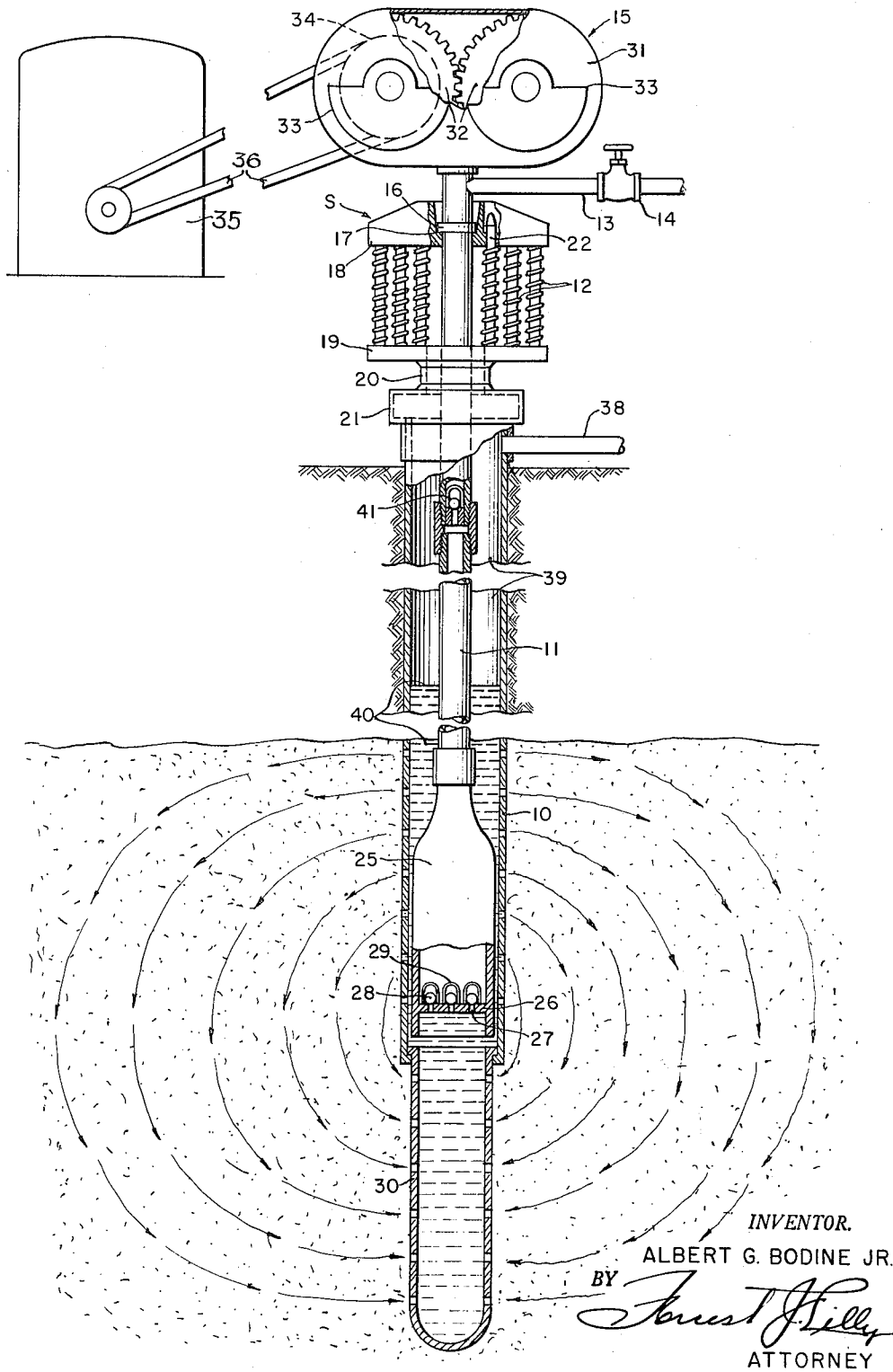


Dec. 22, 1959

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SONIC METHOD OF INJECTING AND CIRCULATING
CHEMICALS IN OIL WELL FORMATION
Filed April 16, 1957

2,918,126



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SONIC METHOD OF INJECTING AND CIRCULATING CHEMICALS IN OIL WELL FORMATION

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Application April 16, 1957, Serial No. 653,102

9 Claims. (Cl. 166—42)

This invention relates generally to the art of chemical injection into, or treatment of, oil wells, and pertains more particularly to sonic methods and apparatus for achieving more effective and deeper dispersion of the introduced chemicals into the oil bearing formation.

Chemical treatment of oil wells, for various purposes, is of course a common practice, the various chemicals used having different effects upon the formation materials in the region around the well. For example, glacial acetic acid acts to remove limes to improve porosity. A range of organic solvents take into solution the large molecule solid and semisolid hydrocarbons which have been deposited over long time intervals of oil flow to the well. Crude oil will also deposit water, which tends to reduce the permeability of the formation adjacent the well. Certain chemical wetting agents or surfactants are effective in mobilizing such deposited water.

Such chemicals have heretofore been generally introduced by literally dumping them into the well. Penetration distance into the well formation, however, is quite limited. It has sometimes been the practice to wash out the perforations in the well casing so as to increase the contact of chemicals with the formation spots which are exposed by the perforations. The perforations are in this case washed by use of an oil well service tool which jets a spray of liquid against the perforations. These well washing tools are of advantage only, however, in instances in which the inside wall of the casing and the perforations have become coated with heavy gelatinous material from the crude oil.

In my Reissue Patent No. Re. 23,381, issued June 26, 1951, I have disclosed the impressing of vibrations upon a descending stream of washing or solvent liquid for the purpose of causing these liquids to work on the casing and formation in an improved manner. As disclosed therein, and also in my Patent No. 2,680,485, issued June 8, 1954, sound waves radiated into the formation greatly facilitate the penetration of the porous formation medium by fluids. More specifically, Patent No. 2,680,485 discloses various forms of auxiliary device incorporated in a sonic type pump for the purpose of causing such pump to radiate sound waves into the formation at substantial energy levels, for the purpose of increasing flow of well fluids from the formation to the pump. The present invention is concerned with the use of such a sonic pump, incorporating a sound wave radiation action, used and arranged in a novel manner which gives unexpected results of deep penetration in connection with the introduction of chemicals into the bottom of the well for the purpose of causing penetration of such chemicals into the formation, and for the further purpose of causing such introduced chemicals to be circulated through a substantial region of the formation and thence back to the sonic pump to be pumped back to the ground surface.

A general object of the invention may be stated to be to accomplish, using a sonic pump equipped with a

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sound wave radiator, a substantially improved degree of penetration of the formation by introduced chemicals, and a circulation of said chemicals from the well bore deep into the formation, and thence through the formation in a return path back to the intake of the pump for return to the ground surface.

The invention can best be described, along with further objects and the various features of the invention, in connection with a suitable embodiment of sonic pump and sound wave radiator such as shown in the accompanying drawings, in which the single view shows partly in longitudinal section and partly in elevation an illustrative form of sonic pump and radiator arranged for the practice of the invention.

Referring to the drawing, numeral 10 designates the perforated casing in the well bore, and 11 designates an elastic steel pump tubing suspended therein from coil springs 12, the upper end of said tubing being adapted to deliver well fluid to pipe 13 having control valve 14. A sonic wave generator 15, hereinafter 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 11 for transmission to the lower end thereof. Tubing 11 has near its upper end an enlarged collar 16, and below said collar is received an aperture 17 formed in a horizontal top plate 18 of a spring suspension device generally designated at S, the collar 16 overhanging and bearing downwardly on said plate 18 for the support of the pump tubing. Spaced below top plate 18 is a bottom or base plate 19 carried by a tubular member 20 mounted atop casing head 21. Between base plate 19 and top plate 18 of the suspension device are a plurality of the coil springs 12, positioned on vertical pins 22 set tightly into base plate 19 and projecting with a sliding fit through top plate 18. The weight of the pump tubing is thus transferred to springs 12 and thence to the casing supported by the earth.

Coupled to the lower end of tubing 11 is an enlarged hollow pipe section 25, of substantial length, such as a quarter wavelength to one-half wavelength of the wave generated in the liquid in the well by the wave originating from generator 15. This pipe section 25 is relatively large so as to provide increased area for generation of waves in the liquid body. In some installations I find this enlargement 25 is unnecessary, the tubing 11 having sufficient cross sectional area to provide adequate waves. The lower end of the pipe portion 25 has a bottom closure wall 26, provided with ports 27 forming valve passages controlled by a like plurality of ball valves 28 furnished with suitable cages 29. In the illustrative embodiment, the lower end of casing 10 carries a perforated liner 30 installed in the bottom of the well hole.

The vibration generator 15 is shown as of a preferred type comprising casing 31 in which are meshed oppositely rotating spur gears 32 carrying eccentric weights 33 which balance out horizontal vibrations but cause vertical vibrations to be additive to produce a substantial resultant oscillatory force in a vertical direction. The driving pulley 34 of the generator, mounted on the shaft for one of the gears 32, is driven by a suitable prime mover, in this case, illustratively, by a carburetor-type internal combustion engine 35, through belt 36.

Casing head 21 is provided with inflow pipe 38, through which chemicals in solution may be introduced to the annulus 39 between the pump tubing and casing, to descend to the lower end of the well annulus, immediately above pipe portion 25, as indicated at 40. Generally, the pump tubing 11 is equipped, at spaced intervals, with ball check valves such as indicated at 41.

The operation of the foregoing apparatus, as a sonic

pump and sonic wave radiator, is as follows: the generator 15, driven by prime mover 35, transmits elastic waves of tension and compression down the pump tubing, causing the check-valved member 25 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 a preferred establishment of resonance in the tubing, are fully discussed in my earlier Patent No. 2,444,912, disclosing a sonic pump. Each downstroke of the bottom end wall 26 occurs at an acceleration greater than gravity, and the check-valve balls accordingly unseat during such time. Fluid displaced by the downwardly travelling wall 26, therefore, is momentarily pressurized therebelow and flows upwardly through the ports 27 and fills the void above the wall 26 caused by the downstroke of the latter. On the upstroke, the check-valve balls seat, and the column of liquid thereabove is elevated. The check valves 41 in the tubing above have similar action. The oscillating pipe member 25 functions to cyclically compress and expand a substantial quantity of well fluid, and furnishes a good wave transmission coupling to the fluid. Pressure and velocity impulses are thus created within the liquid medium, and these are transmitted to the liner 30 and other surrounding formation, to be radiated for substantial distances in the formation as elastic waves traveling in the formation with the speed of sound.

In practice, generator 15 is preferably operated at a frequency which will establish a longitudinal standing wave in the pump tubing, which maximizes sonic energy flow in the system, sonic energy radiation into the formation, and sonic pumping of well fluids up the pump tubing.

In carrying out the process of the present invention, the selected chemical solution is introduced via inflow pipe 38 to the well annulus 39, and descends to the space above the enlarged tubing member 25, opposite which are casing perforations leading to the productive formation which is to be treated. The sonic pump and wave radiator is then operated, and acts to cause the chemical solution to move outwardly through the casing perforations, deep into the formation, thence back through the formation toward the perforated liner (along with the flow of natural well fluids), and inwardly through the liner perforations, to be drawn and pumped upwardly by the sonic pump, in the path generally represented by the arrows in the drawing. The action by which this result is attained will be developed in the ensuing paragraphs.

First, it is necessary that the sonic wave generator deliver energy to the sonic pump at a rate which is in excess of that needed for normal pumping by an amount adequate to accomplish deep penetration of the formation by the chemical, and circulation of the chemical back to the pump. This may be accomplished by use of heavier than usual eccentric weights on the generator, or by use of a generator whose weights may be adjusted outwardly from their shafts. In such case, the prime mover may be simply an electric motor of requisite power output. I prefer, however, to employ as a prime mover a carburetor-type internal combustion engine, which has an inherent torque-response characteristic such that, when driving a resonant load (such as the resonant vibrating pump tubing), it automatically speed regulates itself to deliver power at a resonant frequency just under peak resonance. The engine, when throttled to drive the system in the resonant range, will deliver additional power without material increase in speed when the throttle is further opened. This phenomenon depends upon the fact that the system tends automatically to operate on the low side of the resonance curve, so that as the throttle is further opened, and peak resonance more closely approached, the resulting torque increase holds back on engine speed increase. In accordance with the inven-

tion, therefore, the engine is throttled to operate in the resonant speed range and to deliver greater torque than necessary to supply the energy requirement for normal pumping, with the excess made sufficient to afford adequate energy for sonic wave radiation and for circulation of the chemicals.

It has been explained in the foregoing, and in my aforementioned Patent No. 2,680,485, that sonic waves transmitted through earthen formation promote migration of liquids therethrough. The precise explanation of why this is so remains somewhat open to speculation, but carefully accumulated data establishes the fact. The pump member 25 has been described in the foregoing as effectively acoustically coupled to the formation, so as to transmit sonic waves therethrough; and in the presence of chemical solution, these sonic waves, propagating in the formation and solution, work or open the formation for outflow of the chemical solution from the space near the bottom of the tubing string, through the casing perforations, and deep into the surrounding formation.

A final but essential factor comprises the generation and radiation into the formation, from the lower end of the sonic pump when pumping fluids upwardly into the tubing, of an asymmetric sonic wave, with negative pressure half cycles (rarefactions) very considerably augmented with respect to positive pressure or compression half cycles. These peaked negative pressure or vacuum waves are originated at the pump by virtue of intake of fluids into the pump bottom. They are radiated from the bottom of the pump through the surrounding well fluids in straight paths to the well bore, and then transmitted into and propagated throughout a considerable volume of the surrounding formation. Suction pulses thus created in the formation extend to the well annulus above the pump member 25, and draw the chemical solution from that location outward into the formation, and then, via loop flow paths, such as represented by the arrows in the drawing, down and back to the well bore beneath the pump, and finally into the well bore to be pumped upwardly through the sonic pump and tubing.

It will be seen that in the practice of the invention, the chemical solution is circulated along a path extending outward from the well annulus or bore in one region and inward into the well bore in another region. Penetration of the chemical deep into the formation is promoted by the sonic wave action; while flow along the described circulation path depends upon the vacuum pulses radiated from the pump while pumping fluid from the well bore.

In the normal or usual practice of the invention, the sonic pump is operated to pump fluids from the well bore, and simultaneously to radiate sonic waves into the formation while chemicals are simultaneously being injected into the formation, and circulated back to the pump. The sonically induced injection of chemicals may most advantageously be carried out, in many formations, in concert with simultaneous sonic pumping, whereby the liquid level in the annulus, and the hydrostatic head in the formation immediately outside the annulus, is drawn down by the sonic pumping action while the chemicals are being sonically injected. The resulting dynamic reduction of fluid head, while the chemicals are being sonically injected, "frees" the formation for improved circulation of the chemicals. In other situations, or alternating therewith, however, these operations may be carried out sequentially. For example, the control valve 14 in the pump outflow line may be closed, so that the pump then functions exclusively as a sonic wave radiator. Pumping energy being thus reduced to zero, all available energy from the wave generator is turned into radiation energy, with correspondingly increased sonic wave propagation into the formation, but, of course, without the described negative wave propagation from the

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lower end of the pump. Under these circumstances, the chemical solution can be worked still deeper into the formation, and can be left there for a long sustained time interval, giving opportunity for the chemical reactions desired to go to completion. The outflow valve 14 may then, after a suitable time interval, be opened, either partially, so as to hold a back pressure, or fully, thus partially or wholly re-establishing the negative wave propagation which is responsible for the loop circulation path for the chemicals. With the valve 14 only partially opened, of course, pumping effort and radiation of corresponding negative pressure or suction pulses occur at partial instead of full amplitude, while substantially symmetrical sonic waves continue to be radiated at relatively high energy level. Full opening of the discharge valve establishes normal operating conditions as described hereinabove, with chemical solution continuously fed from the well bore near the lower region of the pump through the formation and back to the well below the pump, to be thence elevated by the pump with other well fluids.

The practice of the invention has the advantage that the reagents or products of chemical action in the formation are maintained in solution by the sustained sonic wave action in the formation, and further, are circulated back to the well bore to be removed by the pump, rather than being permitted to accumulate within and clog structure of the formation. The vibratory action of the sonic pump itself also keeps products of the chemical reaction in solution within the pump apparatus so that they will be pumped out of the well without clogging the internal mechanism of the pump. Further, chemicals issuing from the outflow line can be separated from the well fluids so that a substantial proportion of remaining useful chemicals can be saved for reuse.

The now described process permits more effective and deeper chemical treatment of the producing formation than has heretofore been possible. The spent or only partially used chemicals are removed from the formation along with the products of the chemical reaction, so that the formation is not merely chemically treated, but effectively cleaned both during and following the treatment. In this connection, operation of the apparatus for a period of time after completion of introduction of the chemical solution effectively cleans out the introduced chemicals and products of their reaction with the formation.

I claim:

1. The method of chemically treating oil well formation, which comprises: introducing a chemical solution into the well bore, generating in the lower portion of the well bore sonic waves which propagate into the solution and the surrounding formation, and so facilitate penetration of said solution from the well bore into the surrounding formation, and sonically pumping well fluids from a region spaced along the well bore and adjacent to the region of said penetration of said solution, whereby to create in the well fluids in the well bore and in the surrounding formation negative wave pulses which return said solution to the well bore for removal therefrom.

2. The method of chemically treating oil well formation, which comprises: introducing a chemical solution into the well bore, generating in the lower portion of the well bore sonic waves which propagate into the solution and the surrounding formation, and so facilitate penetration of said solution from the well bore into the surrounding formation, and simultaneously therewith sonically pumping well fluids from a region spaced along the well bore and adjacent to the region of said penetration of said solution, whereby to create in the well fluids in the well bore and in the surrounding formation negative wave pulses which return said solution to the well bore for removal therefrom.

3. The method of chemically treating oil well formation, which comprises: introducing a chemical solution

into the well bore, generating in the lower portion of the well bore sonic waves which propagate into the solution and the surrounding formation, and so facilitate penetration of said solution from the well bore into the surrounding formation, and thereafter sonically pumping well fluids from a region spaced along the well bore and adjacent to the region of said penetration of said solution, whereby to create in the well fluids in the well bore and in the surrounding formation negative wave pulses which return said solution to the well bore for removal therefrom.

4. The method of chemically treating oil well formation, which comprises: introducing a chemical solution into a predetermined region of the well bore opposite the productive formation, generating in the lower portion of the well bore sonic waves which propagate into the solution and into the surrounding formation, and so facilitate penetration of said solution from the well bore into the surrounding formation, and sonically pumping well fluids from another predetermined region of the well bore opposite the productive formation and adjacent to said first mentioned region, in such manner as to create negative pressure pulses in well fluids in said last mentioned predetermined region and in the formation surrounding and between said predetermined regions, whereby to cause circulation of said chemical solution from the first region through the formation to the second region.

5. The method of chemically treating the productive formation around a well bore, using in the well bore a sonic pump and wave radiator comprised of an elastic pump tubing, check-valved at its lower end and provided at its lower end with a sonic wave radiator operable by sonic waves transmitted down said tubing, and provided at its upper end with a wave generator for sending sonic waves therealong, that comprises: introducing a chemical solution into the well annulus above the sonic wave radiator, providing a flow path for said solution from said annulus to the formation in a region spaced along the well bore from the lower end of the pump tubing, and adjacent thereto, establish a standing wave pattern in the tubing, and with such energy delivery as to supply an excess of sonic wave energy beyond that necessary to motivate any sonic pumping that may simultaneously occur, whereby to provide energy for sonic wave radiation from said radiator into the formation and solution, and continuing the operation for a sustained time interval during which the chemical solution penetrates the formation under stimulation by the radiated sonic waves, and is thereafter returned to the well bore by vacuum pulses radiated into the formation from the check-valved lower end of the sonic pump tubing as successive charges of well fluids are sucked thereinto at the sonic frequency of said pump operation.

6. The subject matter of claim 5, wherein the sonic pump and radiator are operated to simultaneously radiate sound waves and pump well fluids from the well bore.

7. The subject matter of claim 5, including the further step of maintaining a back pressure on the pump tubing to partially restrict sonic pumping and correspondingly augment sonic wave radiation.

8. The subject matter of claim 5, including the further step of maintaining a back pressure on the pump tubing to partially restrict sonic pumping and correspondingly augment sonic wave radiation, and thereafter relieving said back pressure to increase the rate of sonic pumping through the tubing, and the amplitude of the vacuum pulses radiated from the pump.

9. The subject matter of claim 5, including the step of stopping flow from the pump tubing to stop consumption of pumping energy and divert such energy to augmentation of sonic wave radiation, whereby to subject the chemical solution to the influence only of augmented sonic waves in the productive formation, and thereafter

permitting flow from the pump tubing whereby to follow up with the step of subjecting the chemical solution simultaneously to the radiated sonic waves and to vacuum pulses originating at the bottom of the pump.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,918,126

December 22, 1959

Albert G. Bodine

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 41, before "establish" insert -- operating said wave generator so as to --.

Signed and sealed this 11th day of April 1961.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

ARTHUR W. CROCKER
Acting Commissioner of Patents