

June 8, 1954

A. G. BODINE, JR.
APPARATUS FOR AUGMENTING THE FLOW
OF OIL FROM PUMPED WELLS

2,680,485

Filed July 23, 1948

2 Sheets-Sheet 1

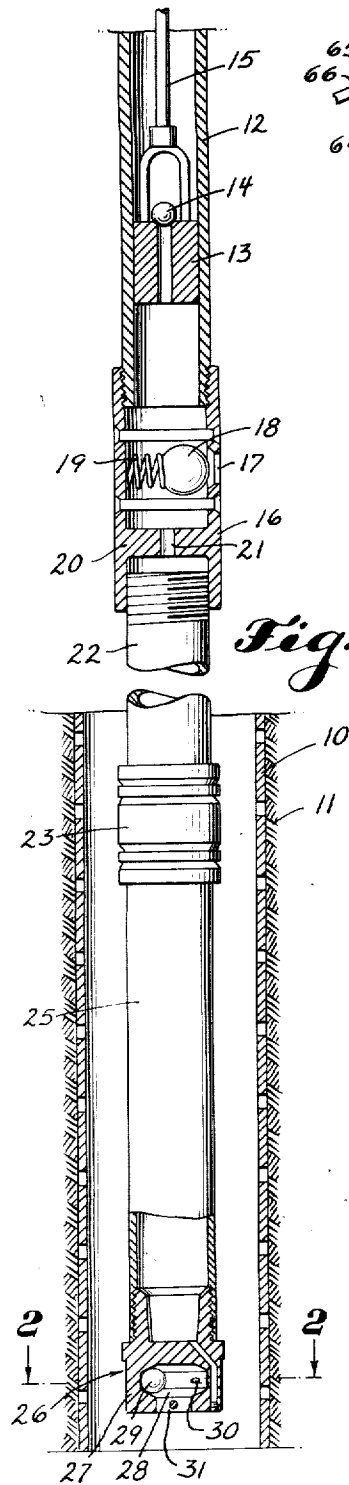


Fig. 1.

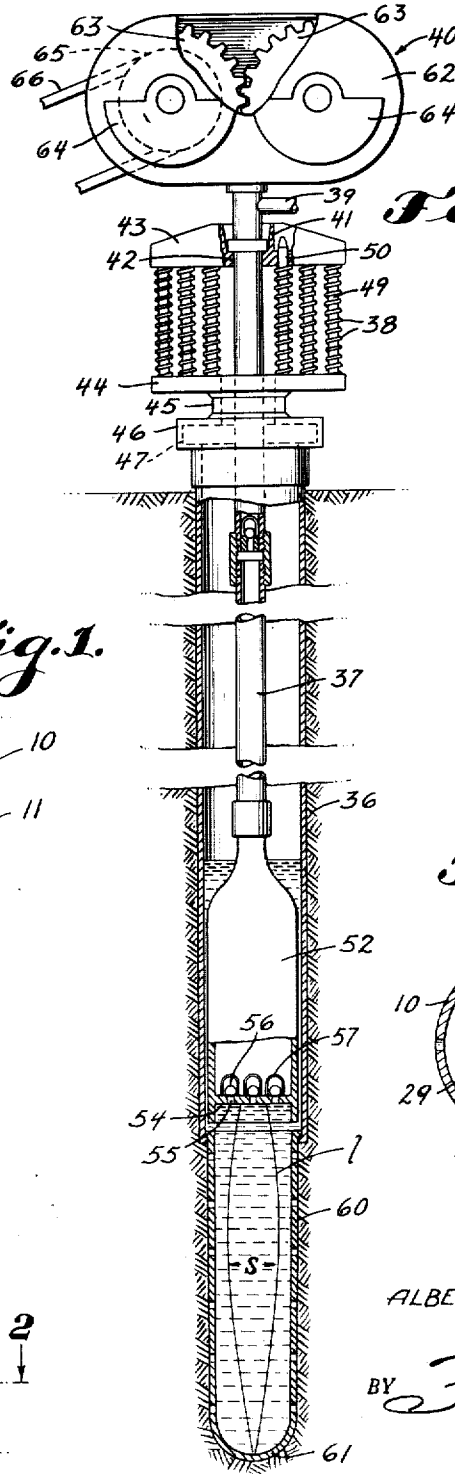


Fig. 2.

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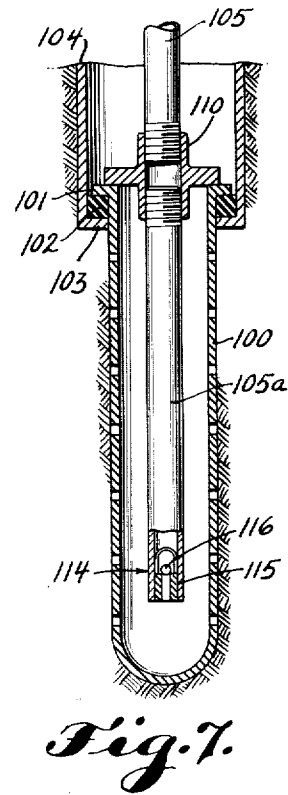
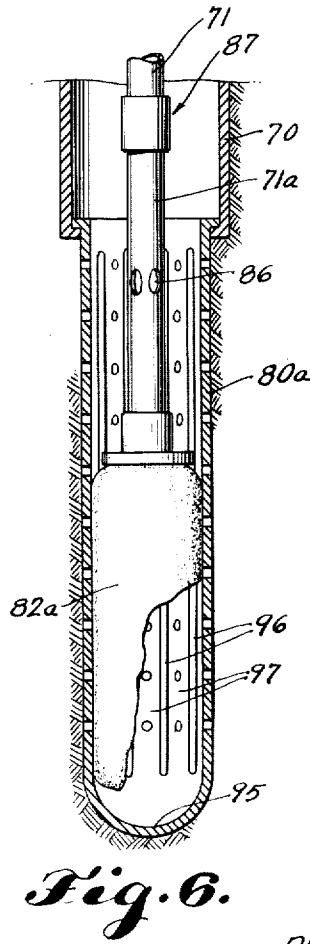
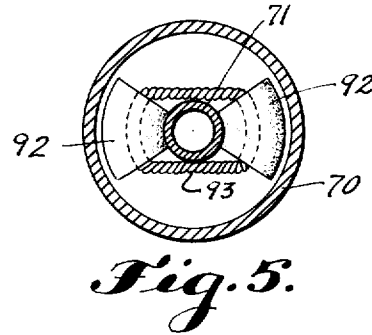
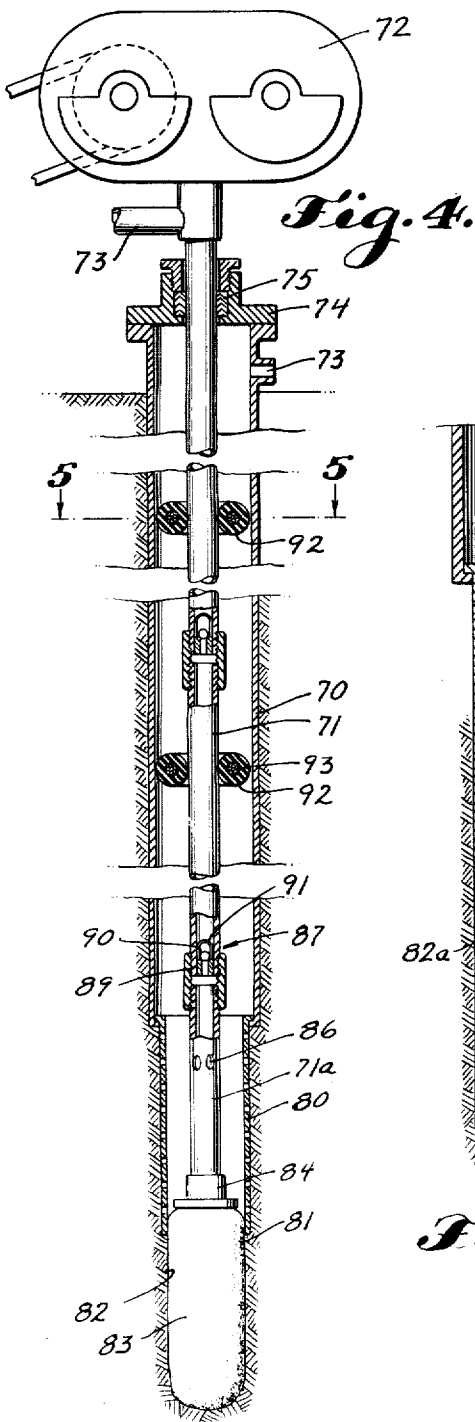
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UNITED STATES PATENT OFFICE

2,680,485

APPARATUS FOR AUGMENTING THE FLOW
OF OIL FROM PUMPED WELLS

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Application July 23, 1948, Serial No. 50,428

17 Claims. (Cl. 166—1)

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This invention relates generally to systems for increasing the flow of wells, particularly oil wells, and deals more especially with a system operable in conjunction with an oil well pump for increasing the normal flow from the oil bearing strata to the pump by application to the strata of elastic waves of sonic character, i. e., waves of compression and tension travelling in the strata at the speed of sound.

The present application is a continuation-in-part of my prior application entitled Method and Apparatus for Boundary Layer Control, Serial No. 771,908, filed September 2, 1947, which application was a continuation-in-part of my prior application entitled Method and Apparatus for Pumping, Serial No. 761,456, filed July 17, 1947, and issued as Patent Number 2,444,912 on July 13, 1948. The present application is also a continuation-in-part of my prior application entitled Sonic System for Augmenting the Extraction of Oil from Oil Bearing Strata, Serial No. 8799, filed February 17, 1948, now Patent No. 2,667,932.

The above-mentioned parent applications, together with my United States Patent Number 2,437,458, deal broadly with methods and apparatus for augmenting the flow from oil bearing strata to a well by application to the strata of elastic waves of sonic frequency (e. g., 20 to several thousand c. p. s.) in such a manner as to cause such waves to travel in the strata for substantial distances from the well, i. e., up to several hundred feet radially into the formation. The precise explanation of the phenomena involved has not been determined with absolute certainty to the present time, but experimental evidence reveals an increase in the mobility of the oil contained in the sandstone up to the order of 50%. By contrast, no increase is found in the rate of travel of water under the same conditions. The various factors involved appear to include heating of the petroleum fluids as a result of sound wave energy dissipation, causing increased gas pressure, as well as reduction in the viscosity of the oil, and therefore augmented oil migration through the formation. Again, it is known that oil is trapped in earthen formations by water films bridging the gaps between sand particles, or closing off the pores in the formation. Periodic vibration of the formation by transmitting sound waves therethrough causes or permits the oil droplets to puncture these water films, and so to become freed for migration. As a further factor, it is known that oil exhibits boundary layer adhesion to the surfaces of the sandstone, which seriously impedes the flow of the oil to the well.

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This boundary layer condition can be materially reduced by transmitting sound waves through the sandstone, which has the effect of reducing the frictional drag of the formation on the well fluid by agitating, breaking up and scrubbing away the boundary layers of the fluid which are otherwise bound adhesively to the formation.

The above-mentioned parent applications disclose various methods and apparatus for generating sound waves, and applying the same to the formation for transmission therein to accomplish the desirable ends already mentioned. In those applications there have been disclosed several embodiments of the broad invention characterized by the application of the invention to the well pump itself, and the present application is directed broadly to these applications of the invention, and contains applicant's broader claims directed thereto.

A major object of the invention may therefore be stated to be to provide a method and apparatus for utilizing a deep well pump, or an auxiliary apparatus associated with a deep well pump, for radiating sound wave energy into the formation for the purpose of augmenting the rate of migration of well fluids from the formation to the well.

It is known that the flow of oil through an oil bearing formation to a well bore sunk therein depends, in the last analysis, upon the pressure differentials between points in the formation, on the one hand, and the interior of the well bore, on the other. A feature of the present invention is the radiation of sound waves deep into the formation, thus enhancing the ability of the oil to travel through the formation according to the principles discussed in the foregoing, and simultaneously therewith, lowering the pressure in the well bore by operating a pump therein, thus increasing the pressure differential between the formation and the well bore. This novel process consisting in simultaneous radiation of waves from the bore into the formation, and lowering of the pressure in the well bore, thereby increasing the pressure differentials as described, establishes optimum conditions for recovery of oil, and will not only augment the flow from a satisfactorily producing well, but will enable oil recovery on an economic basis under conditions otherwise so unfavorable as would indicate abandonment of the well.

According to one major variant of the invention, there is utilized a sonic deep well pump of the general type disclosed in my aforesaid Patent Number 2,444,912, and which in a typical form is characterized by longitudinal transmission of

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 sound wave energy from a wave generator at the ground surface down the pump tubing, resulting in a vertical oscillation of the lower end of the pump tubing and of a check valve carried thereby. The check valve alternately opens and closes with the oscillatory movement of the tubing, and pumps well fluid up the tubing as fully explained in said prior patent. The lower end portion of this pump tubing is, according to the invention, so formed as to act at the same time as a generator of sound waves which are transmitted to and thence radiated into the formation.

According to another major variant of the invention, an ordinary conventional sucker rod pump is employed, but to the lower end of the pump tubing is suspended a sound wave generator, which is driven by pressure energy bled off from the liquid column in the pump tubing. It will be seen that in both cases, I accomplish, first, pumping within the well, so as to lower the pressure in the lower end of the well bore and thus increase pressure differentials between points in the formation and the well bore, and at the same time, and simultaneously therewith, I accomplish radiation of sound wave energy through the oil bearing formation.

Various additional objects and features of the invention will appear from the following detailed description of present illustrative embodiments thereof, reference for this purpose being had to the accompanying drawings, in which:

Figure 1 is a view partly in longitudinal section and partly in elevation, showing an embodiment of the invention;

Figure 2 is a cross-section taken on line 2-2 in Figure 1;

Figure 3 is a view, partly in longitudinal section and partly in elevation, showing another embodiment of the invention;

Figure 4 is a view partly in longitudinal section and partly in elevation, showing another embodiment of the invention;

Figure 5 is a cross-section taken on line 5-5 of Figure 4;

Figure 6 is a view showing another modification of the embodiment of Figure 4; and

Figure 7 is view showing another modification of the embodiment of Figure 4.

Referring first to the embodiment of the invention shown in Figures 1 and 2, numeral 10 designates generally the usual perforated casing embedded in production formation 11. Pump tubing 12, only fragmentarily illustrated, and which will be understood to be entirely conventional in its extension to the ground surface, has mounted therein the usual plunger 13 carrying travelling valve 14 and adapted to be reciprocated by sucker rod string 15. The drawing shows only the lower portion of the well, the well equipment above and at the ground surface being understood as entirely conventional and not requiring illustration herein. Pump tubing 12 has screwed onto its lower end a tubular body 16 having a laterally opening intake port 17 controlled by standing valve 18 and urged against its seat by spring 19. Below valve 18 is a wall 20 pierced by a small fluid port 21, which may discharge fluid downwardly from the pump tubing into a pipe section 22. To the lower end of the latter is coupled, as by flexible coupling 23, a sound wave generator which in this specific illustrative embodiment comprises a gyratory elastic tube or pipe section 25, which in the present instance carries at its lower end a fluid driven wave generator unit 26. The latter comprises a head 27 coupled to

the lower end of pipe section 25 and furnished with an internal annular groove forming a race 28 for a gyrating ball 29, the latter being driven by a tangential fluid jet discharged from tangential nozzle 30 communicating as indicated with the lower end of pipe section 25. The lower end of body 27 has a fluid discharge port 31.

In operation, the pressure of the fluid column which exists in the pump tubing during pumping operation, just as in all conventional pumps of this type, is imposed on the fluid at nozzle 29 during each down stroke of the pump plunger 13 (the valve ball 14 being unseated at such time), and fluid is accordingly discharged from nozzle 29 to drive ball 29 in a circular path at relatively high velocity. This gyrating ball exerts a centrifugal force against the lower end of the elastic pipe 25, causing the latter to be continuously subjected to a rotating force vector in a transverse plane. The force vector is designed to be of sufficient magnitude to bend or deflect the lower end of the pipe in a circular path in a transverse plane. This circular bending deflection of the elastic pipe 25 is propagated the length of the pipe so that each section thereof participates in the gyratory action. The nozzle may be designed to drive the ball, under the column pressure available, at any desired speed, usually in the range of 10 to 1000 R. P. S. Preferably the frequency of rotation of the ball is made to correspond with the fundamental resonant frequency of the pipe 25, which results in resonating the pipe and establishing a standing wave therealong, the latter being characterized by velocity nodes (points of minimum transverse deformation) located at $\frac{1}{4}$ of its length from each end, and velocity anti-nodes (points of maximum transverse deformation) at its center and at both ends. This standing wave is the result of elastic waves of transverse deformation propagated longitudinally up pipe 25 and reflected from its upper end, the reflected waves interfering at the resonant frequency to give the nodes and anti-nodes as described.

It should be noted that the gyratory deformation of each section of the pipe may be analysed to be the resultant of two transverse vibrations occurring in directions at right angles to one another, and with 90° phase difference between them. The generator thus combines the effect and power of two uni-directional vibrators operating in quadrature on direction lines at right angles to one another, and is therefore, in effect, a harmonic vibration generator. It is of course within the scope of the invention to substitute a generator which oscillates or vibrates in but one direction. The action of the pipe 25, whether gyratory (oscillation along two direction lines in quadrature phase) or oscillatory (to and fro) along a single direction line, results in transmission of elastic wave energy to and radially outward through the immediate surrounding medium, which is the well fluid understood to be present in the casing. The sound waves in the well fluid are thus transmitted to the casing, and the casing also set the casing into vibration, and the casing in turn transmits the sound waves into the oil bearing formation. The sound waves thus applied to the formation are transmitted therein for substantial distances as elastic waves of tension and compression, travelling with the velocity of sound in the medium, and as already explained,

these waves augment the oil flow rate through the formation and from the formation into the well. In operation, the pump plunger 13 is reciprocated by means of sucker rod string 15 and the usual reciprocating mechanism at the ground surface (walking beam or the like) with the effect of raising the oil column in the tubing 12, and with the further effect of depressing the pressure within the casing 10 at the bottom of the well. This lowered pressure of course results in migration of oil flow to the well from the surrounding formation, and in combination with the effects of the radiated sound waves, there is achieved a substantially augmented production rate from the well. In many cases, marginal wells can in this manner be placed back on economic production, and in substantially all cases, enhanced production can be achieved.

Reference is next directed to the embodiment of Figure 3, which illustrates a form of the invention applied to a sonic pump of the type first disclosed in my aforesaid Patent Number 2,444,912. In said figure, numeral 36 designates the perforated casing in the well bore, and 37 is an elastic steel pump tubing suspended therein from coil type springs 38, the upper end of said tubing delivering well fluid to pipe 39. A sonic wave vibration generator 40, afterwards to be described, is mounted on the top end of the tubing, and operates to send alternating longitudinal waves of tension and compression down the tubing 37 for transmission to the lower end thereof. Considering the support of the pump tubing from the spring 38 in more detail, the tubing 37 has near its upper end an enlarged head or collar 41. The tubing 37 is received in an aperture 42 formed in a horizontal top plate 43, the head 41 overhanging and bearing downwardly on said plate around aperture 42 for the support of the column. Vertically spaced below top plate 43 is a horizontal bottom or base plate 44 carried by a tubular member 45 and flange 46 bolted to casing head flange 47. Between base plate 44 and top plate 43 are a plurality of coil springs 48, positioned on vertical pins 49 set tightly into base plate 44 and projecting with a working, sliding fit through bores 50 in top plate 43. The weight of the tubing 37 is thus transferred to springs 38, and thence to the casing supported by the earth.

Coupled to the lower end of the tubing is an enlarged tubing section or hollow piston 52, of substantial length, preferably approximately a quarter-wave length of the wave generated in the pump tubing by the oscillation generator 40. This enlarged tubing section or piston 52 has a relatively close fit with the casing, so as to prevent substantial liquid flow in an upward direction in the annular space between it and the casing. The lower end portion of the piston 52 has a bottom closure wall 54, furnished with perforations 55 forming valve passages controlled by a like plurality of ball valves 56, the latter being furnished with suitable cages 57 of any desired character. In the illustrated embodiment, the lower end of casing 36 carries a perforated line 60, having a closed bottom 61 resting on the bottom of the well hole.

The vibration generator 40 may be of any desired type, but as here shown is provided with a casing 62 within which are meshing oppositely rotating gears 63 carrying eccentric weights 64 which balance out horizontal vibrations but causing vertical vibrations to be additive to produce a substantial resonant oscillatory force in a vertical direction. The driving pulley 65 of the sound

wave generator, mounted on the shaft for one of the spur gears, is driven by an electric motor or any other suitable prime mover (not shown) through belt 66.

In operation, this generator 40 transmits elastic waves of tension and compression down the pump tubing, causing the check-valved piston 52 at the lower end thereof to be longitudinally reciprocated through a short displacement distance at the frequency of operation of the generator. This action, and the preferred establishment of resonance in the tubing, are fully discussed in my Patent Number 2,444,912. Each down stroke of bottom end wall 54 with the tubing occurs at an acceleration greater than gravity, and the check valve balls accordingly unseat during such time. Fluid displaced by the downwardly travelling wall 54 therefore flows upwardly through the ports 55 and fills the void above the wall 54 caused by the down stroke of the latter. On the up stroke, the check valve balls will seat, and the column of fluid thereabove is elevated. The oscillating piston 52, working with relatively close fit within the casing, functions to move a substantial quantity of well fluid, and hence furnishes a good wave transmission coupling to the fluid. Sound waves are accordingly set up in the fluid, travelling downwardly to the lower end of the liner, where they are reflected and returned upwardly. Pressure and velocity impulses are thus created within the liquid medium, and these are transmitted to the liner and to the surrounding formation, being thus applied to the formation and thence radiated for substantial distances in the formation as elastic waves travelling in the formation with the speed of sound.

It should be noted that of the many embodiments of pump disclosed in my aforesaid Patent No. 2,444,912, only that of Figures 5 and 6 will afford any practical degree of coupling with the liquid. In the other embodiments, sound waves would not in practice be radiated as far as the oil bearing formation outside the casing. For example, the end area of the pump tubing in the embodiment of Figure 4, or the end area of any of the pistons used with the embodiment of Figure 20, would be an insufficient fraction of the cross-sectional area of the casing for any effective wave transmission coupling to the external well fluid to be expected. The insignificant amount of fluid moved by these areas on each down stroke thereof simply escapes by moving radially out of the way and then up in the large annular space between the pump tubing and the casing, with exceedingly poor coupling efficiency. By having the pumping member nearly fill the casing, however, as does the flared type of tubing end of Figures 5 and 6 of said patent, a substantial quantity of fluid is positively driven, as by a piston in a cylinder, and sufficient wave energy is transferred to the well fluid to be radiated out into the formation. Even with the embodiment of Figures 5 and 6 of said patent, however (see also Figure 6 of my application Serial No. 8,799), there is some disadvantage in that a substantial quantity of fluid is enabled to escape up or down past the flared tubing end on each of its strokes. This by-passing fluid represents loss of sound wave energy, and the improved embodiment shown in Figure 3 of the present application, characterized by the provision of a long close-fitting lower tubing section or piston 42, minimizes this loss, and assures maximum radiation of sound wave energy.

My prior Patent No. 2,444,912 has described

in detail the generation of sound waves of such frequency as will establish longitudinal waves of compression and tension in the pump tubing, these waves being of a wave length which is preferably short relative to the length of the tubing, and in no event longer than substantially four times the tubing length. Said prior patent also described the preferred establishment of standing wave resonance in the pump tubing, and described how the sound waves in the tubing cause vertical oscillation of the check-valved lower end of the tubing, and consequent pumping.

It will be evident how the closed, check-valved lower end of the enlarged tubing section or piston 52 of the present invention, oscillating vertically at the lower end of the pump tubing, will transmit longitudinal sonic waves to the liquid column 1 in the liner below. It is preferred, for maximum energy transmission, to establish a condition of substantial standing wave resonance in the liquid column 1, and a desirable condition in accordance with the invention is a correlation between sound wave frequency and liquid column length establishing substantially an odd number of quarter wave lengths in the liquid column. In this connection, it will of course be understood that a wave length for a given frequency will not be the same in the liquid column as in the steel pump tubing because of the differing velocities of sound in the two media. From a practical standpoint, the standing wave in the liquid column in the liner may be between a quarter and a half wave in length, a wave length in this sense being the length of a wave in the well fluid at the sonic frequency prevailing. A standing wave a little longer than a quarter wave in length is diagrammed in Figure 2 at s, the wave envelope indicating velocity amplitude of liquid particles of the column.

In practice, oscillator 40 is preferably operated at a frequency which will establish a longitudinal standing wave in the pump tubing, thus assuring pumping under optimum conditions, and at a frequency which will also establish a standing wave in the liquid column within the liner. To accomplish this last, adjustment in the length of the liquid column may be made by raising or lowering the pump tubing. It will usually be possible to readily find an operating frequency and a liquid column length such that an overtone frequency of the fundamental generated will give the desired condition of standing wave resonance in the liquid column. In some cases the tubing will resonate at the fundamental, and in some it too will resonate at an overtone frequency.

Under the standing wave conditions described, liquid particles comprising the column 1 will oscillate at high amplitude, and high amplitude pressure waves will accordingly be created and will impinge on the walls of the casing and/or liner, causing the same to vibrate strongly against the formation and thus apply wave energy thereto. This wave energy is thereupon propagated in the formation as elastic waves of compression and tension, travelling in the formation with the speed of sound. The resonated liquid column thus serves as a sonic wave coupling medium between the enlarged wave-generating lower end of the pump tubing and the formation.

Figure 4 shows another embodiment of the invention employing a sonic type of deep well pump, but having characteristics departing from those of the embodiment of Figure 3.

Numeral 70 designates the casing in the well bore, and 71 the elastic steel pump tubing, again provided at the top with sonic wave vibration generator 72 (which may be the same as the corresponding generator of the embodiment of Figure 3). The upper end of tubing 71 is provided with flow delivery pipes 73. Casing head 74 has a packing 75 permitting some degree of vertical oscillation of the pump with reference to the casing head and casing. The upper end of the casing is provided with gas vent 77.

In the present illustrative embodiment, the lower end of the casing carries a perforated liner 80, cut off a predetermined distance below the lower end of the well hole, is indicated at 81. In the open well hole 82 below the lower end of the liner is positioned a solid rubber column 83 of some elastic rubber-like material, preferably a synthetic capable of withstanding deleterious action of the well fluids. The lower end of pump tubing 71 carries a flanged collar 84 which rests on the upper end of this solid rubber column 83, and the entire weight of the pump tubing and sound wave generator 72 is imposed on the rubber column. The pump tubing thus stands in compression on the rubber column, compressing the latter vertically and causing it to expand laterally into intimate pressural contact with the sides and bottom of the well hole.

The tubing 71 has a section 11a opposite perforated liner 80 which is provided with fluid inlet holes 86, and a short distance thereabove the tubing is provided with a check valve unit 87, comprising seat ring 89, valve ball 90, and cage 91. Additional check valve units of a similar nature may be provided, if desired, at vertically spaced points in the pump tubing, at such spacings and for purposes clearly discussed in my aforesaid prior Patent No. 2,444,912.

To center the pump tubing in the casing, and to prevent engagement between the tubing and casing such as would result in loss of vibration energy into the casing, I preferably utilize on the casing a plurality of rubber spools 92, secured in place with a cable 91 which passes through the spools and encircles the tubing, as clearly indicated in Figures 4 and 5. Each such spool 90 is similar in shape to a segment of a doughnut. These spools have radii 92 and 93 conforming with the radii of the pump tubing and casing, respectively. A number of these rubber spool units may be used on the tubing at suitably spaced vertical intervals.

In operation, the vibration generator 72 launches longitudinal waves of tension and compression down the pump tubing, these waves travelling to the lower end of the tubing, and there being reflected back up the tubing as fully described in my pump Patent Number 2,444,912.

Portions of the tubing are thus set into vertical oscillatory movement as a result of the passage of these waves, and the described check valves in the tubing therefore oscillate vertically, causing well fluid entering the tubing by way of ports 86 to be pumped up the tubing to the delivery pipe 73 at the top. It will be evident that the pump tubing may have some vertical oscillatory movement with reference to the casing head 74 at the top, but this is accommodated by the packing 75.

The particular novel characteristic of the embodiment of Figure 4 is the resting of the lower end of the pump tubing on the solid rubber column 83, the tubing thus standing in compression, and placing the rubber column under compression, so that it expands laterally into intimate

contact with the formation. In the operation of the pump, the lower end portion of the pump tubing oscillates vertically against the rubber column 83, thus transmitting sonic waves of tension and compression to the rubber column, and these waves are in turn applied by the rubber column to the walls of the formation, whence they are radiated in the formation as elastic waves traveling with the velocity of sound. The solid rubber column thus serves in this instance as the coupling means between the longitudinally oscillating pump tubing and the formation. It is of advantage, though not an essential, to generate a sonic frequency by means of generator 12 which will resonate the tubing 71 and set up a condition of standing wave resonance therein. Preferably, the wave frequency will be such as to establish a velocity anti-node (point of maximum velocity amplitude) at the lower end of the tubing. The upper end of the tubing will of course be the location of another velocity anti-node, and there may be additional velocity anti-nodes spaced a half wave length apart along the length of the tubing. If a plurality of check valves are employed, these will preferably be located at or near these velocity anti-node regions. The lowermost check valve 87 may advantageously be located sufficiently near the lower end of the tubing to have substantial velocity amplitude by reason of its proximity to the lowermost velocity anti-node of the tubing. Alternately, the lowermost check valve 87 may be located adjacent the velocity anti-node next above that at the lowermost end of the tubing. As stated, standing wave resonance is the preferred and most efficient type of operation, and results in maximum energy transference down the pump tubing and into the formation. However, substantial quantities of energy can be transmitted down the tubing and into the formation even without standing wave resonance, and this feature is accordingly to be considered as an important and preferred feature, but one not entirely indispensable to successful operation.

In Figure 6 I have shown a modification of the lower end portion of the apparatus of Figure 4, wherein the perforated liner, designated in this instance by numeral 82a, is not cut off at or just below the lower end of the pump tubing, but extends downwardly and is provided with closed lower end 95. The rubber column, indicated in this instance by numeral 82a, here is inserted inside the liner, and is compressed tightly thereagainst by assuming the weight of the pump tubing, the same as in Figure 4. To facilitate radial expansion and contraction of the liner section occupied by the rubber column 82 with the cyclic expansive forces exerted by the latter in the operation of the pump, the liner may be formed with a plurality of longitudinal slots or splits 96.

The operation of the modification of Figure 6 is in all fundamental respects the same as that of Figure 4, with the additional feature that the straps 97 intervening between the slots 96 alternately bulge and contract with the cyclic expansive and contractive movements of the rubber column 82a under the sonic wave impulses received from the lower end of the pump tubing resting thereon. The alternately bulging and contracting straps 97, in intimate contact with the formation, will be seen to apply sonic vibratory energy to the formation, causing elastic waves to be radiated in the formation as before.

Figure 7 shows a further modification of the lower end portion of Figure 4, wherein the liner, 75

designated in this instance by numeral 100, has at the top an outwardly turned flange 101 resting on a rubber ring 102 carried by the inturned flange 103 on the lower end of casing 104. Pump tubing 105, understood to be of elastic steel and to be equipped at the top with a vibration generator like that employed in the other embodiments, is screwed into a coupling 110 furnished with an external annular flange 111 which rests on the liner flange 101, and is therefore resiliently supported by the rubber ring 102. The pump tubing is continued downwardly within the perforated liner 100 by a tubing section 105a screwed at the top into coupling 110, and this tubing section 105a is provided near the bottom with a check valve unit 114 having the usual seat ring 115 and check valve ball 116.

The novel characteristic of the embodiment of Figure 7 is that the pump tubing stands in compression against the top of the liner, which is in turn resiliently supported upon the lower end of the casing. Sound waves travelling longitudinally down the pump tubing from the sound wave generator at the top will effect a vertical oscillation of the coupling member 110, causing the liner to oscillate vertically on the resilient ring 102. The lower end of the liner will be understood to be resting on bottom, and the liner will accordingly be caused to alternately expand and contract at the sonic frequency of the vibration generator, thereby applying sonic wave energy to the walls of the formation, whence elastic waves of tension and compression are set up in the formation and are propagated deep into the formation with the velocity of sound. The liner will, in addition, have a substantial degree of vertical oscillation, which will result in transmission of shear waves into the formation.

Several of the illustrative embodiments of the invention have shown a conventional installation employing a perforated liner suspended from the lower end of the casing. It will be understood that this is for illustrative purposes only, and that the invention is equally applicable to other conventional types of oil well installations including those wherein the casing itself is perforated and no liner is employed, as well as those in which an unlined open hole is provided below the lower end of the casing.

The invention thus provides a process for augmenting the production from a pumped oil well by radiating into the formation elastic waves of sonic frequency (by which is meant frequencies anywhere in the approximate range of 20 to several thousand C. P. S.), thereby increasing the ability of the petroleum fluids to migrate through the formation, and, at the same time, depressing the pressure in the lower end of the well bore by operation of the well pump, whereby the petroleum fluids in the formation, whose mobility is increased by the sonic vibratory action in the formation, is caused to migrate through the formation in the direction of the well bore under augmented pressure differentials. The further advantage is gained that a producing well can thereby be maintained in constant state of optimum flow, as distinguished from a practice consisting in occasionally pulling the pump, and treating the formation by means of sound wave equipment run into the hole in the place of the pump for the purpose of shaking and opening up the formation for freer flow to the well. Maximum recovery from a given well is assured by the use of a device in accordance with the invention, used in conjunction with or operated by the

pump, to sustain continuing elastic waves in the oil bearing formation around the well bore during actual pumping of the well.

A number of present embodiments of the invention have been disclosed for illustrative purposes only, and it will be understood that various changes in design, structure and arrangement may be made in these illustrative embodiments without departing from the spirit and scope of the invention as defined in the appended claims.

1 claim:

1. In an oil well, the combination of: a well pump operable within the well bore, said pump including a pump tubing and a check-valved plunger reciprocable therein, and a sound wave generator in the well bore below said pump tubing operable by the hydrostatic pressure head of well fluid in said pump tubing to generate sound waves and to radiate said waves into the surrounding oil bearing formation.

2. Apparatus for pumping a well and for simultaneously augmenting the flow of well fluids from the surrounding formation to the well bore, that comprises: an elastic tubing positioned in said well bore and reaching from the ground surface to the region of the oil bearing formation, a laterally enlarged piston element on the lower portion of said tubing in the space between the tubing and the wall of the well bore, a check valve at the lower end portion of said tubing, and a generator of elastic waves at the ground surface drivingly coupled to said elastic tubing to send alternating longitudinal deformation waves of tension and compression down the same whereby to vertically oscillate the lower end portion of said tubing and said check valve and piston element.

3. Apparatus for augmenting the fluid flow through a porous fluid bearing earthen formation surrounding a well bore sunk therein, that comprises: an elastic tubing positioned in said well bore and reaching from the ground surface to the region of the oil bearing formation, resilient means supporting said tubing near the upper end thereof, whereby said tubing is suspended in tension, a laterally enlarged piston element on the lower portion of said tubing in the space between the tubing and the wall of the well bore, and a generator of elastic waves at the ground surface drivingly coupled to said elastic tubing to send alternating longitudinal deformation waves of tension and compression down the same whereby to vertically oscillate the lower end portion of said tubing and said piston element.

4. Apparatus for augmenting the fluid flow through a porous fluid bearing earthen formation surrounding a well bore sunk therein, that comprises: an elastic tubing positioned in said well bore and reaching from the ground surface to the region of the oil bearing formation, a resilient column lodged in the lower end of the well bore in engagement with the wall surfaces of said bore, the lower end of said tubing resting on said column, and said tubing standing in compression on said column, and a generator of elastic waves at the ground surface drivingly coupled to said elastic tubing to send alternating longitudinal deformation waves of tension and compression down the same whereby to vertically oscillate the lower end portion of said tubing and said resilient column, whereby said column is cyclically deformed and exerts corresponding periodic deformation forces on the wall surfaces of said bore causing elastic waves of compression

and tension to be set up and propagated in the formation.

5. A combination as defined in claim 4, wherein said resilient column comprises a solid body of rubber-like material in intimate engagement with the adjacent sides and bottom of the well bore.

6. Apparatus for pumping a well and for simultaneously augmenting the flow of well fluids from the surrounding formation to the well bore, that comprises: an elastic tubing positioned in said well bore and reaching from the ground surface to the region of the oil bearing formation, an oil inlet opening in the side of said tubing near the lower end thereof, a check valve in the lower portion of said tubing above said inlet opening, a solid body of resilient, rubber-like material lodged in the lower end portion of the well bore in intimate engagement with the adjacent sides and bottom of the well bore, the lower end of said tubing resting on said body, and the tubing standing in compression thereon, and a generator of elastic waves at the ground surface drivingly coupled to said elastic tubing to send alternating longitudinal deformation waves of tension and compression down the same whereby to vertically oscillate the lower end portion of said tubing and said check valve and resilient body, whereby said check-valve cyclically lifts well fluids in said tubing, and whereby said resilient body is cyclically deformed and exerts corresponding periodic deformation forces on the wall surfaces of said bore causing elastic waves of compression and tension to be set up and propagated in the formation.

7. Apparatus for augmenting the fluid flow through a porous fluid bearing earthen formation surrounding a well bore sunk therein, that comprises: an elastic tubing positioned in said well bore and reaching from the ground surface to the region of the oil bearing formation, a resilient body supported in the lower end of said bore in pressure wave transmitting relation with said earthen formation, the lower end of said tubing supported on said body, and said tubing standing in compression supported by said body, and a generator of elastic waves at the ground surface drivingly coupled to said elastic tubing to send alternating longitudinal deformation waves of tension and compression down the same whereby to vertically oscillate the lower end portion of said tubing and said resilient body, whereby said body is cyclically deformed and transmits corresponding periodic compressive forces on said earthen formation causing elastic waves of compression and tension to be set up and propagated in the formation.

8. Apparatus for augmenting the fluid flow through a porous fluid bearing earthen formation surrounding a well bore sunk therein, that comprises: an elastic tubing positioned in said well bore and reaching from the ground surface to the region of the oil bearing formation, a resilient body supported in the lower end of said bore and coupled to said formation to transmit pressure impulses thereto by virtue of periodic deformation of said body, the lower end of said tubing supported on said body, and said tubing standing in compression supported by said body, and a generator of elastic waves at the ground surface drivingly coupled to said elastic tubing to send alternating longitudinal deformation waves of tension and compression down the same whereby to vertically oscillate the lower end portion of said tubing and said resilient body, where-

by said body is cyclically deformed and transmits corresponding periodic compressive forces on said earthen formation causing elastic waves of compression and tension to be set up and propagated in the formation.

9. Apparatus for pumping a well and for simultaneously augmenting the flow of well fluids from the surrounding formation to the well bore, that comprises: an elastic tubing positioned in said well bore and reaching from the ground surface to the region of the oil bearing formation, a check valve at the lower end portion of said tubing, a generator of elastic waves at the ground surface drivingly coupled to said elastic tubing to send alternating longitudinal deformation waves of tension and compression down the same whereby to vertically oscillate the lower end portion of said tubing and said check valve, and radiating means on said lower end portion of said tubing for radiating vibrations into the surrounding well fluids and formation.

10. For use in reducing the clogging of oil flow passages in a production oil well having a pump tubing and pump means connected thereto, an elastic sound wave generator with an output characteristic adapted to generate elastic sound waves for liquid and solid media having the resistance of petroleum containing media to sound wave vibration at the frequency of said generator, an elastic sound wave transmitting means operatively combined with said generator and adapted to couple said generator to a liquid or solid wave energy receiving media in said well, said transmitting means having an attachment means for mounting it on the pump tubing of said well and near the inlet of said pump, so as to position said transmitting means in the producing region of said well, and a power connection means for connecting said generator to a power source in said production field, whereby a sufficient average rate of power delivery may be conducted from said power source to said transmitter and radiated therefrom as elastic sound wave energy which is thereafter transmitted into said producing field so as to reduce the clogging of the oil flow passages and thereby increase the average production rate for said production well.

11. A combination as defined in claim 10 wherein the said generator is a vibrator connected to said production tubing so as to generate vibrations therein, and wherein said wave transmitting means is connected to said tubing so as to receive vibrations therefrom.

12. A combination as defined in claim 10 wherein said wave transmitting means has an enlarged surface for contact with well fluid.

13. For use in reducing the clogging of oil flow passages in a production oil well having a production tubing and pump means connected thereto, an elastic sound wave generator with a coupling means for connecting to the production tubing of said well and having an output characteristic adapted to generate elastic waves of tension and compression in said tubing at the frequency of said generator, an elastic sound wave transmitting means adapted to couple said tubing to a liquid or solid wave energy receiving media in said well, said transmitting means having an attachment

for mounting it on said production tubing of said well so as to be vibrated in response to said waves in said tubing, and a power connection means for connecting said generator to a power source in said production field, whereby a sufficient average rate of power delivery may be conducted from said power source to said transmitter and radiated therefrom as elastic sound wave energy which is thereafter transmitted into said producing field so as to reduce the clogging of the oil flow passages and thereby increase the average production rate for said production well.

14. Apparatus for augmenting the fluid flow through a porous oil bearing earthen formation surrounding a well bore sunk therein, comprising: a casing lining the well bore, a perforated liner at the lower end portion of said casing, an elastic tubing positioned in the well bore and reaching from the ground surface to the region of the oil bearing formation, said tubing being adapted at its lower end portion for firm engagement with said liner, and a generator of elastic waves at the ground surface drivingly coupled to said elastic tubing to send alternating longitudinal deformation waves of tension and compression down the same whereby to vertically oscillate the lower end portion of said tubing and said liner.

15. A combination as defined in claim 14, wherein the casing and liner have overlapped oppositely facing shoulders, and a resilient element is positioned between said shoulders to provide a resilient support of the liner on the casing.

16. For use with vibratory sonic pumps in an earthen well, an acoustic coupler for radiating elastic waves into said well, said coupler being constructed and arranged for mounting on said pump adjacent the pump inlet and so as to be vibrated by the pump, said coupler also having a wave transmitting surface for contact with liquid or solid media in said well when said coupler is mounted on said pump, and said coupler having a wave transmitting response when vibrated at the frequency of vibration of said pump.

17. In oil well producing apparatus, the combination of: a deep well pump operable within a well bore, said pump having a pump tubing, a sound wave radiator mounted near the lower end portion of said tubing and positioned opposite the production formation and adjacent the pump inlet, said radiator being acoustically coupled to the surrounding well fluids and solid formation, and a sound wave generator coupled to said radiator so that said radiator radiates sound waves into the formation while said pump creates pressure differentials between the formation and said well bore.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,056,513	Cambarini	Oct. 6, 1936
2,444,912	Bodine	July 13, 1948

FOREIGN PATENTS

Number	Country	Date
472,864	Germany	Feb. 14, 1929