April 7, 1964 A. G. BODINE, JR 3,127,842

SYSTEM FOR PUMPING FROM SANDY WELLS WITH SONIC PUMP

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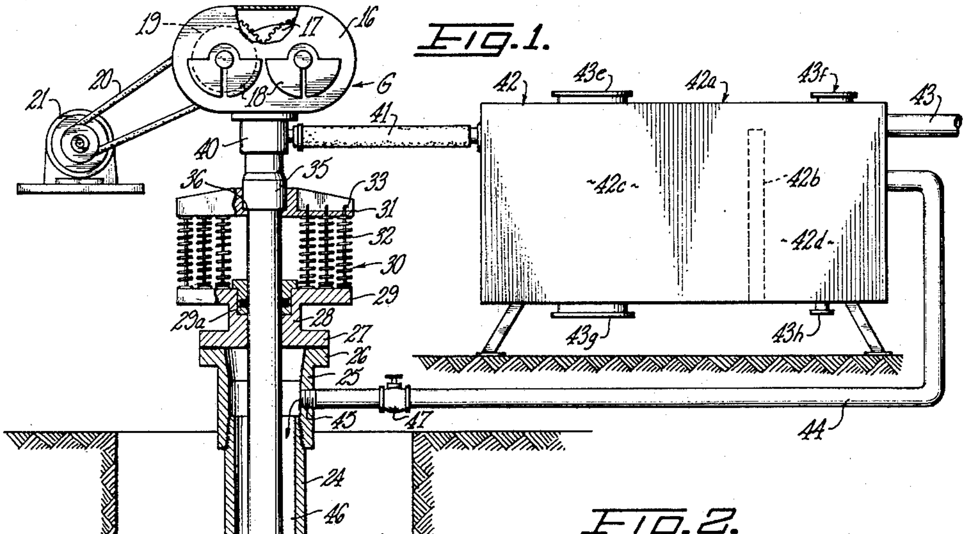

FIG. 1.

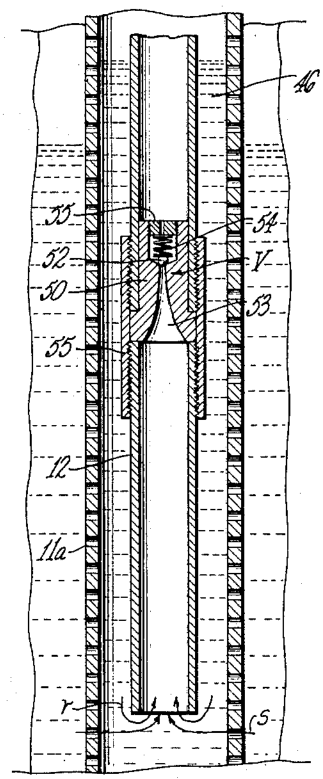

FIG. 2.

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BY [signature]

ATTORNEY

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1

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SYSTEM FOR PUMPING FROM SANDY WELLS WITH SONIC PUMP

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2 Claims. (Cl. 103—1)

This invention relates generally to deep well sonic pumps, of the type disclosed in my United States Patent No. 2,444,912, and more particularly to systems for improving the ability of such pumps to pump wells whose production fluid carries a large proportion of sand.

In my said prior patent, I disclosed a type of deep well pump operated by periodic deformation waves of tension and compression generated by means of a sonic vibration generator at the ground surface and transmitted in a longitudinal direction through an elastic steel column, usually the pump tubing, to certain fluid impelling and check valve means mounted along the column, and, in the case of the column being the pump tubing, these fluid impelling and check valve means are mounted within the tubing. The periodic deformation waves are generated at sufficient frequency to provide longitudinal waves in the tubing having a quarter wave length which is no longer than substantially the length of the tubing. Usually, for deep wells, the tubing length is many times the quarter wavelength of the wave generated in the tubing. In this action, the pump tubing is not bodily reciprocated, but waves of elastic longitudinal deformation travel along the tubing, causing local regions of the tubing to be set into vertical oscillation. The frequency at which these waves are generated may be, for example, 20 cycles per second, and they are generated with sufficient intensity to give a maximum deformation stroke in the tubing of the order of say ½″. For present purposes it is only necessary to understand that the pump tubing is thus set into vertical oscillation at such frequency and with a deformation stroke of the order indicated. For a complete description of the operation of such a sonic pumping system, reference is directed to my aforesaid patent.

The well fluids from some wells carry a large sand content, and the greater this sand content, the more difficult is the well to pump. A proportion of the sand reaching the well bore comes out of suspension in the well fluids, and chokes the well. This is true of both ordinary reciprocating pumps, and of sonic pumps as well. Many wells having good potential for petroleum production are nevertheless so sandy that they cannot be successfully pumped, and now stand abandoned. Sonic type pumps can often produce from very sandy wells, but the production fluid carries so much sand from the formation that problems of subsistence can then arise.

The general object of the present invention is the provision of a sonic pumping system capable of successful pumping of sandy wells, including wells of very high sand content.

A particular object of the invention is to provide a sonic pumping system capable of producing well fluids from a sandy well, and having the operational characteristic that less sand comes to the well from the formation, and substantially all of what sand does come to the well is elevated in suspension in the production column of well fluid.

My invention, briefly stated, revolves about the novel concept of a recirculation of a quantity of de-sanded well fluid back down the well via the annulus around the production tubing, and a combination of this recirculated fluid with the rising production column. By this simple step, a number of important effects are induced to occur, as will presently appear.

2

First, however, it should be understood that the sonic wave action in the pump tubing, i.e., elastic deformation waves of compression and tension, produce sonic fields in the liquid column within the tubing, and in the well fluid streams flowing through the formation to the well bore. The sonic field within the fluid column in the tubing can be quite intensive, and sets up an agitation which tends, under the conditions of relatively high fluid column velocity produced in accordance with the invention, to keep the sand in suspension in the fluid. The sonic energy bled from the tubing and transmitted back through the fluid streams leading to the well bore is not, without special wave radiating formations, of high order of magnitude, but is still sufficient to affect the sand-carrying characteristics of those streams. In particular, when the flow velocities of these streams are low, the sonic field actually tends to cause the sand to drop out of suspension.

These two advantageous conditions, i.e., sand dropping out of suspension in the fluid streams leading to the well bore, and sand staying in suspension in the well fluids rising in the production tubing, are the joint objective of the invention. The first of these conditions means, of course, reduction in the quantity of sand carried out of the formation, and corresponding reduction of the sand problem within the well bore and the pump tubing, as well as reduction in the problem of land subsistence owing to the opening up of cavities by pumping of sand therefrom. The second condition, retention of sand in suspension in the rising production column, is of obvious benefit. The invention achieves both of these benefits by the procedure mentioned briefly above, namely, the recirculation down the well, via the well annulus around the production tubing, or alternatively, via any conduit placed in said annulus, of a good flow of desanded well fluid, and the combining of the recirculated well fluid with the well fluid freshly entering the production from without. It will be seen that the recirculated well fluid when combined with the fluid already rising in the production tubing results in an increased flow velocity up the production tubing; and this increased flow velocity, with the added influence of the sonic field in the production column, results in maintenance of the sand in suspension, so that what sand does enter the well bore with the well fluids and in the region of the lower open end of the production tubing is pumped up the latter, and delivered from the well. The tendency for the well to "sand up" is thus effectively combatted.

It will also be seen that a further effect of the combination of the recirculated well fluid with the well fluid rising in the production tubing is to hold back somewhat on the well fluid streams leading to the well bore, so that the flow velocities of these streams, well back into the formation, are materially reduced. The tendency for sand to be carried by these streams to the well bore is thereby reduced, as explained earlier.

The drawings show an illustrative sonic pump, incorporating certain illustrative improvements in accordance with the invention. In these drawings:

FIG. 1 is a longitudinal sectional view, with portions broken away, of a sonic pump equipped with the improvements of the invention, installed in a somewhat diagrammatically illustrated well; and

FIG. 2 shows the lower end portion of the well and of the pump tubing of the pump of FIG. 1.

In FIGS. 1 and 2 a sonic oil well pumping installation is shown, the well bore being shown to be lined part way down by surface casing **10**, while annularly spaced inside casing **10** is recirculation flow casing **11**, inside of which has been suspended the steel pump tubing **12**, which functions not only as a production conduit to deliver the well fluids from the ground, but also as an elastic column adapted for transmission of elastic deformation waves of tension and compression. Mounted at the top of casings **10** and **11** is a suitable casing head, conventionally indicated at C, and the pump tubing **12** extends upwardly through said casing and has mounted at its upper end an elastic wave or vibration generator G. This generator G comprises a housing **16** containing a device for vibrating the upper end of the tubing **12** in a direction longitudinal of the latter, thereby exerting a vertical oscillating force upon the upper end of the tubing.

The means for generating the vibratory action is here shown of a simple type embodying meshing oppositely rotating spur gears **17** carrying eccentric weights **18**, which balance out horizontal vibrations but are additive to produce a substantial resultant oscillatory force in a vertical direction. The generator has a driving pulley **19** driven through belt **20** from electric drive motor **21**. Since this vibrator is employed to generate elastic waves in the pump tubing which are of the same nature as sound waves, and travel with the speed of sound waves in the pipe, I may properly refer to this vibrator as a sonic wave generator.

Extending upwardly from casing head C, at an annular spacing outside tubing string **12**, is a pipe section **24**, and screwed onto the upper end of the latter is a head **24** having at the top a flange **26**. Bolted to flange **26** is a flange **27** of a tubular fitting **28** on the bottom of the lower platform **29** of a spring support device **30** for the tubing string and wave or vibration generator G, the tubing being packed by a stuffing box at *29a*. The spring supporting device **30** includes an upper plate or platform **31**, supported from lower platform **29** by a plurality of coil springs **32**, vertical guide rods **33** being used inside these coil springs, as indicated. The guide rods **33** may be set rigidly in the member **29**, and project through suitable openings in the member **31** with a free sliding fit. A collar **35** near the upper end of the tubing string overhangs an upwardly facing seating shoulder **36** formed in the member **31**, and it will be understood that the weight of the tubing string and generator G are transferred to the member **31**, and through springs **32**, to the platform **29**. This member **29** is, of course, supported from the casing head.

A delivery fitting **40** at the top end of the pump tubing, between the tubing and the generator G, delivers production fluid to hose **41**, which leads to sand trap **42**, of any conventional or suitable nature, and the latter has main delivery pipe **43**, and also auxiliary delivery pipe **44** leading to a port **45** so as to discharge to the annular space **46** between the sidewall of the tubing string and the production casing. Pipe **44** is controlled by a valve **47** to regulate the amount of production fluid so injected.

The sand trap **42** is indicated to comprise a tank *42a* having therein a transverse partition *42b* forming a sand settlement compartment *42c* and a compartment *42d* for relatively cleaned well fluid which has passed over the upper edge of said partition. The lines **43** and **44** lead from the compartment *42d*. The tank trap and bottom have access holes closed by covers such as indicated at *43e* and *43h* to permit convenient sand removal or cleaning as required. As disclosed in my aforementioned patent on sonic pumps, the pump tubing contains one or more fluid impelling units, illustratively in the form of check valves such as indicated at V, and such valves may comprise a tubular fluid displacing member **50** mounted in the tubing string, preferably at the location of the coupling collar **51**, and a check valve element **52** seating at the top end of the fluid passage **53** through the member **50**. Optionally, the valve element **52** is urged toward its seat by a biasing spring **54**, which may seat at its upper end against a support **55**.

The operation of such a pump is fully set forth in my aforementioned patent. Briefly, the operation is at follows: It will be understood that petroleum fluids in the formation around the well bore migrate to the well bore, pass through the perforations in the lower section **11***a* of the well casing **11**, and so reach and rise within the lower end section of the pump tubing or above the valve V. And it will be recalled that periodic elastic deformation waves of tension and compression travel down the pump tubing **12** as a result of the vertical alternating force applied to the upper end thereof by the sonic generator device G. These elastic waves set local portions of the tubing into vertical elastic oscillation through an amplitude up to say ½″. The tubular valve members **50** carried by the tubing accordingly have this vertical oscillation. On each down stroke, the member **50** travels with an acceleration sufficiently great to separate from the valve element **52**, and fluid displaced by the member **50** travels upwardly therethrough and past the then unseated valve element **52**. On the upstroke, the valve element **52** seats, and the column of well fluid thereabove is dynamically accelerated. The column of well fluid above valve element **52** does not substantially drop during the down stroke of the member **52**, because the acceleration of the latter considerably exceeds the acceleration of gravity. Fluid from the well bore is thus pumped up the production pump tubing and delivered via line **41** to sand trap **42**.

The foregoing description of operation applies to the sonic pump, in absence of the recirculation feature of the present invention. In accordance with the present invention, well fluid which has been desanded in trap **42** is caused to flow via line **44**, at a rate controlled by valve **47**, into and down the conduit afforded by the well annulus **46** between the casing **11** and the pump tubing. At the bottom this well fluid reverses direction and enters the lower end of the pump tubing, as represented by the arrows *r*. It there combines with well fluids which have entered via the casing perforations, as represented by the arrows *s*. The combined flows rise in the pump tubing under the sonic pumping effect developed as described hereinbefore.

It will be evident that the combined flow of entering well fluid, i.e., flow directly from the formation, and recirculation flow, will tend toward maximization of flow velocity up the pump tubing. This increased flow velocity, together with the reduction in the proportion of sand content owing to addition of a proportion of de-sanded liquids, tends to keep the sand in the combined fluids in the pump column from dropping out of suspension, and the elastic sonic wave activity within the rising production column, owing to the sonic wave action of the pump tubing, help keep the sand in suspension by distributing it more uniformly in the fluids and by keeping it sonically agitated. Sand carried to the well bore by the well fluids is thus satisfactorily pumped up the production column. It will be noted that the recirculation fluid must be supplied at a rate such that the rate of upward flow of the combined fluids in the production tubing is above the rate at which a material quantity of sand drops out of suspension under the condition of sonic wave transmission and vibration maintained in the tubing.

In addition, as already mentioned, the practice of the invention results in carrying a reduced quantity of sand from the formation to the well bore.

In this connection, it will be seen that the addition of the recirculation flow up the pump tubing will in general reduce the proportion of flow up the tubing of well fluids which are arriving directly from the surrounding formation. The velocities of the fluid streams from the formation to the well bore are correspondingly reduced, and loose sand is not so readily picked up and carried along to the pump by these streams. Moreover, as explained hereinbefore, the sonically vibratory pump tubing leaks sonic wave energy into these streams of well fluids coming from far back in the formation, and the effect of the sonic wave transmission back along the very low velocity streams is to cause sand carried thereby to drop out of suspension, so that a reduced quantity of sand is transported to the well.

The invention thus accomplishes two novel results. It reduces the velocity of well fluid streams migrating to the wall, and reduces the proportion of sand carried thereby to the well. Also, by increasing the velocity of fluids up the production column, it promotes the ability of the pump to lift to the surface whatever proportion of sand does arrive in the well from back in the formation.

In the operation of the pump, the valve **47** is used to control the rate of recirculation fluid flow directed down the well annulus, and thus the proportion of recirculated fluid in the production column. It will be evident that this proportion will vary with different wells and with different sand contents in the natural production fluid. To secure the benefits of the invention, the recirculation flow must evidently be a material fraction of the total flow up the production tubing. In general, the level of the recirculation liquid maintained in the well annulus **46** need not be given attention. The valve **47** is simply set so as to provide a recirculation flow rate which is found, on test, to establish adequate production from the formation, with sand content regulated to the level deemed best for the case in hand.

It will be seen that the rate of fluid flow directed down the well annulus is such that the flow rate of the combined fluids up the pump tubing exceeds the flow rate, or velocity, at which sand drops out of suspension.

One illustrative embodiment of the invention has now been shown and described. It will be understood, however, that this is for illustrative purposes only, and that various changes in design, structure and arrangement may be made without departing from the spirit and scope of the invention as defined by the appended claims.

I claim:

1. The method of producing petroleum fluid from a sonic well pump in a well bore in a petroleum producing formation characterized by presence of a substantial amount of free, unconsolidated sand, and which sonic well pump embodies an elastic pump tubing extending from the ground surface down the well bore to the level of the producing formation, with means for generating sonic waves and transmitting said waves along said tubing, there being fluid impelling means within said tubing, and a wall around said pump tubing so as to define therearound a well annulus which communicates at the bottom with the open lower end of the pump tubing, the lower portion of said well annulus being also in communication with well fluids from the formation, that includes:

generating said sonic waves and transmitting them along said pump tubing so as to activate said fluid impelling means,

directing a flow of fluid down said well annulus, whereby said fluid combines with well fluid from the formation, and the combined fluids enter and are pumped up the pump tubing, and

supplying the fluid directed down the well annulus at a rate such that the flow rate of the combined fluids up the pump tubing is greater than the rate that permits sand particles in the rising fluid in the pump tubing to fall out of suspension therein under the conditions of wave transmission in said tubing.

2. The method of producing petroleum from a sonic well pump in a well bore in a pretroleum producing formation characterized by presence of a substantial amount of free, unconsolidated sand, and which sonic well pump embodies an elastic pump column extending from the ground surface down the well bore to the level of the producing formation, with means for generating sonic waves and transmitting said waves along said column, there being fluid impelling means mounted along and coupled to said column, a production fluid conduit along said column arranged with the production fluid therein coupled to said fluid impelling means, said conduit being open at its lower end to well fluids from the formation, and a second fluid conduit along said column, communicable at its lower end with the lower end of said production fluid conduit, that includes:

generating said sonic waves and transmitting them along said pump column so as to actuate said fluid impelling means,

direction a flow of fluid from a ground-surface source down said second conduit, whereby said fluid combines with well fluid from the formation, and the combined fluids enter and are pumped up the production conduit, and

supplying the fluid directed down said second conduit at a rate such that the flow rate of the combined fluids up the production conduit is greater than the rate that permits sand particles in the rising fluid in the production conduit to fall out of suspension therein under the conditions of wave transmission in said column.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,127,842 April 7, 1964

Albert G. Bodine, Jr.

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

Column 6, line 32, for "direction" read -- directing --.

Signed and sealed this 17th day of November 1964.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents