

June 18, 1957

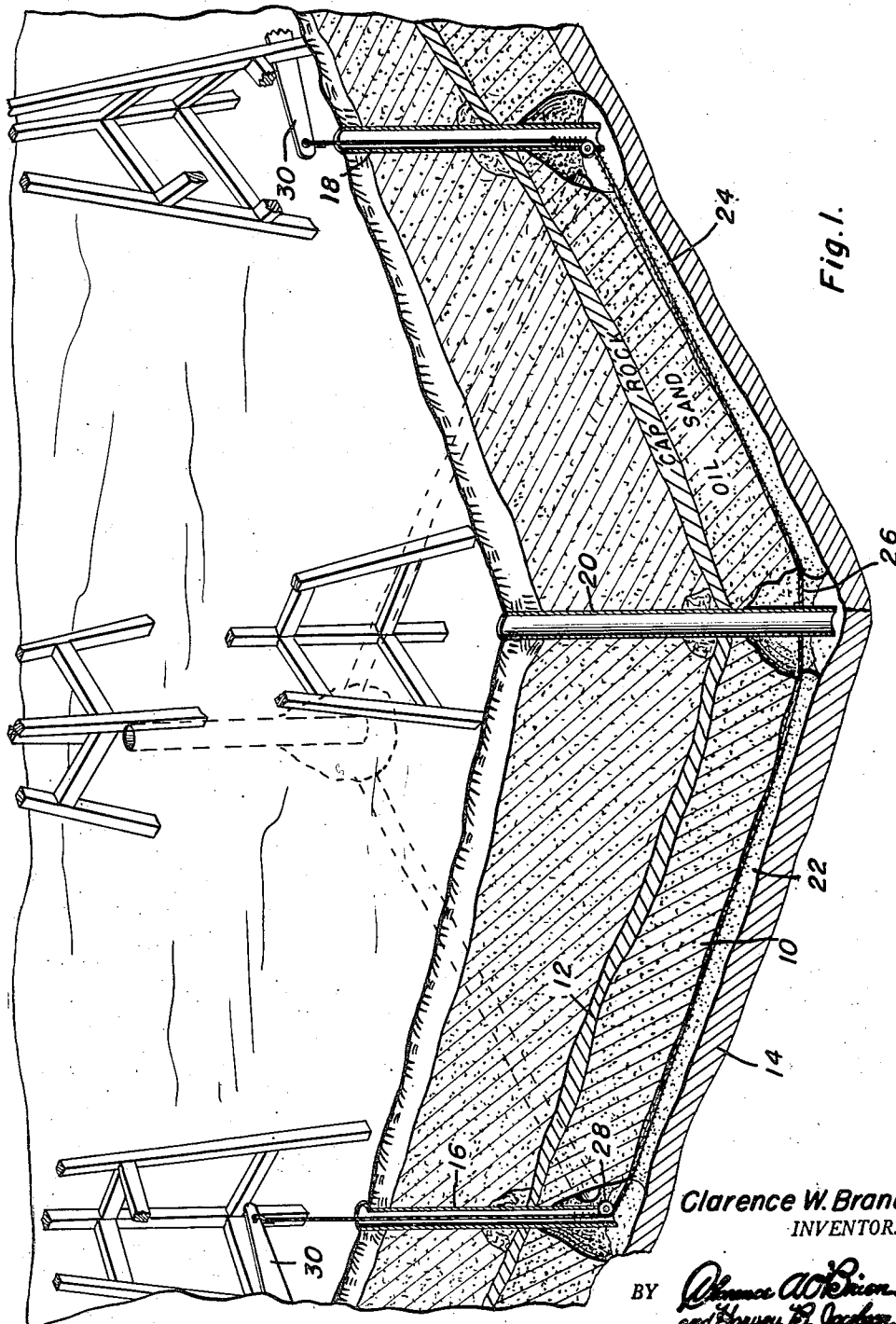
C. W. BRANDON

2,796,129

OIL RECOVERY PROCESS

Filed Aug. 13, 1951

5 Sheets-Sheet 1



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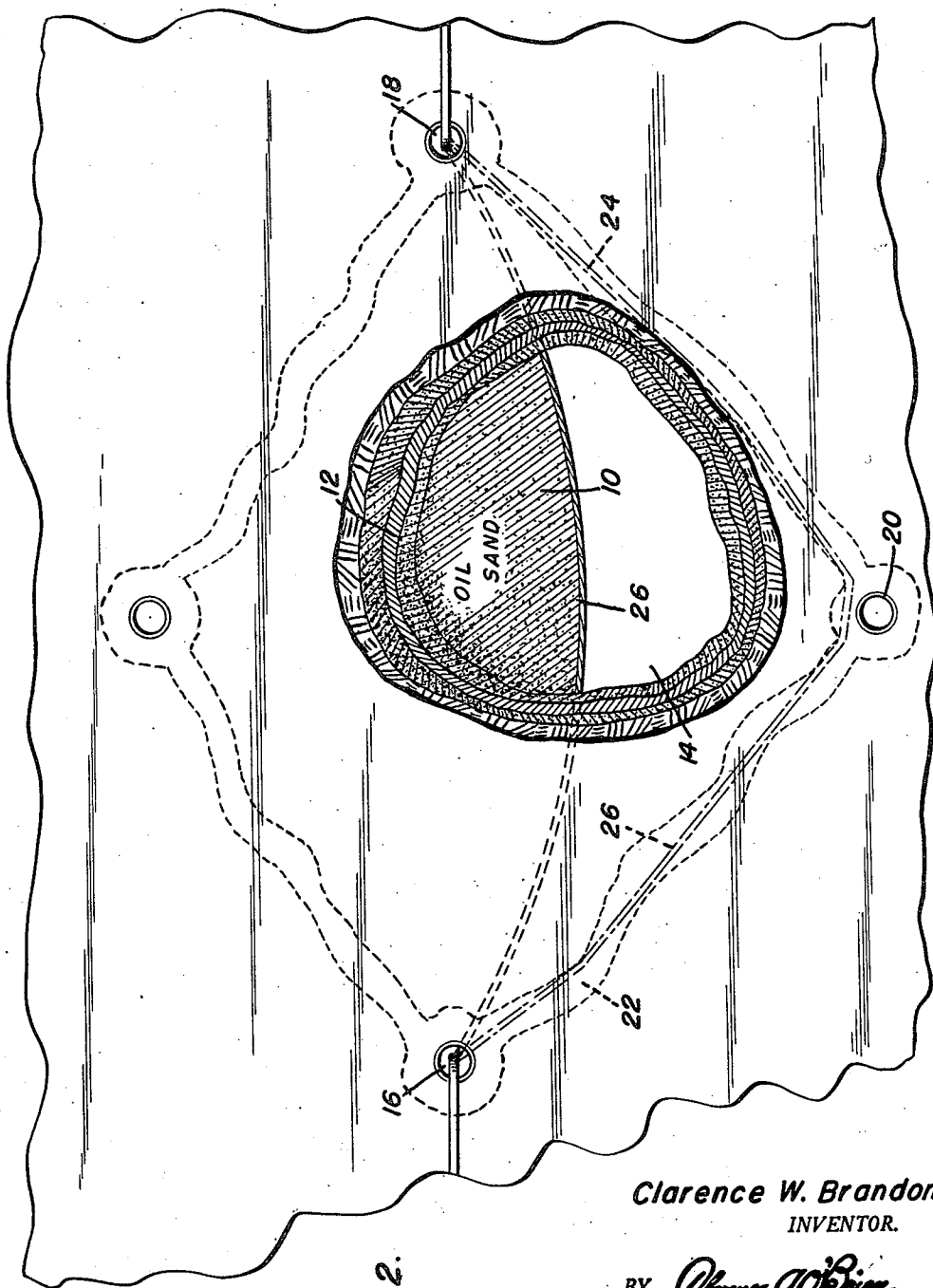


Fig. 2.

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5 Sheets-Sheet 3

Fig. 3.

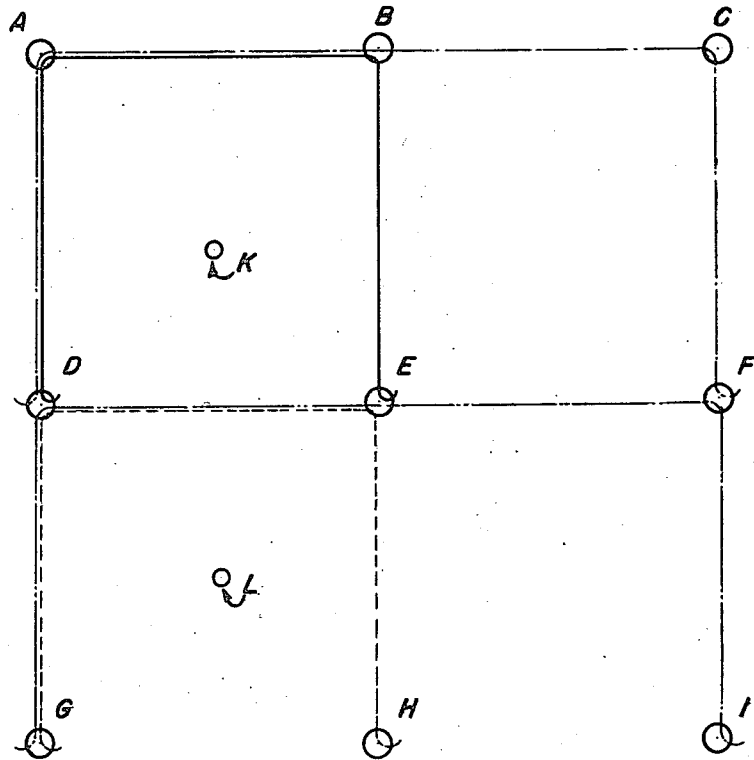
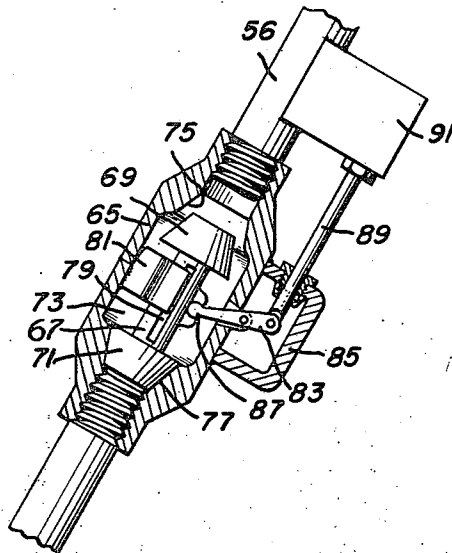


Fig. 7.



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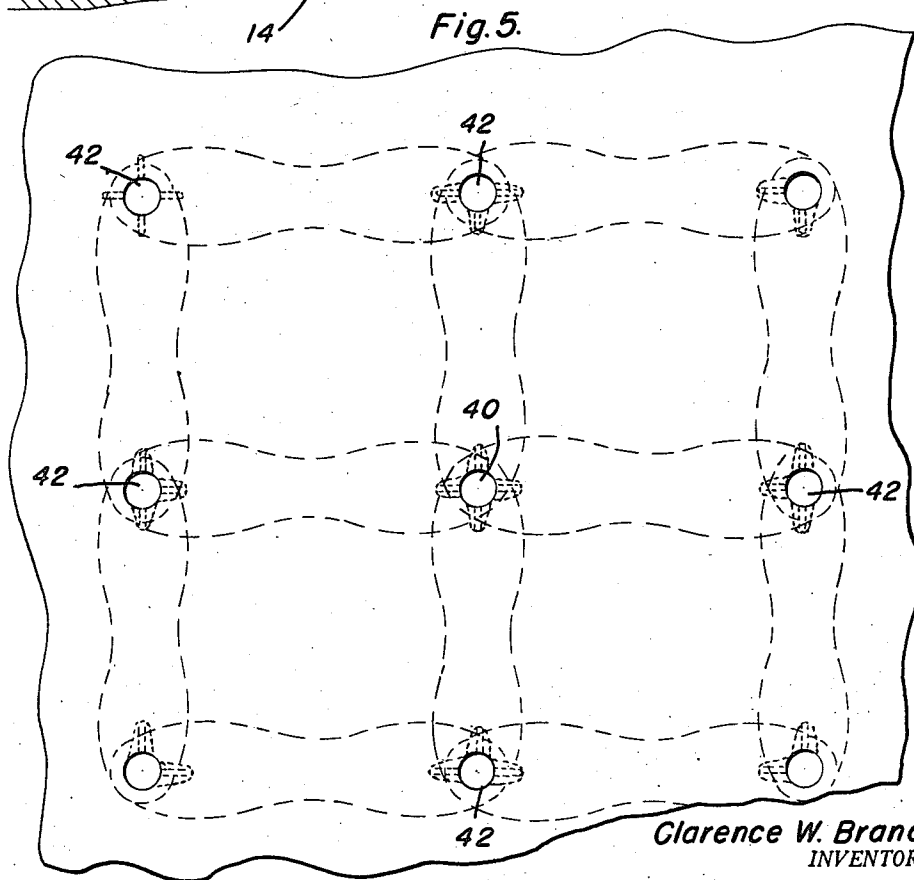
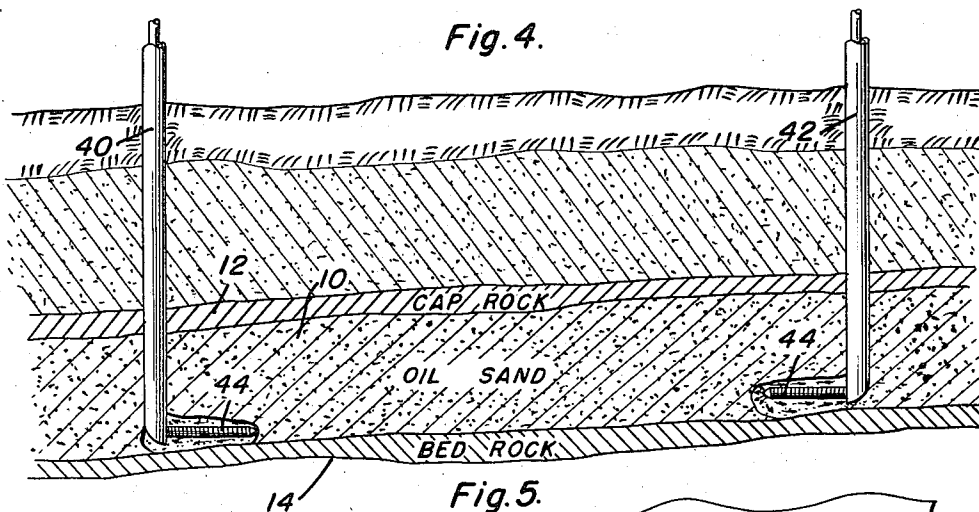
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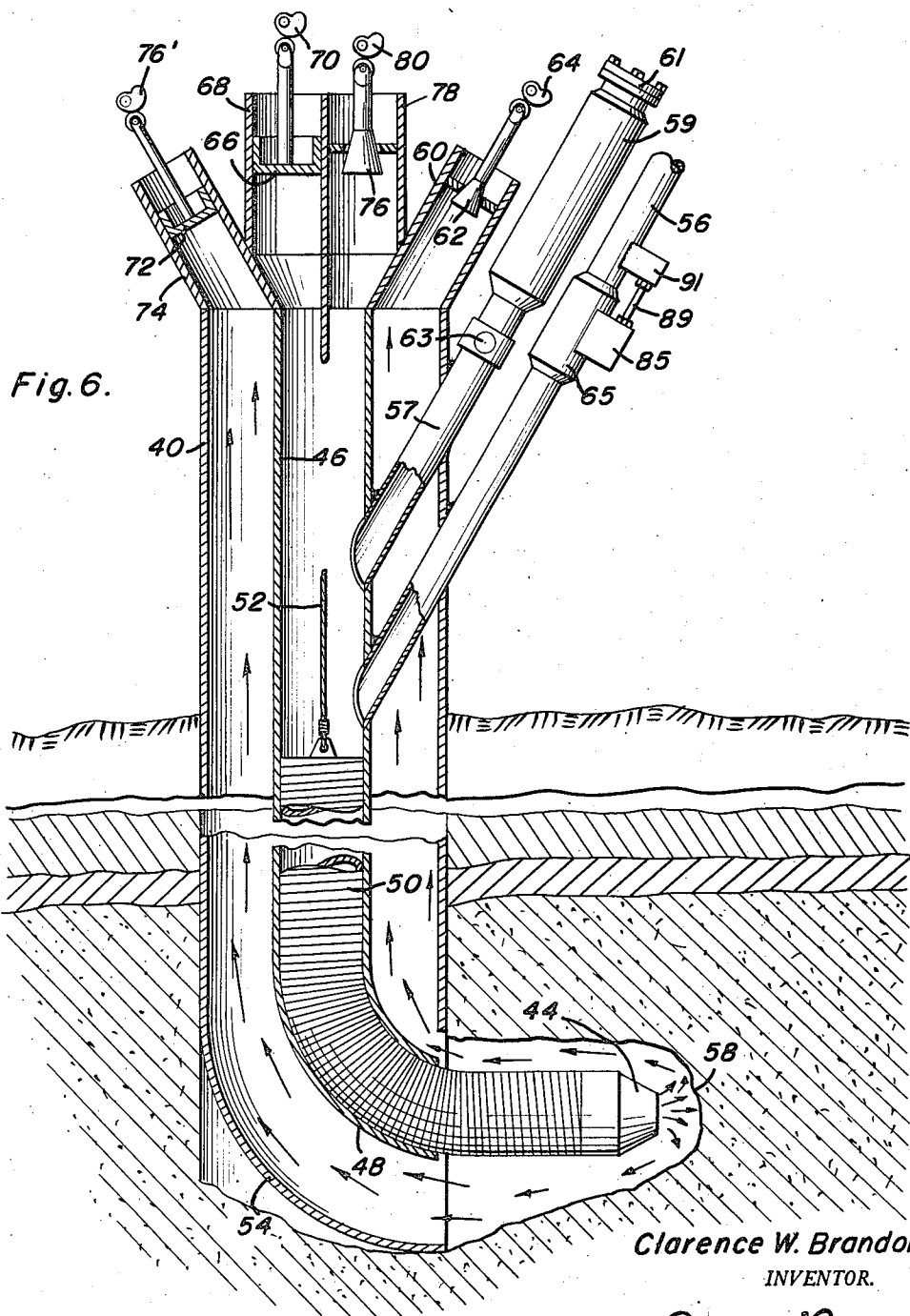
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2,796,129

OIL RECOVERY PROCESS

Clarence W. Brandon, Tallahassee, Fla., assignor of one-eighth to Orpha B. Brandon, Tallahassee, Fla., and one-half to N. A. Hardin, Catherine H. Newton, and Hazel H. Wright, all of Forsyth, Ga., and one-twentieth to Harvey B. Jacobson, Washington, D. C.

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9 Claims. (Cl. 166—9)

This invention comprises novel and useful improvements in oil recovery processes and more specifically pertains to improved methods for recovering oil and petroleum deposits from petroliferous strata with a greater efficiency than heretofore possible; and especially pertains to effecting a substantially complete recovery of the residual mobile oil and petroleum deposits remaining in oil bearing sands of either the Cenozoic or Paleozoic formations after normal oil producing methods, including re-pressuring, water drives and the like have been completed.

It is well known in the petroleum producing industry that normally less than 30% of the mobile petroleum deposits of a Paleozoic field are removed by normal well drilling operations; and not more than an additional 35% are recoverable by presently known water drive methods of production, leaving at least 35% of the original total mobile deposits retained in the oil bearing strata and heretofore impossible of reclaiming.

The present almost universal practice of dealing with this condition is to employ a water drive which consists in repressuring the oil strata formation with water under any desired pressure from one or more well bores, and to attempt, by this pressure, to drive the oil globules to adjacent well bores where the same may be withdrawn. As above pointed out, this practice is successful to the extent of, at most, an additional one-half of the 70% of the original oil deposit left by the usual preceding oil well producing methods.

In coping with the above mentioned conditions and problems, I utilize a mechanical undercutting of the productive formation together with wave pulsations of various frequencies as a means for applying energy at desired places within the strata.

An additional object is to controllably vary the elasticity of a transmitting medium to thereby alter the vibrational characteristics of wave pulsations applied thereto.

More specific objects of the invention, in conformity with the preceding objects, are to produce a resultant wave pulsation in a medium having more perfect directional control; having an extremely effective disruptive effect upon cellular formation and porous bodies of all characters; having a minimum transmission loss of energy between the place of generation and the place of use.

A further extremely important object is to effectively control and cause the flow of fluids within a porous or cellular formation by the application of high frequency wave pulsations applied thereto through a fluid pressure medium.

Another extremely important object, in accordance with the immediately preceding object, is to provide a method of disrupting porous or cellular formations by the application of high frequency wave pulsation thereto of controllable amplitude and/or pitch through a fluid pressure medium.

An important object of the invention is to provide a method as set forth in the foregoing objects in which it shall be possible to physically mine and remove the oil sands from the oil strata, either all or in part, as desired,

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in order to obtain samples, for subjecting the sands so removed to any desired process or treatment for recovering the immobile oil particles adhering thereto, and to provide cavities in the formation by the removal of these sands to facilitate the application of treating mediums thereto and especially the subjecting of the strata to pulsations of high frequencies.

An additional object of the invention is to provide a method in accordance with the preceding objects which shall effectively wash the sand formation with water, oil or any other desired fluid medium to effectively strip the mobile and the immobile oil particles from the sand strata; and to impose upon this washing action high frequency pulsations in both the washing medium and in the sand strata to render the washing action more effective.

Yet another very important object of the invention is to provide a method as hereinbefore set forth which shall admit of the gravelling of a sand formation either alone or in conjunction with any of the above noted operations; and especially as regards Cenozoic deposits for preventing clogging of the oil drainage passages by sand and the like.

A still further important object of the invention is to provide a method whereby a mechanical cutting agent may be applied to the lower portion of a petroliferous strata of the Paleozoic type for severing or undercutting the same to effect a subsequent disruption of the capillary formation; and wherein and/or when the mechanical cutting means is applied in operative position to the strata formation, its action will be assisted by the introduction of gases into the formation and/or through the agency of high frequency pulsations in a hydraulic cutting medium and impressed upon the gases to control their gaseous and liquid phase and thus their rupturing effect.

A still further important object of the invention is to provide an oil recovery method for the depleted oil deposits wherein selected portions of the lower part of an oil bearings and strata may be physically or hydraulically undercut and/or removed and replaced by gravel to facilitate the drainage of oil from the overlying sand formation.

Yet another object of the invention is to provide a method wherein various predetermined portions of an oil strata may be undercut and removed leaving selected portions to remain as supports for the rest of the strata for later removal, with a view to undercutting, breaking by the disruptive effect of controllably varied internal pressures in the strata; or removing the strata in accordance with known geological contours of the strata to effect more efficient drainage and recovery of oil therefrom.

Figure 1 is a diagrammatic perspective view, partly shown in section, illustrating the manner in which a mechanical cutting cable or other device may be employed for undercutting an oil strata through a plurality of well bores;

Figure 2 is a fragmentary top plan view of a portion of an oil field showing in top plan the arrangement of Figure 1, parts being broken away to show the different stratas of the field;

Figure 3 is a diagrammatic plan view of a portion of an oil field illustrating various manners of undercutting the field in accordance with my method;

Figure 4 is a diagrammatic view in vertical section through a portion of an oil field formation, showing the preliminary stages in the tunneling operation of Figure 1;

Figure 5 is a diagrammatic top plan view of a portion of an oil field illustrating the simultaneous tunneling and strata disrupting operations between a plurality of wells;

Figure 6 is a vertical sectional view, somewhat diagrammatic and with parts broken away, of an apparatus for effecting the hydraulic operation and causing the compounded high frequency vibrations utilized in this invention;

Figure 7 is a detail view of a part of the apparatus of Figure 6.

Mechanical undercutting of strata

Figures 1 and 2 disclose diagrammatically one exemplification of the manner in which the principles of this invention may be applied to the recovery of oil from a strata by physically disrupting and/or undercutting the same and releasing the capillary lock by which mobile oil globules are held in the interstices of the sand formation. Shown in Figures 1 and 2 is a typical sand formation of a Paleozoic oil field wherein the numeral 10 designates the oil bearing strata, while the numerals 12 and 14 respectively indicate the cap rock and the bed-rock layers of the oil sand formation.

In the example illustrated, the method is to be applied to an oil field in which the normal methods of production, including repressuring by the possible previous use of a water drive method of reclaiming oil have been applied and the flow of the field has now ceased, or reached a rate of production which is no longer profitable. Indicated at 16 and 18 are a pair of well bores which, in conjunction with the well bore 20, are disposed in a triangular relation.

In accordance with this method of my invention, these existing and possibly abandoned well casings and bores are utilized in order to obtain preliminary access to the oil bearing sand strata 10 at a minimum cost, at a maximum convenience and saving in time, as well as to enable effective use of information available from previous operation of this oil field regarding the geological formation of the same. It is of course apparent that I may drill original bores into the formation wherever found to be desirable; and may apply my methods to underdeveloped fields. It is proposed to establish tunnels 22 and 24 which respectively communicate the intermediate well casing or bore 20 with the two oppositely positioned casings or bores 16 and 18, below the top surface of and preferably at the bottom surface of the oil sand strata 10, substantially upon the bedrock 14.

The principles of this method of the invention are not limited to any particular way for effecting the formation of the tunnels 22 and 24, since various known subterranean tunneling methods or apparatuses may be employed. As set forth hereinafter, hydraulic methods of tunneling are deemed to be peculiarly efficacious in oil fields of this character.

It will of course be understood that the tunnels 22 and 24 will not necessarily be directed in straight lines between the well casings or bores, but may obviously be of irregular pattern, as shown in Figure 2. Where hydraulic tunneling methods are employed, as set forth hereafter, the tunneling will preferably follow the path of least resistance and previous water drive operations, insofar as they have previously established subterranean passages, will probably be of advantage therein. However, my method also comprehends a directional tunneling action as set forth hereafter. Actually, the straightness or irregularity of these tunnels is of little consequence or importance in the present method, it being merely necessary that a tunnel passageway be established between the wells in the manner suggested.

Once the tunnels have been established, a physical sand cutting means is introduced into and passed through these tunnels, this cutting means being indicated at 26 as consisting of a cutting cable or chain of any desired character and which has one end portion extending downwardly through a well casing or bore 16 and from thence through the tunnels 22 and 24, and having its other portion extending upwardly through the casing or bore 18.

While undoubtedly numerous ways can be devised for inserting the cutting device in the tunnels, I deem the following to be simple and effective. A lead line with floats will be inserted to the bottom of a well bore and

then fed by water flow through the tunnels and up the selected bore. The lead line will provide a means for drawing the cutting cable through these passages.

Suitable cable guiding means 28 will be provided at the bottoms of the well bores 16 and 18 in order to position the cable horizontally across the face of the oil sand strata 10 and prevent reciprocation of the cable at its turns from damaging the well casings. Since it will be recognized that many different types of cutting devices and guiding means therefor may be provided, and as my invention is not limited to any particular structural arrangement of the same, detailed explanation and illustration appears to be unnecessary.

The cutting device may be either a member having loose ends, each of which is connected to a reciprocating member 30, caused to vertically reciprocate from any suitable power source, not shown, whereby the entire cable will be given a reciprocating or sawing motion, or the cable may be in the form of a continuous or endless band or cutting member and may be given a continuous rotation.

In either event, it will now be apparent that upon actuation of the cable by either reciprocation or rotation of the same, that portion of the cable contacting the face of the sand strata 10 will abrade, cut and saw the same. By virtue of the angular relationship of the cable sections between the casing 20 and the two casings 16 and 18, it will be evident that the cable will undercut the sand strata until eventually the cable will be disposed at a substantially straight line between the casings 16 and 18, in a manner which will be apparent from Figure 2.

This triangulation method may obviously be continued through the field by progressing to successive well bores until the entire field is covered.

It is worthy of note at this point that the oil strata has an internal pressure, frequently retained therein at substantially its original value by the above described "capillary lock," which causes the face of the formation to burst outwards as the same is weakened by the cutting device. This outflow of oil, water and gases serves to wash the cutting device and the face of the strata, facilitating the cutting operation. It is within the intent of this invention to increase or vary the internal pressure as set forth hereafter.

However, alternative methods of undercutting the entire field either by sections or by a cut across the entire width of the field may be employed. As previously described in connection with Figures 1 and 2, the entire area of the field may be covered as a series of steps, each step utilizing a triangular arrangement of well bores. During this triangular method of cutting, adjacent well bores may be utilized as the three corners of a triangle; or relatively greater spaced wells may likewise be used, the cutting proceeding from the three corners as above mentioned.

As shown in full lines in Figure 3, a strip method of cutting is possible. Thus, the cutting device may be inserted down a well bore, as at D, then connected by tunnels to the wells at A, B and E and up the well bore at E, thus disposing the cutter in a U-shaped arrangement. When the cutting device has reached a position across D, E or has substantially reached such a position, the operation may be repeated for the well bores G, D, E and H, as shown in dash lines in Figures 3, thus cutting in a step-by-step arrangement an entire longitudinal strip. Alternatively, the cutting device could be disposed substantially along the entire row of wells, A, D, and G and the other wells along this line, then across the end of the oil fields at the well A and B, then down the row of well B, E, H to the end of that row of wells, the ends of the cable passing up through the end wells of each row. Thus, a single cutting device and in a single cutting operation an entire strip of the oil field could be undercut.

Finally, however, it is evident that the cable or cutting

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device could be disposed across the entire width of the oil field, as shown in dash and dot lines in Figure 3, as by running the intermediate portions of the cables between the wells D, A, B, C, F, with the ends of the cables coming up through the well bores D and F for operation. The entire oil field could then be cut in a step-by-step manner, as above set forth, the operating ends of the cables being successively moved back to wells G and I and so forth, until the entire field is traversed. Finally, however, in some instances, the sides of the cable could extend along the entire length of the field as through the wells D, A, G on one side and the wells C, F and I, and so forth on the other side, or a mid-portion of the cable be inserted across the width of the field, as between the wells A, B and C.

As will thus be apparent, this method will effectively permit the employment of a different arrangement for undercutting an oil strata.

With any of the above methods of cutting, it is evident that the cable may be worked at different vertical levels. Thus, in very thick oil strata, it may be preferred to make the initial undercutting operation at the bedrock of the strata; and make successive horizontal cuts between the bedrock and the cap rock in accordance with the character and dimensions of the formation. This can be readily done by merely raising the guide rollers supporting the cable at the bottom of the well bores through which the cable ends are operated, to thereby position the horizontal section of the cable at the desired elevation in the oil strata.

It will be particularly noted that the above described method enables the partial or complete undercutting of the sand formation, thus enabling the superincumbent strata to collapse either under its own weight or under the assistance of jars and shocks applied thereto in any desired manner. The collapsing of the sand strata above the undercutting will obviously disrupt the capillary formation thereof, permitting drainage of the mobile oil particles contained therein, under the influence of gravity, to the bottom of the undercutting channel, from whence the oil may be readily removed from the ground in any desired manner.

Even if the undercutting above mentioned does not cause collapse and dropping of the strata, it will facilitate the draining of oil from the strata downwardly under the influence of gravity into the undercutting channel which would constitute an oil collecting basin, the extent of this drainage depending upon the effectiveness of the capillary block in the superposed formation.

The method as hereinbefore set forth further envisions and contemplates the physical removal of that portion of the sand strata which has been removed by the cutting means 26, and it is possible to withdraw the sand so removed either by the physical action of the cutting means 26, or through the agency of various carrying mediums, such as oil, water, or the like, thereby providing clearance space which will facilitate and permit the collapse of the superposed strata.

It will now be readily understood that by the above described methods of cutting, that various predetermined portions of the oil strata may be undercut leaving untouched "columns" which will support the rest of the strata. This will enable the operator to undercut and disrupt the strata formation, establish drainage channels and passages to the best advantage in accordance with topographical conditions existing in the oil strata and the like.

In some instances, it may be preferred to replace the sand cut away by the cutting means 26 by filling this space behind the cutting means with gravel or the like. This gravel fill will, upon collapse of the overlying strata, provide a drainage means permitting the flow of oil from the broken capillary formation of the disrupted strata toward the oil lifting and discharging means of the operation.

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I wish it to be clearly understood that the foregoing methods are to some extent applicable to all types of oil formations and also are useful at all stages of the development of an oil field, from prior to its first producing well until repressuring operations have ceased to produce profitably. However, I have emphasized its use in Paleozoic formations, since the foregoing method, as well as those to be hereinafter set forth, represents to date the only feasible method of reclaiming any appreciable portion of the last 35% of the original oil deposits necessarily abandoned in these formations by heretofore known methods of oil recovery.

Further, the present invention constitutes processes which will permit and facilitate recovery of both the mobile and immobile oil and in both the absorbed and adsorbed conditions.

Hydraulic tunneling means and method

Attention is now directed more particularly to Figures 4 and 6 for an explanation and understanding of a preferred manner of establishing tunnels between predetermined well bores. From a predetermined oil well casing of a selected well bore, or from a new bore provided for that purpose, it is proposed to establish tunnels to one or more adjacent well bore casings 42. While various known methods may be employed for establishing such tunnels and the present invention is not limited to any particular means, the means to be now described and the methods pertaining thereto are considered to be especially suitable for purposes of this invention.

From the bottom of one or both of the casings 40 and 42 there are laterally directed the nozzle portions 44 of the hydraulic tunneling devices towards the opposite well casing to which it is desired to extend a tunnel. Optionally, both nozzles may be operated simultaneously in order to drive two tunnel sections toward a junction with each other, or alternatively, one nozzle alone can be employed to drive the entire tunnel to the other well bore.

Figure 6 discloses an apparatus suitable for this tunneling operation. The casings 40 and/or 42 include the usual well tubing 46 which, at its lower end, has a curved laterally extending terminal portion 48 terminating at the side of the casing and being positioned and directed against the face of the oil sand strata and in substantial alignment with the other well casing to which the tunnel is to be established. Slidable within the tubing 46 and its terminal portion 48 is a flexible conduit 50 having upon its lower end the above mentioned nozzle portion 44. A cable 52, operated in any desired manner, provides means whereby the flexible conduit 50 may be moved downwardly in the tubing 46 and extended laterally from the terminal portion 48 thereof to thus feed the nozzle into the oil sand strata as the tunnel is being formed and progresses toward the other well bore.

In the well bores, at the lower ends of each of the casings 40 and 42, there is provided an arcuate guard or shield 54 which is substantially concentric with the lower portion of the curved terminal 48 of the tubing and which direct the return flow of the pressure medium into and up the casing 40 as illustrated by the arrows in Figure 6.

In contrast with the usual manner of merely supplying a fluid medium under pressure through the nozzle 44 and attempting to increase the pressure thereof until the same, by sheer force, penetrates the oil sand strata and reaches the other well bore, or establishes a junction with the other tunnel section being started from the well bore, the present invention in general consists in rendering the pressure of the fluid medium more effective to penetrate the strata by causing successive pressure fluctuations of the pressure medium at the face of the strata and within the interstices thereof.

These fluctuations subject the face of the strata and the face of the material within the interstices of the strata to pressures which are alternately greater and less than the pressure within the strata. When the pressure of the pressure medium exceeds that within the strata, the latter

will be augmented or raised, especially in that portion nearer the face of strata. When the converse condition exists, the internal pressure within the strata will forcefully burst or explode the face of the strata outwardly, disrupting the same.

This disrupting of the capillary formation of the strata is greatly augmented and hastened by increasing the extremes between the high and low pressures applied to the strata; by increasing the surging of the pressure medium within the pores of and against the strata by imparting high frequency vibrations to the pressure medium; and increasing the eroding action of the medium within the pores of the strata by the preceding processes.

In initiating the tunneling operation, the fluid medium is supplied under pressure from any suitable source by the conduit 56 into the tubing 46 and discharge from the nozzle portion 44 against the face of the oil sand strata as illustrated. This pressure medium will cut into and form a tunnel or channel in the oil sand strata, the material removed by the fluid medium being ejected as indicated by the arrows in Figure 6 upwardly in the casing 40 and discharged from a conduit 60 under the control of a valve 62 through a control or operating member such as a cam 64.

Obviously, if desired, the outflowing pressure fluid from 60 may be returned to the conduit 56 to cause a recirculation of the same during the tunneling operation.

As so far described, this circulation of the pressure medium will, in conformity with known procedures, cause some disruption of the strata. Regulation of the pressure in the conduit 56 or of the valve 62 or both will maintain any desired mean pressure upon the pressure medium. However, in addition to the circulation of the fluid medium under waves of various pressures, it is intended to render the excavating action of the same more effective as well as more accurately directed and controlled by applying pulsations to the fluid medium and by imposing high frequency vibrations thereon, the character of the pulsations and the vibrations being varied and controlled.

The casing 40 is provided with an impulse producing means in the form of a piston 72 reciprocable in a conduit 74 under the control of an actuating cam 76' or similar member, while the tubing 46 is provided with an impulse producing piston 66, reciprocable in a conduit 68 under the control of a cam 70 or other actuating means, and further with a pressure release valve 76 operable in a conduit 78 under the control of an actuating cam 80.

By periodic and/or adjustable manipulation of the pistons 66 or 72, a pulsation or wave motion may be transmitted through the pressure medium which functions as an elastic or closed hydraulic column. The rigid column of the pressure medium will transmit the impulses or energy shocks, without substantial loss to the strata. There, the pressure impulses pass from the denser transmitting medium to a more elastic resilient medium consisting of the oil particles and gas bubbles at the oil face of the strata, and produce a turbulent washing of the latter into the formation. With the change of medium, the impulses are converted to vibrations having a much greater amplitude and this facilitates the above mentioned washing and penetrating action.

By using both pistons 66 and 72, separate pulsations, each of a predetermined pattern or character may be separately produced and imposed upon the pressure medium to produce a resultant vibration or wave. It should be noted that these two separate pulsations may be varied as to intensity, character and phase so as to reinforce, cancel or modify each other so that the resultant pulsation may have much greater extremes between its high and low pressure, may have portions cancelled out by interference and otherwise altered as desired. Moreover, the speed of travel of the wave pulsation of piston 66 to the nozzle and sand face is different from that of piston 72, since in the first instance the velocity of the medium

is added thereto while in the latter it is subtracted therefrom. This difference is utilized to properly time and synchronize the peaks and lows of the two waves to obtain a resultant wave having desired predetermined peaks and valleys.

In applying this method of tunneling, it is intended that the fluid applied to the sand strata from the casing 40 shall materially exceed in pressure the pressure existing within the capillary formation of the oil sand strata. Consequently, the fluid will tend to be driven outwardly from the nozzle into this capillary formation assisted by the pulsations and vibrations and toward the adjacent well casings. At the same time, pulsations of a similar character will be produced in the fluid being applied to the nozzle of the adjacent casings 42. The pulsation from the driving casing 40, if opposite in phase to that of the "pulling" casing 42 will guide and augment the penetrative effect, since the oil sand strata therebetween will be subjected to a high pressure adjacent the casing 40 at the same time that a greatly reduced pressure prevails at the casings 42. This condition may be maintained for any desired length of time, this length of time being varied during the treating of the formation, and is found to be most effective for penetrating the oil sand strata, but will be periodically reversed, whereby the casings 42 become the driving casings and the casing 40 becomes the pulling casing for the operation. It will be evident that this cycle of reversing the pushing and pulling effect upon the opposite ends of the sand strata between the two casings will tend to extend the tunnel sections toward each other under the pressure impulses and high pressure conditions prevailing at their nozzles, and the low pressure region created at one well will pull or guide the flow of pressure fluid from the high pressure region of the other well casing toward the low pressure region.

The effectiveness of this driving and guiding action upon the pressure fluid of the tunneling operation will be greatly augmented by the imposition of high frequency vibrations thereon of predetermined character. The above mentioned pistons will obviously be capable of variation in the extent and rate of their travel, to enable the attaining of any desired rate and amplitude of pulsation within the fluid medium.

The opening and subsequent sudden closing of the pressure medium discharge valves 62 and 76 with predetermined timing and adjustable rates of movement will set up, by a ram action, a hammering effect in the fluid columns of the tubing 46 and of the casings 40 or 42. As is well known, this hammering effect is capable of producing relatively enormous and rapid pressure oscillations in the fluid column which will be transmitted and directed by the nozzle portions 44. These oscillations will be imposed upon the above mentioned fluctuations and vibrations, and may be united and combined to augment the pressure peaks or drops to further increase their differences. By using the appropriate combinations of one or both of the pistons and valves, an infinite variety of resultant frequencies of pulsations or vibrations are possible. The force and pressures exerted by the fluid medium upon the opposite faces of the oil strata between the two casings may thus be of relatively enormous magnitude and by virtue of the complementary action of a pressure peak upon one side of the strata simultaneously with a pressure reduction on the other side, it is evident that the penetrative effect of the fluid medium into the capillary formation will be tremendously increased.

As will be readily understood, the paths of travel of the fluid medium will be relatively wide adjacent the well casings from which they originate, and will tend to thin out or narrow intermediate the well casings, due to the guiding and pulling effect of the reduced pressure area upon the high pressure medium flowing from the other well casing. This path of travel is indicated in dotted lines in Figure 5 for a series of well casings in which a

central casing is considered to be acting as a driving casing for forcing tunnels to the four adjacent receiving casings 42. It is contemplated, however, that each well casing in turn will function alternately as driving and receiving stations for each of the adjacent well changes, thereby permitting the establishment of tunnels simultaneously between a plurality of adjacent well bores.

In the arrangement of Figure 5, it is intended that any desired system of control may be utilized to effect the above mentioned alternating operation of the driving and pulling force applied to the fluid medium, this feature of the invention being readily adaptable to a large number of arrangements.

In accordance with the above described operation as suggested in Figure 5, it will be readily seen that a plurality of nozzles 44 may be utilized in one or more of the casings in order to simultaneously tunnel toward a plurality of adjacent casings. Since, however, this application of the principles of this invention involves merely a duplication of equipment, and constitutes no change in the fundamental principle and intent of the invention, further illustration and explanation is deemed to be unnecessary.

As hereinbefore described, it is believed apparent that it is entirely feasible to establish and create by the above mentioned hydraulic mechanism and operation any desired tunnels between selected well bores. These tunnels may be utilized as hereinbefore set forth for the reception of cutting means for undercutting the oil strata. However, this hydraulic operation may be utilized either in conjunction with the mechanical cutting device previously set forth or alone and by itself as a cutting agent for undercutting, channeling, penetrating and disrupting the oil and strata. In considering this inherent function of the hydraulic operation, the particular nature of the capillary formation of the oil strata should be particularly considered.

The period of high pressure of the fluid upon the face of the strata may be maintained for any desired period of time as dictated by experience to permit this increase of the pressure within the pores of the formation, at least in those pores contiguous to the face of the formation. It is contemplated that when the hydraulic operation is first started, the high pressure may be sustained for several days if necessary, while the vibrations and oscillations are being applied. However, as the strata formation is being attacked and penetrated and the oil and gas deposits thereof are loosened, the duration of the high pressure necessary to penetrate will decrease with intervals of as low as a few minutes will be sufficient.

Obviously, this process will result in increasing the diameter of the passages or tunnels produced by the tunneling device and this process will be continued and can be continued as long as necessary to attain tunnels of the requisite diameter to permit passage of the previously mentioned lead lines and floats therethrough and the drawing of the cutting device in the form of a cable thereafter.

Still further, however, if this tunneling, cutting and pulsating action is continued sufficiently, it is evident that the entire sand formation may be undercut and collapsed or disrupted, thus effectively breaking the capillary lock and permitting the recovery of the oil deposits therein.

By virtue of the pulsating and high frequency vibration of the pressure medium, it is evident that a surging and washing action of the gases and oil between the sand particles is effected which will efficiently strip both the mobile and the immobile oil particles therefrom, rendering still more efficient the oil recovery from the strata.

Moreover, I may in some instances introduce into the pressure medium and present at the oil and gas front in the strata inert gases such as carbon dioxide and fluids which will liquefy or dissolve under the peak pressures of

the pressure medium whereby they will be carried into the pores of the strata formation; and will vaporize or come out of solution when the pressure is reduced, to thereby assist in bursting and tearing the strata formation.

When the above described hydraulic operation is utilized in conjunction with the mechanical undercutting of the strata, the internal pressuring of the formation will render the same easier to cut by the movement of the cutting device across the face of the same so that upon movement of such device, the particles of the formation adjacent thereto will readily burst outward under their internal pressures upon weakening of the physical structure by the cutting device. This will result in an outflow of oil, water and gas from the strata into the cut made by the cutting device, thereby producing a continuous yield of oil during the cutting operation; cleansing the cutting device by this outflow of material therefrom; and effecting a cleansing or scavenging of the cut itself by the outflow of material therefrom.

In some instances, I may apply fluid pressure into the formation in advance of the cutting or undercutting operations. This applied pressure will raise the internal pressure of the formation and cause a driving of the oil and gas deposits thereof toward the lower pressure of the weakened zone of the cutting.

For this purpose, as shown in Figure 3, I utilize an abandoned well or if necessary a new bore K to apply pressure, which may be of a pulsating or vibrating nature, to the interior of the formation when the cutting device is operating between the wells DABE as previously mentioned. As the cutting device advances along the strata, the pressure fluid is applied to successive wells K and L. Thus, a pressure drive is applied to the oil strata where it will be most effective in driving oil to the cutting and facilitate the cutting operation by bursting the face of the strata at and during the cutting and by washing the same.

Set forth in the patent of C. E. Riestle, Jr., Patent No. 2,547,778, issued April 3, 1951, is a method for increasing the yield of oil from oil bearing strata formations, wherein a portion of the strata is expanded, lifted and fractured generally along horizontal planes of cleavage, by applying hydraulic pressure through a well bore upwardly against an undercut portion of the strata, and thus vertically raising the surrounding area of the strata.

The present invention contemplates an improvement of the method of the above patent by not only hydraulically lifting and fracturing the strata but simultaneously therewith more completely and readily establishing an enlargement of the generally annular drainage basin about a well bore by disrupting the internal structure of the sand strata to increase the volume of the basin; and will enable the limits of the basin to be enlarged along predetermined desirable directional lines of travel.

In addition, the actual process of enlarging the collecting basin is accompanied by a more effective and simultaneous withdrawing and stripping of the oil deposits from the oil sands by use of the foregoing hydraulic wave and vibrational effects to enable their collection in the basin. Still further, this invention contemplates maintaining a minimum pressure in the basin during the above mentioned pulsations and vibrations to hold the same expanded while gravel is applied thereto to fill this space and assist in holding the raised strata in its elevated position, thereby facilitating drainage of the oil.

In any of the hereinbefore set forth methods, it is possible to introduce gravel into the formation during and without interrupting the hydraulic operation. This may be conveniently effected by the apparatus of Figure 6, wherein a conduit 57 communicates with the interior of the tubing 46. A gravel hopper 59 having any suitable means for filling the same, such as the removable cover 61, discharges gravel into the conduit under control of the valve 63.

The turbulence, vibration and velocity of fluid of the fluid pressure medium in and from the tubing 46, con-

duit 50 and nozzle 44 will convey the gravel into the cutting and tend to deposit it at the desired locations. In addition, I may introduce an inert gas into the water to assist in conveying the gravel and directing its travel.

Shown in Figure 7 is a conventional uniform flow safely valve consisting of a casing 65 interposed between two sections of the conduit 56. A double ended valve, having a stem 67 and opposite valve heads 69 and 71, is axially reciprocable in a valve chamber 73 in the casing 65. Opposite ends of the casing have valve seats 75 and 77, respectively, engageable by the valves 69 and 71. The stem is longitudinally slotted at 79 to receive a stationary guide lug 81 carried by the casing which prevents rotation of the valve.

An operating lever 83 extends through the side of casing 65 into a housing 85 and has one end swiveled at 87 to a lug on the valve stem and the other end pivoted to a rod 89. The latter extends outwardly of the housing 85 and into a housing 91.

In the housing 91 is a control member, not shown, of any desired character which is connected to the rod 89 and extends into the conduit 56. The control member is responsive to variations in pressure in the conduit 56 both above or below predetermined limits for closing one of the valve seats. Thus, if a pressure wave travels up the conduit 56, which might damage the pump supplying fluid to the conduit, the control member engages the valve 69 with its seat 75. Conversely, if the pressure within the conduit is suddenly lowered, the valve 71 will be caused to engage the seat 77, as illustrated in Figure 7.

Having described the invention, what is claimed as new is:

1. A method of cutting an oil bearing strata of a subterranean formation which comprises; providing a plurality of bores each extending into the strata, providing a tunnel in the strata connecting a pair of the bores, positioning a cutting device in said tunnel and against the face of the strata, applying motion to the cutting device through said pair of bores to penetrate the face of the strata, applying through another of said bores lying within the strata being cut a fluid into the strata under a pressure in excess of the internal pressure of the strata and thereby increase the internal pressure in that portion of the strata to which the cutting device is applied whereby to assist the cutting of the strata.

2. A method of cutting an oil bearing strata of a subterranean formation which comprises; providing a plurality of bores each extending into the strata, providing a pair of intersecting, angularly related tunnels in the strata each connecting a single one of the bores with one of a pair of adjacent bores, positioning a cutting device in said intersecting tunnels and against the face of the strata in operative contact therewith, operating through the pair of adjacent bores the cutting device to penetrate the strata, applying fluid into another of said bores lying within the strata being cut under a pressure exceeding the internal pressure of the strata whereby to raise the internal pressure of the strata at the cutting device and thereby assist the latter in cutting the strata.

3. The method of claim 2 including the step of fluctuating the pressure of the fluid.

4. That method of reclaiming oil from an oil bearing strata of an oil field which includes the steps of establishing tunnels in the strata between a first well bore and two adjacent well bores, inserting a cutting device in said tunnels with portions of said cutting device extending into said adjacent well bores and imparting movement to said cutting device to undercut the face of the strata exposed in said tunnels, and raising the internal pressure within the strata by the introduction of a fluid under pressure through an additional bore lying within the strata in advance of the cutting device.

5. A method of removing oil deposits from a petrolierous strata which consists of establishing vertical bores into the interior of the strata, connecting said bores by horizontally extending passages in said strata, introducing a cutting device through said bores into said passages, operating said cutting device to produce separation of the strata along a horizontal plane, permitting the oil in the strata to drain into the separation, recovering the oil from the separation, and raising the internal pressure within the strata by the introduction of a fluid under pressure through an additional bore lying within the strata in advance of the cutting device.

6. The method of claim 4 wherein said fluid introduced under pressure includes a liquifiable gas.

7. The method of claim 1 wherein said applied fluid includes a liquifiable gas.

8. The method of claim 4 including the step of causing collapse of the undercut portion of said strata.

9. The method of claim 1 including the step of causing collapse of the undercut portion of said strata.

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