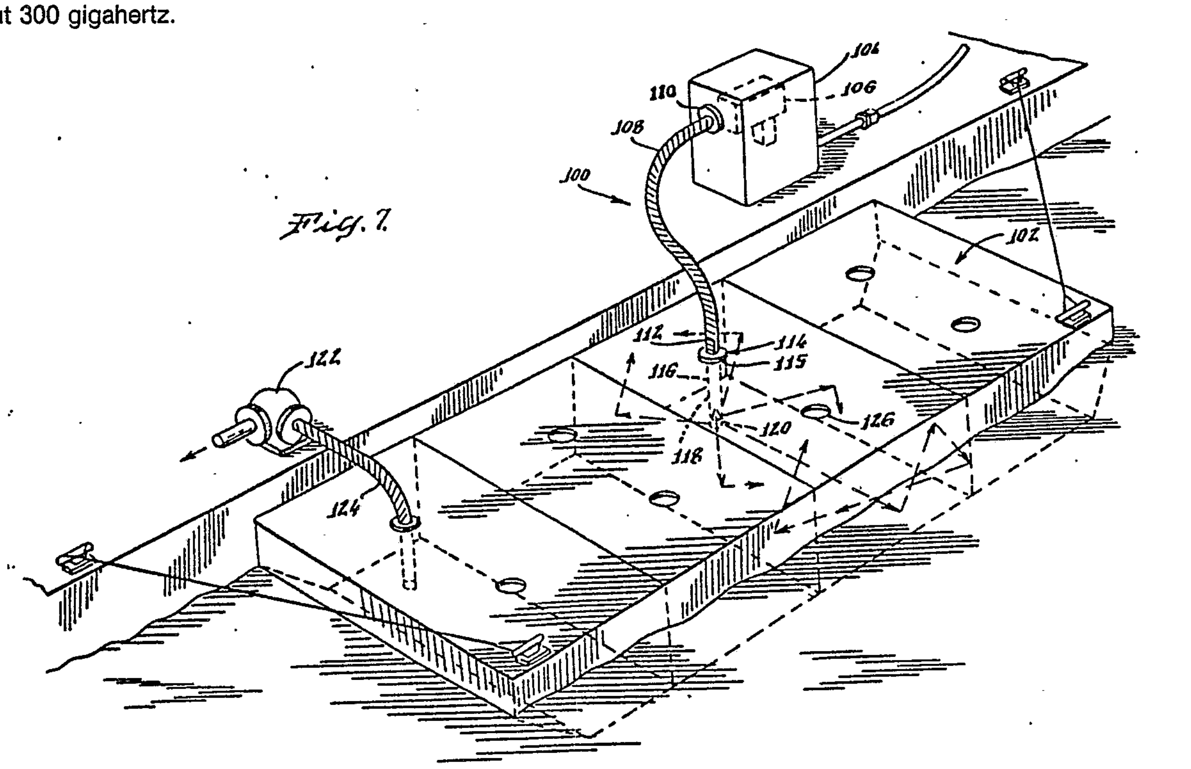
(72) Inventor: Klaila, William J.
208 A Long Plantation Road
Lafayette LA 70508(US)

(74) Representative: Muir, Ian R. et al
HASELTINE LAKE & CO. Hazlitt House 28
Southampton Buildings Chancery Lane
London WC2A 1AT(GB)

(54) Electromagnetic energy heating.

(57) There are disclosed methods and apparatus for increasing the fluidity of hydrocarbon fluids, by applying to those fluids electromagentic energy in the frequency range of from about 300 megahertz to about 300 gigahertz.

Fig. 7



EP 0 307 003 A2

METHOD AND APPARATUS INVOLVING ELECTROMAGNETIC ENERGY HEATING

The present invention relates to the treatment of hydrocarbon material with electromagnetic energy, and more particularly to a method and apparatus for recovering fractions from hydrocarbon material, facilitating the removal and cleansing of hydrocarbon fluids, insulating storage vessels, and cleaning storage vessels and pipelines.

United States Patent Re. 31,241, reissued on May 17, 1983, discloses a method and apparatus for controlling the fluency of hydrocarbon fluids by using electromagnetic energy.

The present invention represents an improvement over the method and apparatus disclosed in the aforementioned reissue patent for facilitating the removal of hydrocarbon fluids as well as providing a novel method and apparatus for recovering fractions from hydrocarbon fluids, insulating storage vessels, and cleaning storage vessels and pipelines.

It is an object of the present invention to provide an improved method and apparatus for heating hydrocarbon material with electromagnetic energy.

A method and associated apparatus is provided for recovering fractions from hydrocarbon material, including the steps of generating electromagnetic energy generally in the frequency range of 300 megahertz to about 300 gigahertz, in accordance with the lossiness of the material, transmitting the generated electromagnetic energy to the hydrocarbon material, directing the transmitted electromagnetic energy to a plurality of hydrocarbon material locations and exposing the hydrocarbon material at the locations to the electromagnetic energy for a sufficient period of time to sequentially separate the hydrocarbon material into fractions, and removing the resulting fractions. A plurality of frequencies within the aforementioned frequency range or in combination with frequencies outside this range may be utilized in accordance with the lossiness of the fractions to be removed. The temperature of the high viscosity hydrocarbon fluid is precisely controlled by changing the broadcast location for the electromagnetic energy to effectively sweep the hydrocarbon fluid to optimize oil production while decreasing its viscosity to facilitate its separation and removal from a vessel. Further, the electromagnetic energy may be used to clean storage vessels of scale and rust and a metal shield can be placed in the storage vessel to effectively create an insulating layer for the storage vessel from a portion of the hydrocarbon fluid present in the vessel. A plurality of RF frequencies spaced far enough apart to preclude wave cancellation and having varying field strengths may be used simultaneously in accordance with their absorptivity by the various fractions to be recovered so as to achieve maximum efficiencies in recovering the fractions.

Other objects, aspects and advantages of the present invention will be apparent from the detailed description considered in conjunction with the drawings, as follows:

Fig. 1 is a side elevational view, with parts broken away, of an apparatus for providing clean, separated oil from hydrocarbon fluids stored in vessels;

Fig. 2 is an enlarged side elevational view of the energy deflector of Fig. 1;

Fig. 3 is an enlarged side elevational view of another embodiment of the energy deflector;

Fig. 4 is an enlarged side elevational view of another embodiment of the energy deflector;

Fig. 5 is an enlarged side elevational view of another embodiment of the energy deflector;

Fig. 6 is an enlarged side elevational view of another embodiment of the energy delfector;

Fig. 7 is a perspective view of an apparatus for increasing the fluency of high viscosity oil and sludge found in the hold of a vessel;

Fig. 8 is a side elevational view of an apparatus for increasing the fluency of oil in a pipeline;

Fig. 9 is a side elevational view, with parts broken away, of an apparatus for in situ recovery of hydrocarbons from hydrocarbon material;

Fig. 10 is a schematic and side elevational view, with parts boken away, for in situ recovery of fractions from oil shale, coal, peat, lignite and tar sands, showing the separation and scrubbing of the fractions;

Fig. 11 is an enlarged view of an applicator and deflector for in situ recovery of fractions from hydrocarbon material;

Fig. 12 is an enlarged view of a coaxial waveguide applicator, deflector and pump for in situ recovery of fractions from hydrocarbon material; and

Fig. 13 is a side elevational view, with parts broken away, of a storage vessel including metal shields for providing an insulating layer of hydrocarbon fluid.

Referring to Fig. 1, an apparatus in accordance with the present invention is illustrated at 14 for use with a vessel or open or closed top oil storage tank 15 or mud pit. The hydrocarbon fluid, such as oil, stored in the tank 15 often contains water, sulfur, solids and other undesired constitutents or contaminates, including bacterial and algae, as well as scale and rust, all of which may be considered as basic sediment. Moreover, during storage, the contamination and viscosity of the oil will often increase to the point where the LACT (Lease Acquisition Custody Transfer) measurement is often too great for pipeline acceptance. Advantageously, the apparatus 14 not only heats the oil to decrease its viscosity and increase its fluency, but also separates water, sulfur and basic sediment from the oil in the tank 15, resulting in clean oil. The exiting gases, including sulfur, may be collected via a collection line and holding tank (not shown) which are in communication with the top of the tank 15.

The apparatus 14 includes a radio frequency (RF) generator 16 which includes a magnetron 17 or klystron, or other similar device, such as a solid state oscillator as disclosed in the aforementioned reissue patent, which is capable of generating radio waves in the frequency range of 300 megahertz to about 300 gigahertz and generally utilizing from 1KW to 1MW or more of continuous wave power. It should be understood that a plurality of magnetrons 17 or oscillators, or a klystron may be used to generate a plurality of heating frequencies which are far enough apart to prevent interference and which may have greater absorptivity to certain fractions which it is desired to remove. The oscillator may be modified or another oscillator may be provided to generate a frequency outside of this range for use with the aforementioned frequencies in accordance with the lossiness of the fractions to be removed. The magnetron 17 is mechanically coupled to an applicator 18 which is transparent to radio waves in the aforementioned frequency range. The applicator 18 is in the shape of an elongated tube with an open upper end 19 and a closed bottom end 20. The applicator is preferably constructed from radiotransparent materials so that it is permeable to RF waves in the desired frequency range but impermeable to liquids and gases. The applicator is attached to a tubular waveguide 21 which passes through metal tank cover 22 that is bolted and grounded to the tank 15 by a plurality of nuts and bolts 24.

A metal transition member 26, which includes a flanged end 28, is bolted to one end of 90° metal elbow 30 by bolts and nuts 32. The tubular end 33 of the transition member 26 is attached to the tubular waveguide 21. The other end 34 of the 90° elbow 30 is bolted to one end of rectangular metal waveguide portion 36 by nuts and bolts 38.

The other end of the rectangular waveguide 36 is coupled to WR x coaxial transition member 40 with nuts and bolts 42. Flexible coaxial member 44 is fitted with flanged ends 46 and 48 which have internal gas barriers to allow the flexible coaxial member 44 to be charged with an inert gas refrigerant, such as Freon, to increase its power carrying capacity while preventing the flow of gases emanating from the hydrocarbon fluid back into the RF generator 16, which may result from a rupture or leakage in the applicator 18. Flanged end 46 is coupled to the WR x coaxial transition member 52 with bolts and nuts 54. The flanged end of the coaxial x WR transition member 52 is coupled to the RF generator 16 through an extension 56.

A controller 58 controls the energization of the RF generator 16 and receives signals from a plurality of temperature sensors 60 A-E arranged within the tank 15. The controller 58 is coupled to the sensors 60 A-E by wires or by fiberoptic transmission lines 62. The sensors 60 A-E are vertically spaced at predetermined locations within the tank 15.

A generally conically shaped energy deflector 64 is arranged within the applicator 18 for upward and downward movement to control the broadcast locations for the electromagnetic energy propagated through the applicator 18. This upward and downward movement is provided by a motor 66 which drives a pulley 68 causing it to wind or unwind cable 70 attached to the energy deflector 64, thereby controlling the vertical broadcast location of the deflector 64 within the tank 15. A separate frequency may be transmitted through the waveguide 36 to activate the motor 66. Preferably, the energy deflector 64 is initially located near the bottom of the applicator 14 and moved gradually upward.

By broadcasting the energy in this manner, the magnetron 17 may run continuously at full power to operate at the greatest efficiency, the temperature at various layers within the hydrocarbon fluid are effectively controlled, so that the production of oil is maximized, and the life of the magnetron 17 is prolonged.

The motor 66 is connected to a power source (not shown) through controller 58 by line 72. The controller 58 activates the motor 66 to move the deflector 64 thereby changing the broadcast location for the electromagnetic energy in response to the temperatures sensed by sensors 60 A-E. The frequency and period of application of the electromagnetic energy is controlled by the controller 58 which may be preset or programmed for continuous or intermittent upward and downward cycling to achieve homogeneous heating of the hydrocarbon fluid or localized heating to achieve the highest yield or best production of oil at minimum energy cost. The broadcast location of the energy deflector 64 may be preset to provide predetermined controlled continuous or intermittent sweeping of the electromagnetic energy through the hydrocarbon fluid by employing a conventional timer and limit stops for the motor 66.

Valves 74 A-D may be located in the vertical wall of the tank 15 to draw off the oil after treatment with electromagnetic energy. After heating with electromagnetic energy, as shown in Fig. 1, there is a bottom layer 76 which is essentially basic sediment and water. Above the bottom layer 76 is an intermediate layer 78 which is a mixture of mostly oil with some basic sediment and water. Finally, above the layer 78 is a top layer 80 which represents the resulting oil which has been cleansed and is free of basic sediment and water. An access hatch 73 is provided for removing the resulting basic sediment, which may include "drilling mud" solids. Any bacteria and algae present in the hydrocarbon fluid are disintegrated by the RF waves, with their remains forming part of the basic sediment.

To further aid circulation and cleansing of the layer of oil 80, a conventional conduction heater 75, such as a gun barrel heater, may extend into the tank 15. Heater 75 circulates hot gases through piping 77 to provide a low cost source of BTUs to further heat the oil once the water and basic sediment has been separated from the oil and the oil is sufficiently liquified or fluid for convection currents to flow. These convection currents further aid in reducing the viscosity of the oil and removing fine sediment. A spark arrester 79 is provided in the piping 77 to eliminate any sparks in the exiting gases. The cleansed oil may be passed through a filter to remove any remaining fine sediment.

By utilizing the method and apparatus of the present invention, clean oil is readily and easily separated from basic sediment and water. This is accomplished by heating the hydrocarbon fluid in the tank 15 with electromagnetic energy which causes the water molecules which are normally encapsulated within the oil to expand rupturing the encapsulated oil film. Heating can be accomplished with radio frequency waves because water has a greater dielectric constant and greater loss tangent than oil, which results in a high lossiness, thereby allowing it to absorb significantly more energy than the oil in less time resulting in rapid expansion of the volume of the water molecules within the oil film, causing the oil film to rupture. The water molecules then combine into a heavier than oil mass which sinks to the bottom of the tank, carrying most of the sediment present in the oil with it. However, to further facilitate removal of the basic sediment, particularly fines, brine or salt water may be spread across the surface of the top layer of oil 80 after the viscosity of the oil 80 has been lowered, through heating with electromagnetic energy in accordance with the present invention. The heavier salt water will rapidly gravitate through the layer 80 of oil toward the bottom of the tank 15, carrying the fine sediment with it.

Layers 76, 78 and 80 have resulted from treating hydrocarbon fluid containing oil, basic sediment and water stored in tank 15, by sweeping the fluid with electromagnetic energy in accordance with the apparatus in Fig. 1 having a power output of 50 KW for approximately 4 hours. However, it should be understood that the power output and time of exposure will vary with the volume of the tank 15, the constituents or contaminates present in the hydrocarbon fluid, and the length of time during which the hydrocarbon fluid has been stored in the tank 15.

Since hydrocarbons, sulfurs, chlorides, water (fresh or saline), and sediment and metals remain passive, reflect or absorb electromagnetic energy at different rates, exposure of the hydrocarbon fluid to electromagnetic energy in accordance with the present invention will separate the aforementioned constituents from the original fluid in generally the reverse order of the constituents listed above. Further, acids and condensible and non-condensible gases are also separated at various stages during the electromagnetic energy heating process. The optimum frequencies, loss tangents and boiling points for the various fractions present in the hydrocarbon material which it is desired to recover can be obtained from Von Hippel, TABLES OF DIELECTRIC MATERIALS, (1954), published by John Wiley & sons, Inc., and ASHRAE HANDBOOK OF FUNDAMENTALS, (1981), published by The American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.

Referring to Fig. 2, the applicator 18 and energy deflector 64 are shown enlarged relative to that illustrated in Fig. 1. The deflector 64 is suspended within the applicator by the dielectric cable 70 which is constructed of radiotransparent materials which are strong, heat resistant and have a very low dielectric constant and loss tangent. The height of the energy deflector 64 will determine the angle of deflection of the electromagnetic energy.

Referring to Fig. 3, an alternative embodiment for the deflector 64 shown in Fig. 1 is illustrated as 82. The deflector shown in Fig. 1 is illustrated as 82. The deflector 82 has a greater angle of deflection (lesser included angle) than the deflector 64 to cause the deflected waves to propagate from the applicator 18 in a slightly downward direction below a horizontal plane through the deflector 82. This embodiment enables the radio frequency to penetrate into payzones which may be positioned below the end of a well bore, when the method and apparatus is utilized for in situ heating in a geological substrate.

The energy deflector 82 is suspended by a fiberoptic cable 84 which provides temperature readings. In this respect, the individual fiberoptic strands 83 of the cable 84 are oriented to detect conditions at various locations in a vessel or borehole. The information transmitted to the remote ends of the fiberoptic strands 83 can be converted into digital signals converter for recording and/or controlling power output levels and positioning of the deflector 82. For example, it may be desired to provide a vertical sweep pattern of the RF energy in response to the temperature gradients sensed by the fiberoptic strands 83. The frequency for use with the fiberoptic strands 83 is selected to be sufficiently different from the frequency of the RF generator 16 to prevent interference or cancellation.

Referring to Fig. 4, the radiotransparent applicator 18 is is brazed to waveguide 21 at 88 for downhole applications where the high temperatures encountered would be detrimental to a fiberglass applicator.

Arranged within the applicator 18 is another embodiment of an energy deflector designated 88 which is constructed of pyroceram or other dielectric material with a helical wound band of reflective material 90, such as stainless steel. Instead of providing the aforementioned band of metal 90, a spiral portion of the alumina or silicon nitride energy reflector 88 may be sintered and metallized to provide the desired reflective band.

Other means may be employed to raise and lower the deflector to accomplish the sweeping function, including hydraulic, vacuum, air pressure and refrigerant expansion lifting systems. Further, the waveguide coupling from the RF generator 16 may also be utilized to send control signals from the controller to the motor or other mechanism for raising and lowering the RF deflector. The frequency for such control signals must be selected to be sufficiently different from the frequency or frequencies selected for the electromagnetic energy which heats the hydrocarbon fluid to prevent interference or cancellation.

Referring to Fig. 5, another form of energy deflector shown at 91 is essentially a right triangle in cross section with a concave surface 93 for focusing all of the deflected electromagnetic energy in a particular direction to heat a predetermined volume in a vessel or a particular payzone or coal seam in subsurface applications.

Referring to Fig. 6, another form of energy deflector shown at 94 includes interconnected segments 95A-95D which provide one angle for deflection of the electromagnetic energy when the deflector is abutting the applicator 18 and another angle of deflection for the electromagnetic energy when the cable 70 is pulled upwardly causing the segments 95A-95D to retract. Other means may be employed to change the angle of deflection of the deflector 94, such as a remote controlled motor.

The disposal of drilling fluids known as "drilling mud" has become a severe problem for the oil industry. The apparatus shown in Fig. 1, modified to incorporate any of the energy deflectors illustrated in Figs 2-6, may be utilized to reconstitute drilling mud for reuse by application of radio frequency waves to remove the excess liquids and leave a slurry of bentonite, barite salts, etc.

Referring to Fig. 7, apparatus 100 is employed to remove high viscosity hydrocarbon fluid or sludge from vessels, enclosures, and ships such as oil tankers or barges 102. A mobile RF generator 104, which includes an oscillator, klystron or magnetron 106, has attached at its output 110 a flexible coaxial waveguide 108. The other end 112 of the waveguide 108 extends through a manhole 115 in the barge 102. A sealing connection 114 is fluid tight and radio frequency tight. The waveguide 108 is affixed at its other end to a tubular waveguide 116 which is attached to a radiotransparent applicator 118. Positioned within the applicator 118 is an energy deflector 120 which is capable of upward and downward broadcast movement and may be of any one of the types disclosed in Figs. 2-6. A suitable mechanism for moving the energy deflector 120 upwardly and downwardly, such as disclosed in Fig. 1, is employed.

The oil heated by RF waves may be removed from the respective compartment of the barge 102 by a suction pump 122. The pump 122 has a flexible hose 124 which is positioned within a manhole 126 in the same compartment for extraction of the heated oil.

The arrows emanating outwardly from the deflector 120 and the applicator 118 indicate a typical pattern for the radio frequency waves. As the waves leave the radiotransparent applicator 118, they are absorbed by the oil/water mixture or penetrate slightly into the inner tank skin of the sidewalls heating the oil trapped in the pores where they are absorbed or reflected by the mental walls of the compartment until all of the RF energy is eventually converted into heat in the hydrocarbon fluid.

It has also been discovered that the rust and scale buildup on metal surfaces such as the walls of oil tanker or barge compartments can be removed, leaving bare metal walls, by employing the method and apparatus of the present invention. By directing RF energy to the walls, a film of water is trapped under the layer of rust. This is heated and expands, forming steam which causes the rust layer to flake off in large sheets.

Referring to Fig. 8, the present invention is shown for use with an oil pipeline, specifically with a T connection indicated at 130; the oil flow being shown by the solid arrows. A waveguide 132 having a flanged end 134 is coupled to a mating flange 136 of the T connection 130. a radiotransparent sealing disc 138, is sandwiched between the flanges 134 and 136 by bolts and nuts 140. A metal RF shield ring 142 is arranged circumjacent the disc 138 and sandwiched between the flanges 134 and 136. The RF waves propagate through the oil in the T connection 130 and through the oil in the pipeline 144. This arrangement heats the oil to decrease its viscosity, thereby requiring less pumping energy to drive the oil through the pipeline 144, and further cleans the walls of the T connection 130 and pipeline 144 of paraffin causing the same to homogenize and remain in solution.

Referring to Fig. 9, an apparatus 150 is shown positioned in an injection well 152 located adjacent at least one producing well 154. The apparatus 150 includes an RF generator 158 which is electrically coupled to a power source (not shown). A magnetron 160 positioned within the RF generator 158 radiates microwave energy from an antenna or probe 162 into waveguide section 164 for propagation. A waveguide extension 166 has one end coupled to the waveguide section 164 with bolts and nuts 168 and its other end coupled to a waveguide to coaxial adapter 170 with bolts and nuts 172. A flexible coaxial waveguide 174 is coupled at one end to the adapter 170 through a gas barrier fitting 176. The other end of waveguide 174 is coupled to a coaxial to waveguide adapter 178 through a gas barrier member 180. A transformation member 182 is coupled at one end to the adapter 178 with bolts and nuts 184. The other end of the transformation member 182 is coupled to a tubular waveguide 186. A radiotransparent applicator 188 is attached to the tubular waveguide 186 at 187. The applicator 188 and energy deflector (not shown) may include any of the types illustrated in Figs. 2-6 for broadcasting RF waves. Further, the energy deflector will be coupled to a raising and lowering means, e.g., of the type illustrated in Fig. 1.

The waveguide 186 is positioned within a casing 190 formed in the well 152. The well head 191 is capped by a sealing gland 192 which effectively seals the waveguide 186 therein. A plurality of thermocouples 194 are positined in the well 152 between the casing 190 and the waveguide 186 and extend to a location adjacent the bottom of the well 152. Leads 196, which connect the thermocouples 194 to a controller (not shown) extend through a packer seal 198. The packer seal 198 would not be used if it is desired to produce the resulting oil, water and gases through the annular space 199 between the casing 190 and waveguide 186. In the absence of the packer seal 198, the expansion of the oil, water and gases will drive the same up through the annulus 199 until the constituents in the immediate vicinity of the applicator 188 are removed. Subsequently, the annulus 199 can be packed off with the packer seal 198 and the hydrocarbons further heated to drive the resulting oil, water and gas to the producing well 154. For example, if the temperature of the oil is increased to 400°F, there is approximately a 40% increase in the volume of the oil.

The RF energy emanating from the applicator 188, as represented by the arrows, heats the hydrocarbon material in the geological substrate causing the release of water, gases, and oil, with the hot oil, water and gas flowing into the bottom of the producing well 154 after the deflected RF energy melts sufficiently through the solidified oil to establish a flow path to the producing well 154. The pump set 22 pumps the oil, water and gas mixture through a perforated gas pipe 202, centered in the well casing 210 by centralizer 204 and production string 206 located in well casing 210 to a takeout pipe 208. Specifically, the pump set 200 moves a sucker rod 212 up and down in the production string 206 to draw oil, water and gas through the production string into the take-out pipe 208.

The injection well 152 illustrated in Fig. 9 may be fitted with supplementary drive means, such as pressurized steam or carbon dioxide for injection into the geological substrate through the annulus 199 formed between the well casing 190 and the waveguide 186 to aid in further heating the hydrocarbon material, but more importantly to drive the heated water, gas and oil to the producing well 154. Carbon dioxide may be employed as the driving medium.

Referring to Fig. 10, there is shown apparatus 220 for in situ production of oil, gas water ans sulfur from oil shale, coal, peat, lignite or tar sands by co-generation. A well 222 is formed through the overburden 224 and into the bedding plane 226. The well 222 includes a steel casing 230 and a waveguide 232 positioned within the casing and coupled to a radiotransparent applicator 234 housing an energy deflector 236, as described in Figs. 1-6. Means to raise and lower the energy deflector 236 described in Fig. 1 should be included, but the same has been eliminated for clarity. The waveguide 232 is affixed to the well head 238 with a packing gland seal 240 and to transition elbow 242 which includes a gas barrier. Coupled to the remote end of the transition elbow 242 is a flexible coaxial waveguide 244 which is coupled to an RF generator 246 which includes a magnetion, klystron or solid state oscillator (not shown). Current is supplied to the RF generator 246 from an electric generator 248 driven by a turbine 250. High pressure steam is supplied to the turbine 250 from a boiler 252.

Low pressure extraction steam which exits from the turbine 250 is supplied to the annulus 254 between the casing 230 and the waveguide 232 in the well 222 by a steam line 251. The application of low pressure steam to the oil shale, coal, peat, lignite or tar sands, in addition to the RF energy serves to decrease the viscosity of the kerogen or oil in the formation, causing the water, oil and gas to expand and flow into the open hole pump 256, where it is forced upwardly under tis own expansion and by the steam pressure to the surface with the oil and gas entering exit oil line 258 and the steam entering steam return line 260. The steam entering the steam return line 260 can be demineralized in demineralizer 262, condensed in condensate tank 264 and resupplied to the boiler 252.

The entering oil and gas is transmitted from the oil line 258 to a conventional liquid/gas separator 260. The separated oil is then transmitted to a storage tank for pipeline transmission.

Referring to Fig. 11, a canted or angled energy deflector 280 has a particular use in a well bore 282 in which the payzone 284 is inclined or offset relative to the well bore 282 so that the radio frequency energy can be directed to the seam or payzone 284. The deflector 280 is arranged at the bottom of an applicator 286 which is coupled to a waveguide 288 with an E.I.A. flange 290. A corrosion resistant covering 292 surrounds the waveguide 288 and flange 290. Extending downwardly from the casing 292 is a perforated liner 294 which is transparent to RF waves and protects the applicator 286.

Referring to Fig. 12, a coaxial waveguide arrangement is illustrated at 300 for in situ production of oil through a small diameter well bore 302. The well bore 302 includes a casing 304 and a perforated radiotransparent liner 306 which extends downwardly therefrom. A coaxial waveguide 308 is positioned within the well bore 302 and coupled to a radiotransparent applicator 310 with an E.I.A flange 312. A fibreglass or other corrosion resistant covering 314 surrounds the waveguide 308 and the flange 312. The waveguide 308 includes a hollow central conductor 316 which is maintained in a spaced relationship from an outer conductor 317 with dielectric spacers 319, only one of which is shown. The conductor 316 extends through the applicator 310 for interconnection with a submersible pump 318 positioned within the liner 306. The interior of the central conductor 316 includes a fiberglass or polyethylene lining 320 to provide a production conduit through which oil is pumped to the surface. The pumped oil helps to cool the inner conductor 316 by absorbing heat therefrom which in turn helps to maintain a lower viscosity in the producing oil by further heating it. The cooling effect of the oil on the central conductor 316 prevents overheating and dielectric breakdown of the dielectric spacers 319.

The pump 318 is electrically driven, receiving power through a power cable 322. The pump 318 may be pneumatically or hydraulically operated or actuated by a magnetic field produced by RF waves which have a different frequency than that of the RF waves used for heating. The coaxial waveguide 308 is smaller in diameter than the waveguide illustrated in Fig. 11 to allow access to wells 302 having small diameter bores.

Preferably, the pump 318 is supported by support wires 324 or rods coupled between eyelets 323 affixed to the pump and eyelets 315 affixed to the flange 312. A dielectric oil pipe 326 has one end coupled to the pump 318 with a flange 328 and passes through a central opening 330 in the energy deflector 332. A liquid tight seal is applied therebetween. The other end of the oil pipe 326 is coupled to the central conductor 316 with a dielectric coupling member 334.

The RF waves propagated through the waveguide 308 are radiated or broadcast outwardly from the portion of the central conductor, designated 336, which functions as a 1/4 wave monopole antenna. Any Rf waves that travel past the antenna 336 are deflected by the energy deflector 332.

Referring to Fig. 13, there is shown an apparatus 350 for use in a vessel containing hydrocarbon fluid to effectively utilize a portion of the hydrocarbon fluid to provide an automatic layer of insulation for the vessel by providing a specific thickness of immobile oil in contact with and adjacent tothe interiior tank walls when the ambient temperature or temperature conditions are low. The R value of the insulation and the U factor will vary in accordance with the k factor of the oil.

The tank 352 includes a perforated metal shield or wire mesh 354 arranged concentric with and spaced from the tank side walls 356. The shield 354 is held from the sidewall 356 by standoff brackets 358. Similarly, perforated metal shields 355 and 357 are positioned a predetermined distance from the bottom surface 359 and top surface 366, respectively. Standoff brackets 361 and 363 are arranged between the metal shield 355 and bottom surface 359 and metal shield 357 and top surface 366, respectively.

During mild and warm temperature conditions, the oil can expand and contract without restriction and flow through the perforations 360, 365 and 367 so that it is available for use. However, when the temperature conditions are cold and tank walls 356, 359 and 366 become cold, the viscosity of the oil will increase so that the oil will not be able to flow through the perforations 360, 365 and 367 and will tend to solidify inwardly toward the shields 354, 355 and 357 forming a thick insulation layer which is no longer capable of transferring external heat to the interior of the tank 352 by convection.

The apparatus of Fig. 1 may be utilized to maintain the fluency of the oil in the tank 352 which is located interiorily of the shields 354, 355 and 357. As illustrated in Fig. 13, it is preferred to introduce RF waves from the top of the tank 352 into a radiotransparent applicator 362 which is liquid tight at its bottom end. This arrangement insures against oil leakage from the tank 352 should the applicator 362 be damaged or fractured. The RF waves propagated through the radiotransparent applicator 362 are deflected into the oil by the energy deflector 364 where they are absorbed and converted into thermal energy. The RF waves will not penetrate beyond the shields 354, 355 and 357 and are reflected back into the oil by shields 354, 355 and 357, if they have not already been absorbed. The shield 357 across the top surface 366 of the tank 352 may be eliminated since the heated soil when it cools will form a solid layer near the top surface 366. However, a small passage must be provided through this top solid layer for communication with the heated oil below to provide a vapor flow path, for example, piping 372 transmits heat from the anode cooling system of the magnetron 368 of the Rf generator 370 to the tank 352. The piping 372 extends for a predetermined distance below the top surface 366 to penetrate any resulting solid oil layer by recirculating the deionized anode cooling solution through the piping 372 submerged in the oil.

Claims

1. A method of increasing the fluidity of a hydrocarbon fluid comprising the steps of:
generating electromagnetic energy in the frequency range of from about 300 megahertz to about 300 gigahertz;
transmitting and deflecting said energy at various locations into said fluid through a flexible waveguide and applicator; and
coupling the flexible waveguide to a manhole in the vessel with sealing means to prevent loss of said energy which is transmitted into the hydrocarbon fluid and prevent the entrance and exit of gases and liquids.

2. A method as claimed in claim 1 including the step of providing an inert gas shield and removing the heated hydrocarbon fluid by pumping it into a storage medium.

3. A method of reducing the viscosity of oil flowing in an oil pipeline and removing paraffin from the walls of the pipeline, comprising the steps of:
coupling a waveguide to the pipeline
providing a radiotransparent sealing member between the waveguide and pipeline which is transparent to electromagnetic energy but impermeable to the oil in the pipeline;
generating electromagnetic energy in the frequency range less than 300 megahertz to about 300 gigahertz;
transmitting said energy into the pipeline through the waveguide;
heating the oil in the pipeline and the paraffin on the sidewalls of the pipeline; and
homogenizing the heated paraffin with other hydrocarbons in the oil to cause the paraffin to remain in solution in the oil.

4. An apparatus for reducing the viscosity of oil flowing in a pipeline and removing paraffin from the walls of the pipeline, comprising:
waveguide means for coupling to one end of the pipeline;
radiotransparent sealing means positioned between said waveguide means and the end of the pipeline, said radiotransparent sealing means being transparent to electromagnetic energy but impermeable to the oil in the pipeline;
radio frequency generating means for generating electromagnetic energy in the frequency range of less than 300 megahertz to about 300 gigahertz;
said radio frequency generating means being coupled to said waveguide to transmit electromagnetic energy into the pipeline through said radiotransparent sealing means to heat the oil in the pipeline and the paraffin on the sidewalls of the pipeline so that the paraffin homogenizes with the other hydrocabons in the oil and remains in solution in the oil.

5. Apparatus for removing high viscosity hydrocarbon fluid from a vessel by increasing the fluency of fluid, comprising:
radio frequency generator means for generating electromagnetic energy in the frequency range of less than 300 megahertz to about 300 gigahertz;
waveguide means and radiotransparent applicator means in the shape of a tube with a closed end;
deflector means positioned in said applicator;
means for moving the deflector means within said applicator means; and
sealing means for coupling said waveguide means to a manhole in the vessel to prevent the loss of said energy when said waveguide and applicator means are postioned within the vessel and said radio frequency generator means is energized and to seal against the entrance and exit of gases and liquids.

6. Apparatus as claimed in claim 5 including pumping means for removing the hydrocarbon fluid after its viscosity has been reduced by heating with electromagnetic energy.

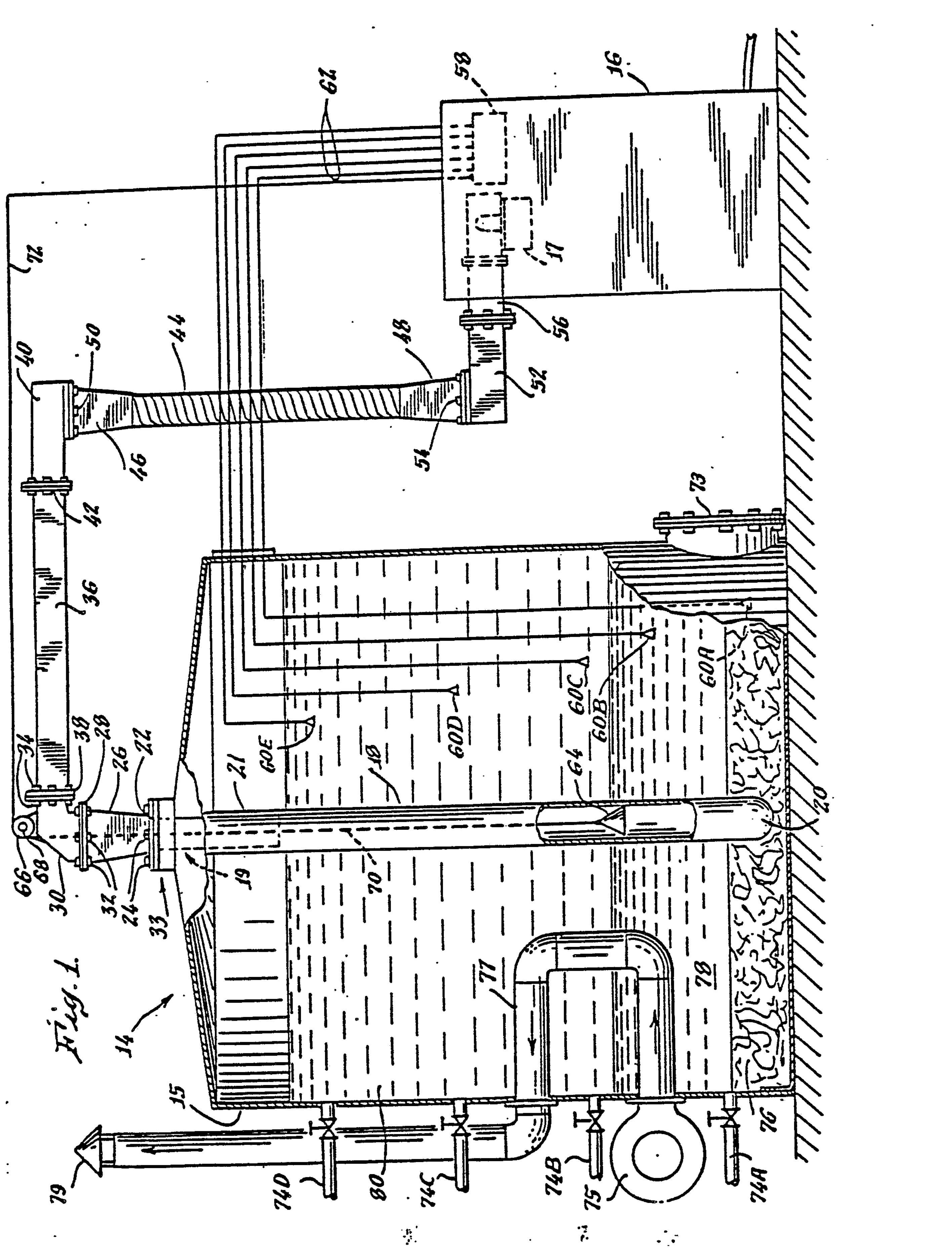

14
15
16
17
18
19
20
21
22
24
26
28
30
32
33
34
36
38
40
42
44
46
48
50
52
54
56
58
60A
60B
60C
60D
60E
62
64
66
68
70
72
73
74A
74B
74C
74D
75
76
77
78
79
80

Fig. 1.

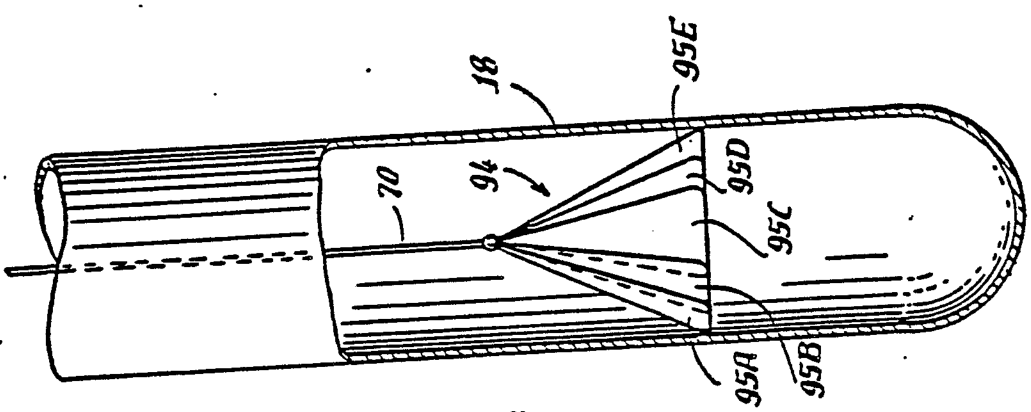


Fig. 6.

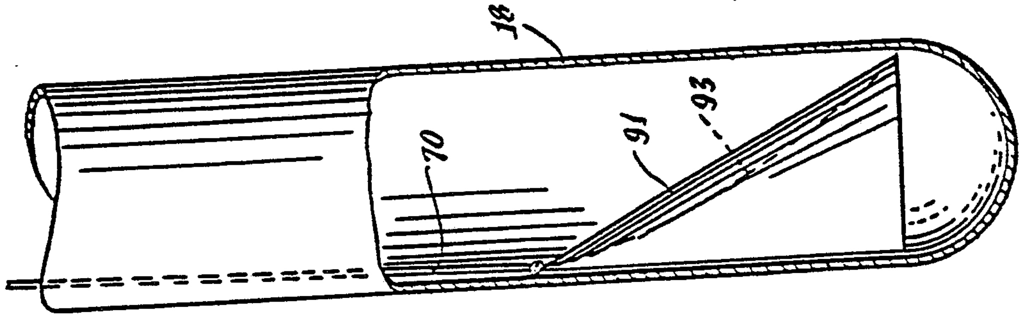


Fig. 5.

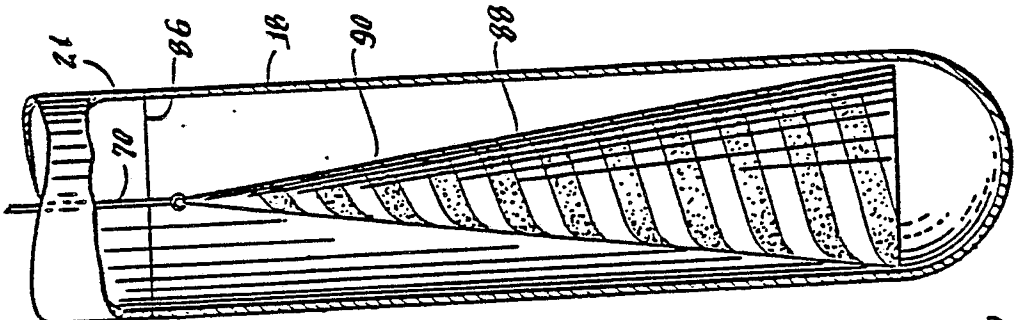


Fig. 4.

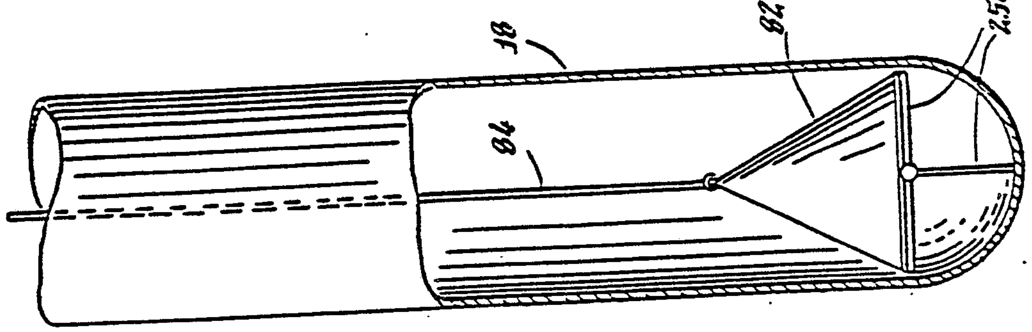


Fig. 3.

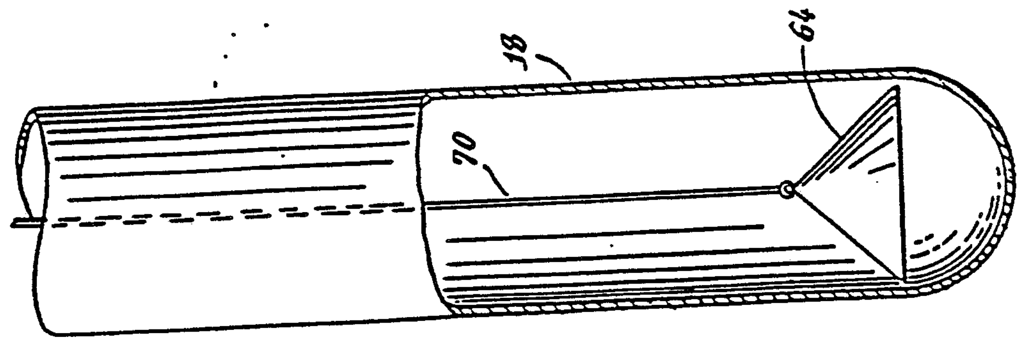


Fig. 2.

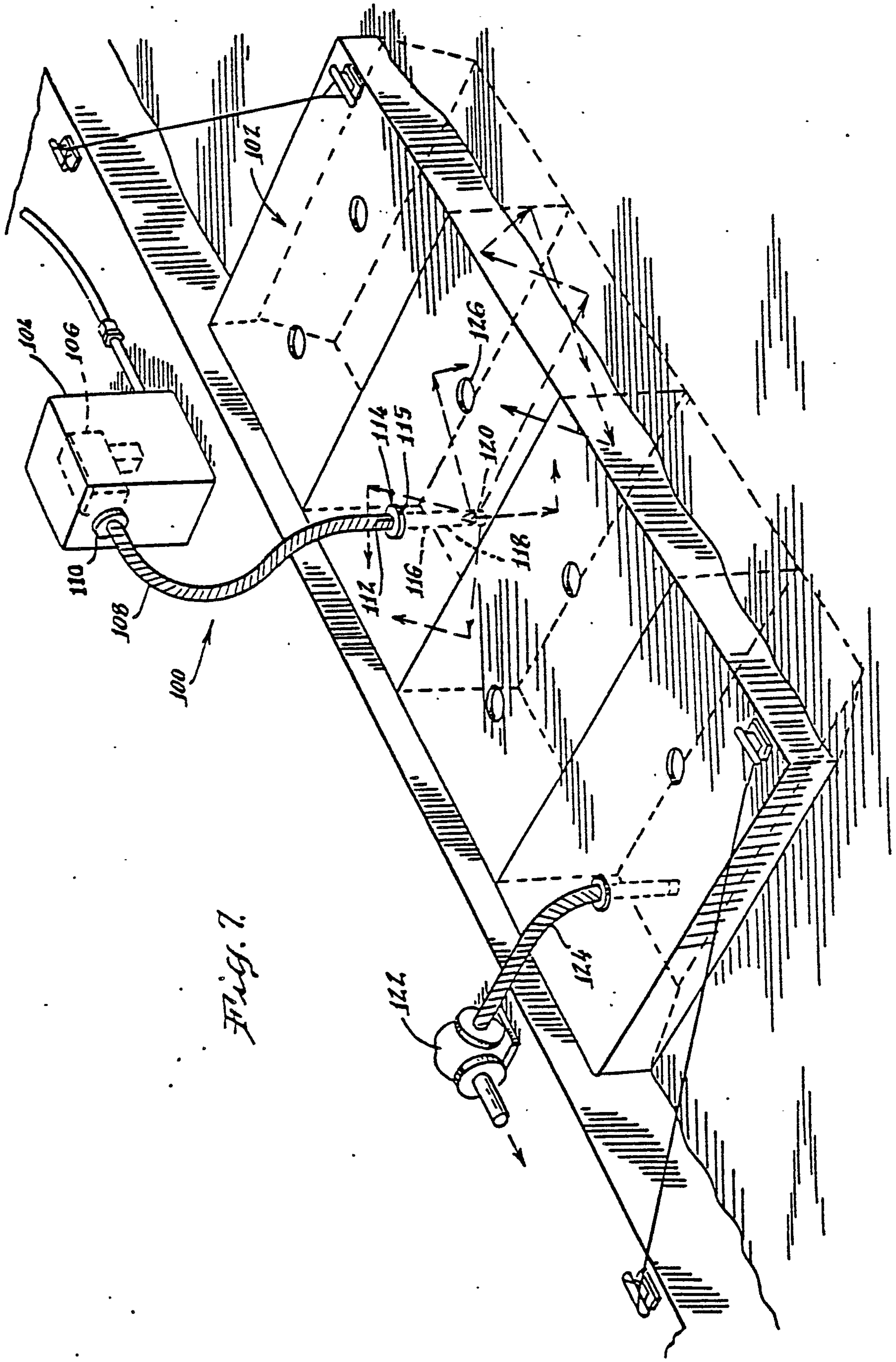


Fig. 7

Fig. 8.

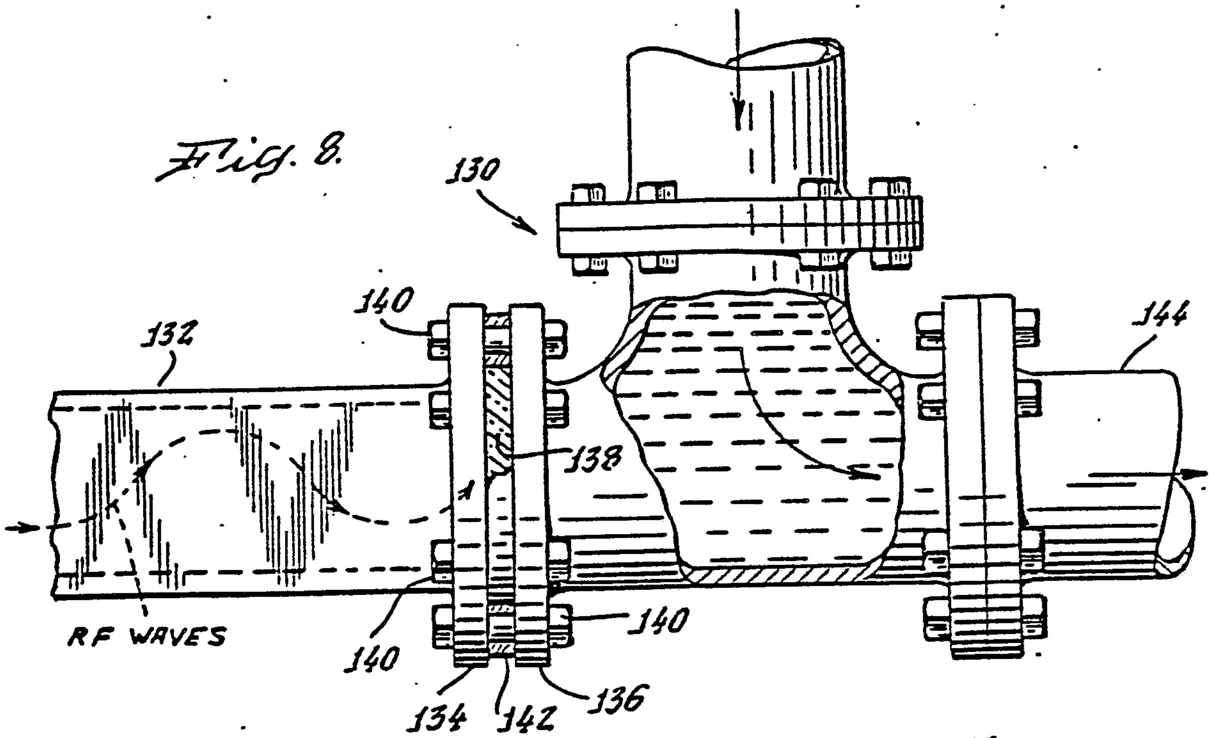


Fig. 11.

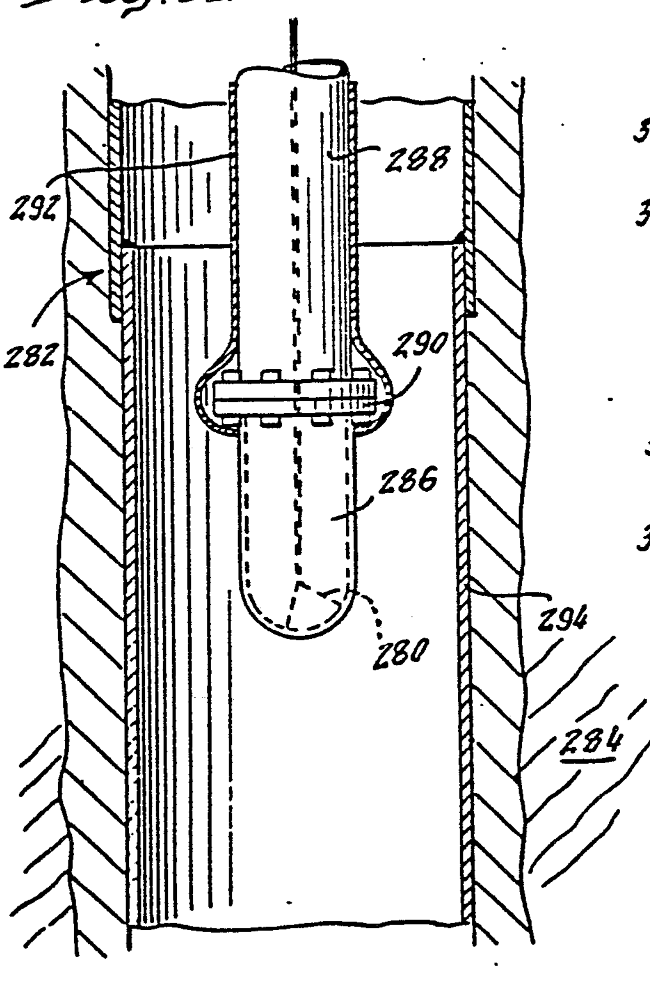


Fig. 12.

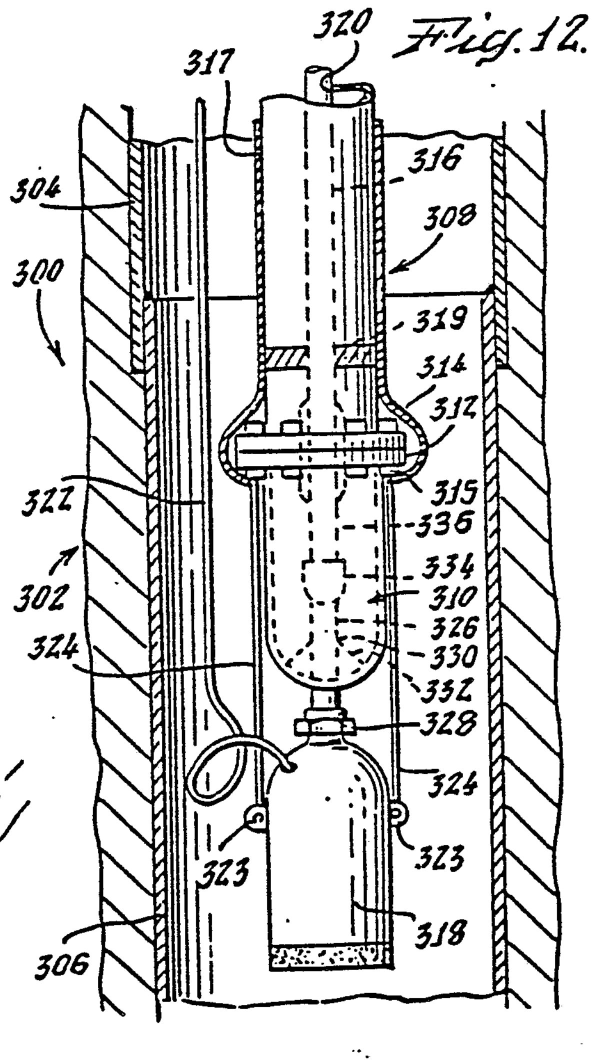
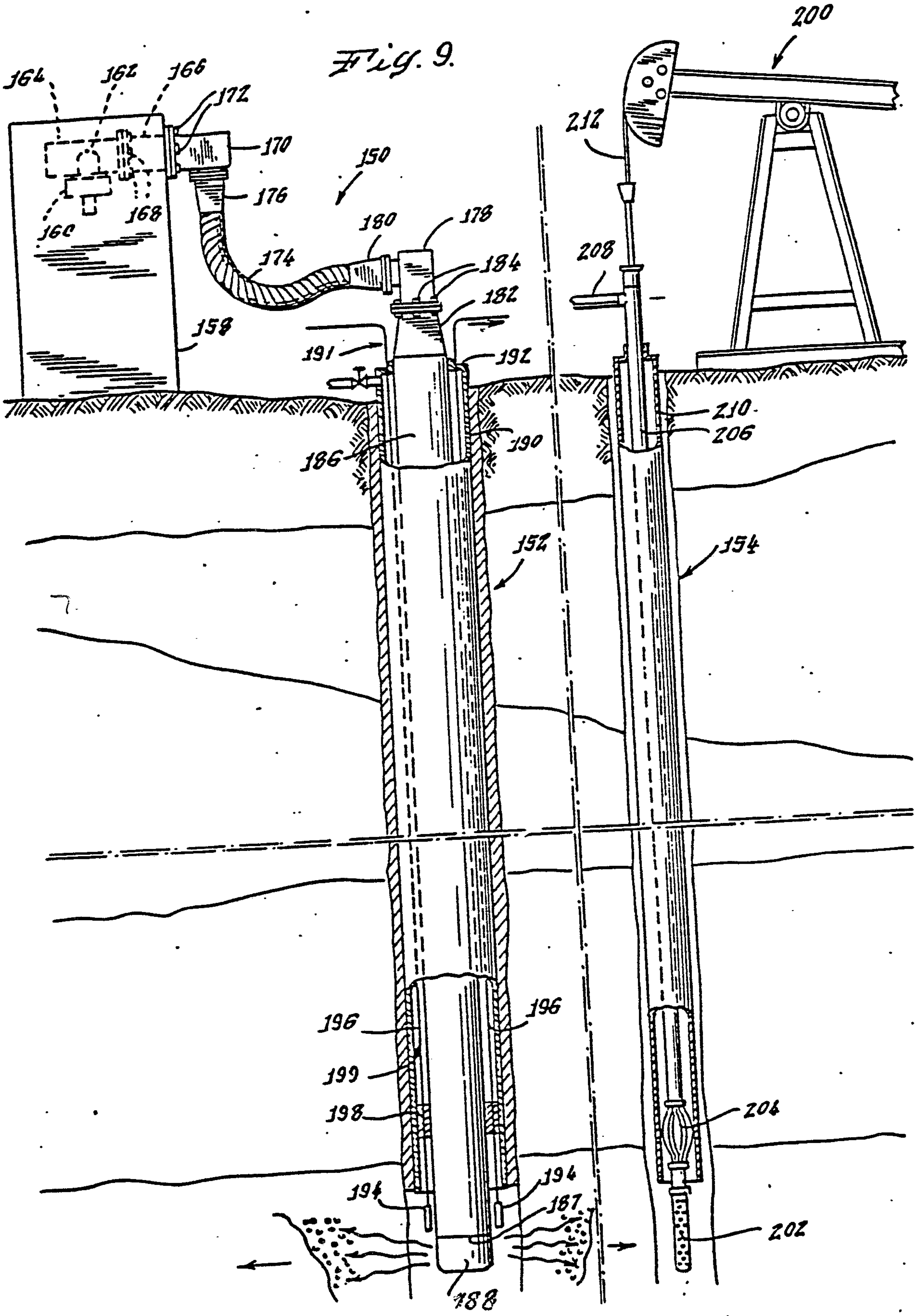


Fig. 9.


164
162
166
172
170
150
176
168
160
178
180
174
184
182
158
191
192
186
190
200
212
208
210
206
152
154
196
196
199
198
194
194
187
188
204
202

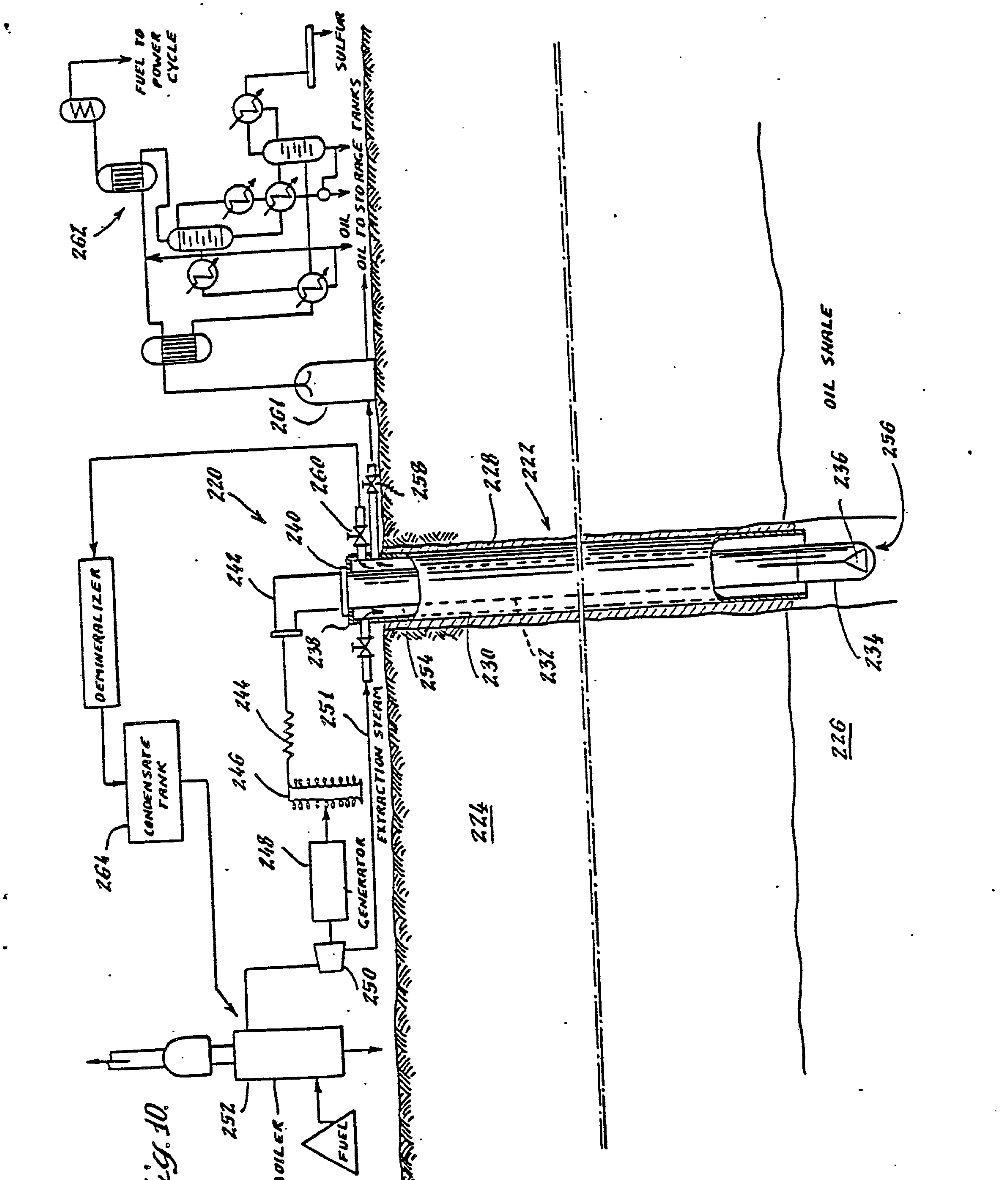
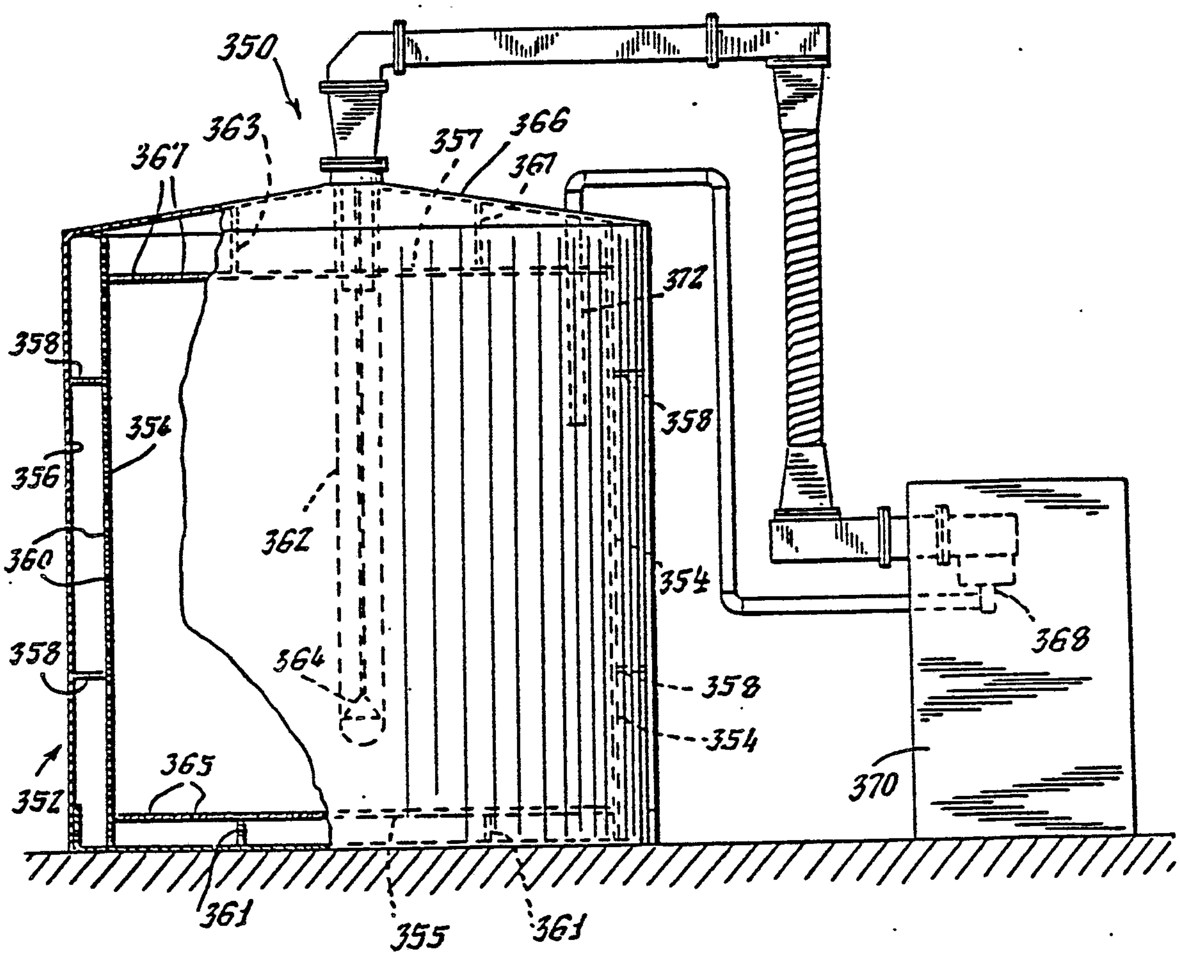

FUEL TO POWER CYCLE
262
SULFUR
OIL
OIL TO STORAGE TANKS
261
260
258
220
240
242
238
228
222
DEMINERALIZER
CONDENSATE TANK
264
244
246
248
251
EXTRACTION STEAM
GENERATOR
254
230
232
224
OIL SHALE
256
236
234
226
250
252
BOILER
FUEL

Fig. 10.

Fig. 13.


350
363
367
357
366
367
372
358
356
356
358
362
360
354
358
364
368
358
354
365
370
352
361
355
361