April 17, 1956 O. ROTHERHAM 2,742,091

APPARATUS AND METHODS FOR INCREASING WELL PRODUCTION

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Fig. 1.

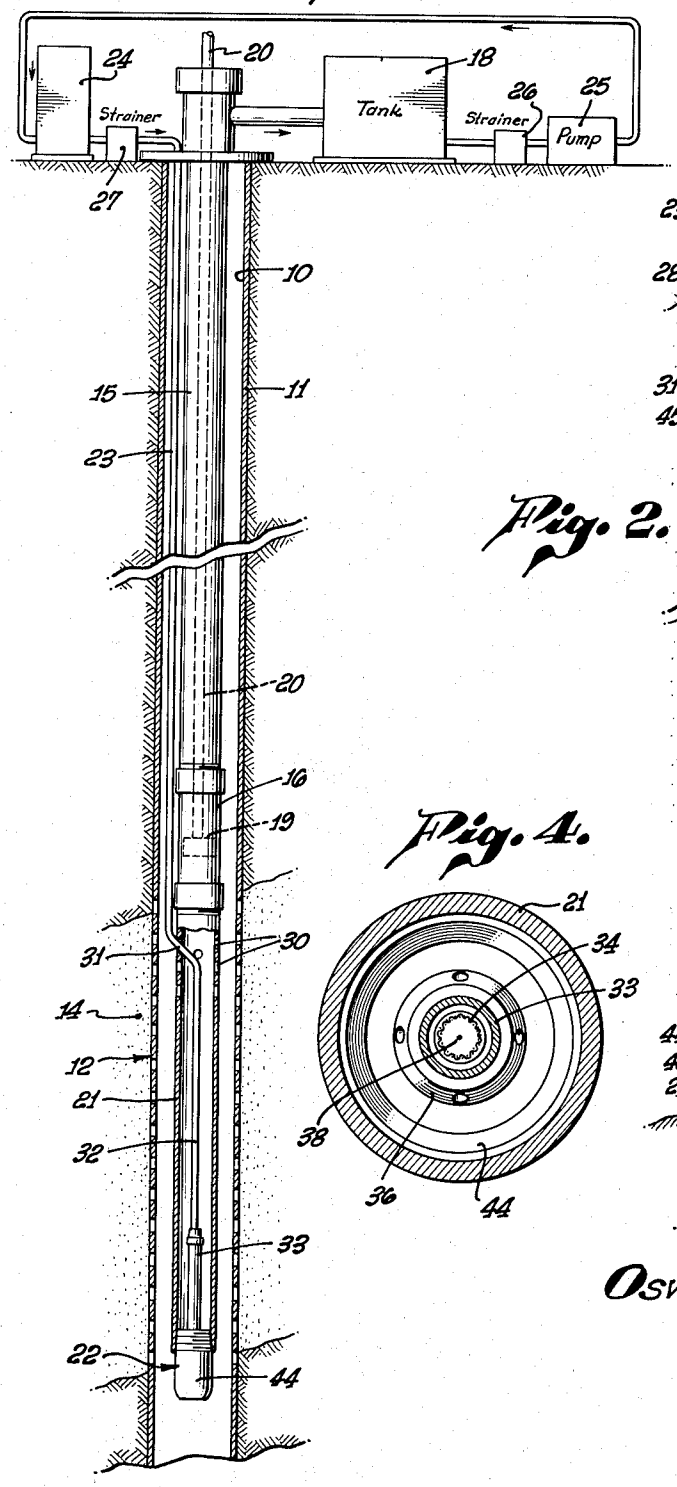


Fig. 2.

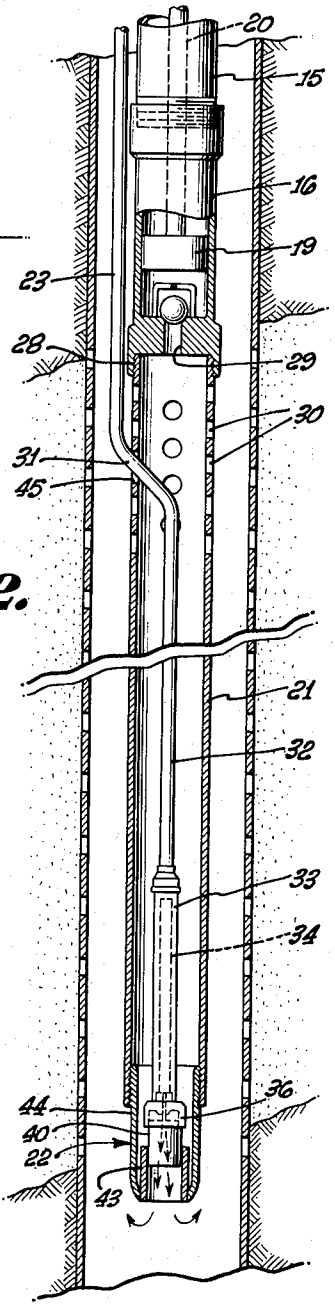


Fig. 4.

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Fig. 3.

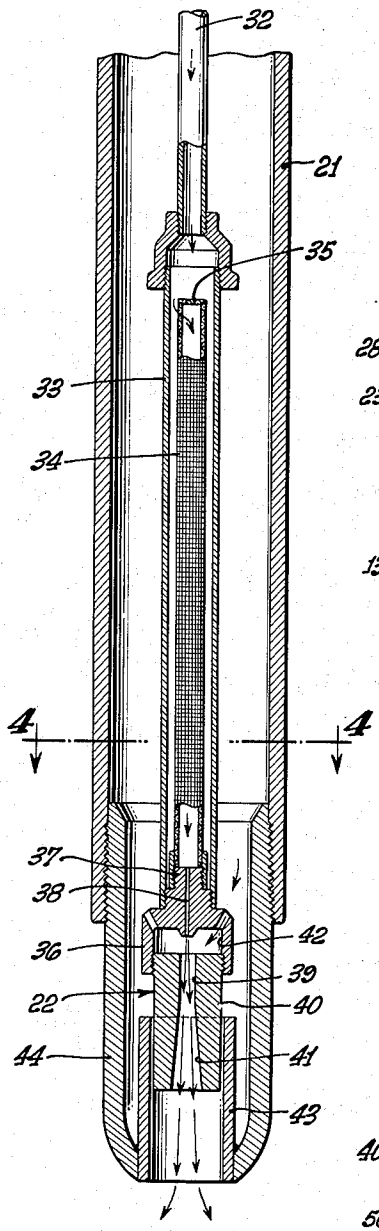


Fig. 5.

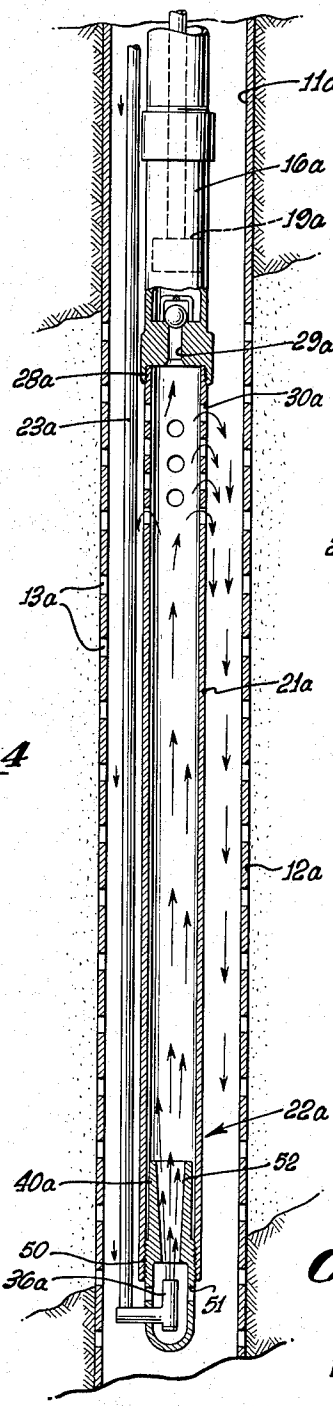
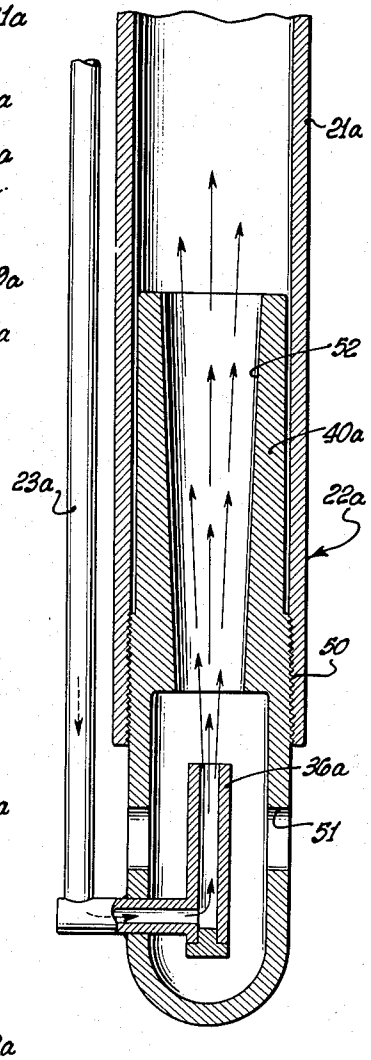


Fig. 6.



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APPARATUS AND METHODS FOR INCREASING WELL PRODUCTION

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Application November 15, 1951, Serial No. 256,410

17 Claims. (Cl. 166—40)

This invention relates to improved apparatus and methods for increasing the productiveness of a well.

In a producing oil well, the rate of production is often impaired by the accumulation of waxes, paraffins, naphthenes and the like at the production zone. In particular, these materials usually accumulate within the production apertures of the well liner and within the pores of the surrounding formation, in a manner progressively reducing the rate at which fluid may pass through the formation and liner to the pump.

Though various expedients have been heretofore proposed for attempting to remove or prevent the accumulation of such deposits, none has proven as effective as might be desired. For instance, some of these proposed methods have had the disadvantage of only intermittently removing the deposits, as by introducing a quantity of hot oil into the well when the production has fallen to a predetermined rate, with the result that the average rate of production is of course far less than the actual capacity of the well. Other proposals have attempted to clean the well continuously, rather than merely intermittently, but have not done so efficiently, and have consequently left the well at all times partially closed.

The general object of the present invention is to provide improved apparatus and methods adapted to substantially completely clean a well of waxes and other deposits, and to keep it clean continuously while the well is producing to at all times maintain a maximum rate of production. As will appear, this result is achieved by maintaining a continuous localized circulation of well fluid along a closed path at the production zone of the well, and introducing into that localized circulation of fluid an additive material brought down from the surface of the earth and adapted to treat the well in a manner preventing the accumulation of unwanted deposits. Preferably, the substance introduced into the circulation is a hot fluid, such as heated oil, which mixes with the well fluid and raises its temperature to a value sufficient to prevent the solidification of any waxes or the like. The circulation carries this heated mixture vertically along the entire extent of the perforated liner to keep all of the apertures and the adjacent formation clean. The invention also contemplates introducing into the circulation a detergent, solvent or other substance, where the use of such a material is indicated.

Best results and maximum simplicity may be attained by employing the additive fluid itself for effecting the localized circulation of the well fluid. For this purpose, the apparatus within the well may include a fluid aspirator or ejector device adapted to introduce a high velocity jet of hot oil or the like into the well fluid, in a manner mixing the two fluids and causing their circulation together.

Structurally, I may employ a body, preferably tubular, extending vertically within the perforated production liner of a well and dividing a portion of the well into two vertically extending spaces. This body, which may be connected to the lower intake end of the usual well pump,

is provided with apertures placing the two spaces in communication at vertically spaced locations, so that the fluids may follow a closed path upwardly within one space and then downwardly within the other. During this movement, the heated fluid passes and cleans the perforations of the liner, and heats the liner to an extent maintaining the surrounding formation clean. The circulation also serves to keep sand and other solids in entrainment within the fluids, to be taken with the fluids by the pump rather than accumulating in and eventually closing off the bottom of the well.

It is usually desirable to position the fluid circulating ejector within the lower portion of the tubular body. Hot oil may be supplied to the ejector from a heater at the surface of the earth, and under the influence of a circulating pump which may also be located at the surface of the earth. Preferably this circulating pump takes suction directly from the production oil taken from the well. The hot oil is conducted from the heater and pump to the ejector through a line extending downwardly within the well, and desirably having a lower portion located within the circular body of the device, so that a certain amount of heat is transferred to the fluid within the body even before the hot oil reaches the ejector. This portion of the hot oil supply line which is located within the tubular body of the device may contain a strainer for effecting a final cleaning of the heated oil to protect the ejector against clogging by impurities in the oil.

Additional features of the invention have to do with the preferred method of placing in production an initially cold well which is to be circulated in accordance with the invention. Specifically, this method comprises first producing the well at a relatively slow rate while continuously circulating heated fluid within the well to raise the temperature of the well to a desired value, and then increasing the rate of production of the well while still maintaining the desired well temperature.

The above and other features and objects of the present invention will be better understood from the following detailed description of the typical embodiments illustrated in the accompanying drawings, in which:

Fig. 1 is an overall view, partly diagrammatic and partly in section, of an oil well having heating and circulating apparatus embodying the invention;

Fig. 2 is an enlarged fragmentary vertical section through the portion of the apparatus of Fig. 1 located at the level of the producing formation;

Fig. 3 is a further enlarged fragmentary sectional view corresponding to that of Fig. 2 but showing especially the aspirator or ejector through which hot oil is introduced into the well;

Fig. 4 is a horizontal section taken on line 4—4 of Fig. 3;

Fig. 5 is a vertical sectional view corresponding to that of Fig. 2 but showing a variational arrangement; and

Fig. 6 is an enlarged fragmentary vertical sectional view of the lower portion of the Fig. 5 apparatus.

Describing first the Figs. 1 to 4 form of the invention, and with particular reference to Fig. 1, I have shown at 10 a conventional oil well, lined along most of its vertical extent by the usual well casing 11. At a production zone deep within the well, casing 11 has a perforated portion 12, through whose wall apertures 13 oil flows from the surrounding producing formation 14 into the well. Extending downwardly within the well is a tubular production string 15, carrying at its lower end the usual pump 16, by which the oil is taken from the well and pumped upwardly within string 15 for delivery through line 17 at the surface of the earth to tank 18. Pump 16 may typically comprise a vertically reciprocable piston 19 operable by rod 20 at the surface of the earth.

The production zone heating and circulating apparatus,

with which the present invention is particularly concerned, includes a tubular vertically elongated body 21 extending downwardly beneath pump 16, and an aspirator or ejector device 22 located within the lower portion of body 21. Ejector 22 acts to introduce hot oil into the well in a manner to mix with the production oil and cause a continuous circulation of the resultant heated mixture within the production zone of the well.

Hot oil is supplied to ejector 22 through a line 23 leading downwardly within the well from a heater 24 located at the surface of the earth. The oil is forced through heater 24 and line 23 to the ejector by a pump 25, which may be located at the inlet side of the heater, and which preferably takes its suction from tank 18 into which the production oil is delivered. A strainer 26 may be connected into the line between tank 18 and pump 25, to remove any impurities from the oil, and a second strainer 27 may be connected into the hot oil line at the discharge side of the heater for removing from the oil any particles picked up during passage through the heater.

The tubular body 21 is threadedly connected at 28 to the lower end of production pump 16, and the interior of body 21 communicates upwardly with the intake passage 29 of the pump. Body 21 is located within the perforated portion 12 of the well casing, and is preferably of a vertical extent corresponding substantially to that perforated portion of the casing. Body 21 may typically be formed of a number of interconnected pipe stands. Near its upper end, body 21 has a number of side wall apertures 30, through which oil from within the well may enter the tubular body to be taken by pump 16.

The upper portion of hot oil supply line 23 extends downwardly within the well along the outside of production string 15 and pump 16. Beneath pump 16 and at the upper end of tubular body 21, hot oil supply line 23 curves inwardly at 31, and then extends downwardly at 32 along the center of body 21 to carry ejector 22. At its lower end, line 32 has a somewhat enlarged diameter portion 33, containing a strainer 34 through which the hot oil passes before delivery to the ejector. This strainer comprises a vertically elongated tubular screen 34, having an upper transverse screen wall 35 (see Fig. 3), and serving as a final protection against delivery of impurities to the ejector.

The ejector or jet pump 22 includes a first or nozzle section 36 threadedly connected at its upper side to the lower enlarged diameter portion 33 of the hot oil delivery tube. The lower portion of strainer 34 is mounted about a projection 37 at the upper side of ejector section 36. The ejector section contains a small vertically extending nozzle passage 38 through which hot oil flows from within strainer 34 to discharge downwardly as a high velocity jet stream 39. A lower section 40 of the ejector contains a vertically extending passage 41 through which jet 39 is directed. The upper section 36 of the ejector has a number of circularly spaced passages through which oil from within tubular body 21 and about the hot oil delivery tube may flow into the inner ejector chamber 42, for entrainment in and intermixture with the hot oil stream. The resulting heated mixture is discharged downwardly, then curves upwardly, as indicated by the arrows, to flow upwardly about body 21, and then into its upper wall apertures 30. Some of the heated oil entering body 21 through apertures 30 is taken by the pump, while the rest of the heated oil flows downwardly within body 21 to the ejector, thus producing a continuous circulation of heated oil at the production zone within the well. It is noted that the positioning of portion 32 of the hot oil supply line within body 21 facilitates the transference of heat to the oil within the well, since as the circulating oil flows downwardly between body 21 and tube 32, it picks up a certain amount of heat from the oil within tube 32.

The ejector is positioned within the lower portion of body 21 by reception of lower section 40 of the ejector within tubular guide portion 43 of a fitting 44 threadedly connected to the lower end of body 21. The lower section 40 of the ejector and tubular guide 43 form a sufficiently close fit to prevent the leakage of any appreciable quantity of oil downwardly therebetween, but at the same time are loose enough to permit vertical movement of the ejector in response to expansion of the hot oil supply line 23 due to the heat of the oil. For the same purpose, the curved portion 31 of the hot oil supply line extends into tubular body 21 through a vertically elongated slot 45 in the wall of that body, which slot has a vertical dimension sufficiently greater than the corresponding portion of the hot oil supply line to permit relative vertical movement of the hot oil line as a result of its expansion and contraction.

In starting the operation of the Figs. 1 to 3 apparatus within a cold well, it is desirable during an initial period to produce the well at a rather slow rate such that a large percentage of the hot oil introduced into the well through the ejector remains at the bottom of the well, thus rapidly building up the temperature at the production zone. When the temperature in the bottom of the well reaches a desired value high enough to melt and prevent the accumulation of any waxes, paraffins, naphthenes or the like, typically about 150° F., the production rate is increased as much as desired or possible, and the rate of introduction and temperature of the hot oil are regulated to at all times maintain that desired temperature.

Due to the maintenance of a continuous circulation of hot oil upwardly between tubular body 21 and the perforated portion 12 of the well casing and then downwardly within body 21, the apertured portion of the casing is at all times kept at a sufficiently high temperature to prevent the accumulation of clogging waxes, paraffins, naphthenes, and so forth, within apertures 13. Also, this heat prevents the accumulation of such materials within the pores of the adjacent portions of the producing formation 14, or within any cavities which may be formed about the well casing as a result of the flow of sand or the like into the well with the production oil. A further advantage of the increased temperature at the production zones resides in the capacity of the heat to break down gas bubbles in the oil, in a manner assuring the delivery of a maximum of liquid and a minimum of gaseous froth to the pump. Also, the increased temperature reduces the viscosity of the oil so that the pump is freely operable and capable of drawing in a substantially complete charge upon each stroke of its piston. As is well known, when the oil is cold and of high viscosity, it will not flow freely through the pump inlet, and the pump therefore may only take a partial charge upon each piston stroke.

The circulation of fluid of course has the advantage of distributing the heat of the oil substantially uniformly along the entire production zone. The circulation also serves the purpose of maintaining any sand within the well in suspension, so that the sand is taken by the pump instead of accumulating in and clogging the bottom of the well. It is also noted that this circulation may be employed to introduce into the well an additive such as a detergent, solvent, acid or the like, for treating the liner or surrounding formation.

Figs. 5 and 6 represent a variational form of well heating and circulating apparatus, which is substantially the same as that of Figs. 1 to 3 except as to the formation of its ejector or aspirator 22*a*, and the line 23*a* by which heated oil is conducted to the aspirator. The liner 11*a*, 12*a*, pump 16*a*, tubular body 21*a*, and the apparatus at the surface of the earth are the same in Figs. 5 and 6 as Figs. 1 to 3, and will therefore not be described in detail.

Ejector 22*a* of Figs. 5 and 6 is formed and mounted to produce a circulation of fluid reversed from that of Figs. 1 to 3, that is the oil flows upwardly within tubular body 21*a* and then outwardly through its upper apertures 30*a* to pass downwardly at the outside of body 21*a*. Ejector 22*a* includes a first section 40*a* thread-

edly connected to body **21***a* at **50**, and containing side inlet apertures **51** and an upwardly diverging discharge passage **52**. Hot oil delivery tube **23***a* extends downwardly along the outside of body **21***a* to connect with a jet tube or nozzle portion **36***a* of the ejector, which directs a high velocity jet of heated oil upwardly through passage **52** and body **21***a*. This jet of hot oil entrains and mixes with oil from a secondary stream entering the ejector through openings **51**. As will be appreciated, the continuous circulation of heated oil within the production zone serves the same purposes as does the circulation of oil in the Figs. 1 to 3 form of the invention.

I claim:

1. Well apparatus comprising a tubular body having an upper end connectable to the lower end of a well production string and communicating upwardly therewith, said body having a side wall aperture near the upper end thereof, said body having a second aperture near the lower end thereof, an aspirator within a lower portion of said body adapted to discharge a high velocity fluid jet at a location acting when the body is contained within a well to produce a localized circulation of fluid moving in a first vertical direction within the body, in a second vertical direction at the outside of the body, passing from the inside to the outside of the member through one of said apertures, and passing from the outside to the inside of the member through the other aperture, and a conduit extending downwardly from the surface of the earth to conduct a heated fluid to said aspirator and having a portion extending downwardly within said body from the upper portion thereof toward the aspirator.

2. Well apparatus comprising a tubular body having an upper end connectable to the lower end of a well production string and communicating upwardly therewith, said body having a side wall aperture near the upper end thereof, said body having a second aperture near the lower end thereof, an aspirator within a lower portion of said body adapted to discharge a high velocity fluid jet therein to produce a localized circulation of fluid moving in a first vertical direction within the body, in a reverse vertical direction at the outside of the body, passing from the inside to the outside of the member through one of said apertures, and passing from the outside to the inside of the member through the other aperture, a conduit extending downwardly from the surface of the earth to conduct a heated fluid to said aspirator and having a portion extending downwardly within said body from the upper portion thereof toward the aspirator, and a strainer contained within said conduit for removing impurities from said heated fluid.

3. Well apparatus comprising a tubular body having an upper end connectable to the lower end of a well production string and communicating upwardly therewith, said body having a side wall aperture near the upper end thereof, said body having a second aperture near the lower end thereof, an aspirator within a lower portion of said body adapted to discharge a high velocity fluid jet therein at a location acting when the body is contained within a well to produce a localized circulation of fluid moving in a first vertical direction within the body, in a reverse vertical direction at the outside of the body, passing from the inside to the outside of the member through one of said apertures, and passing from the outside to the inside of the member through the other aperture, a conduit extending downwardly from the surface of the earth to conduct a heated fluid to said aspirator and having a portion extending downwardly within said body from the upper portion thereof toward the aspirator, and means mounting said conduit and aspirator for vertical movement relative to said body in response to thermal expansion and contraction of said conduit.

4. The method of treating a well that comprises forming a defined endless circulation path for the well fluid at a production zone deep within the well, conducting an additive fluid downwardly within the well from the surface of the earth, and discharging a jet of said additive fluid into the well fluid along said endless path at a location to cause circulation of the well fluid and additive fluid therealong.

5. The method of placing a cold well in production that comprises causing a localized circulation of well fluid along an endless path at a production zone deep within the well, introducing a heated fluid from the surface of the earth into said circulating fluid to raise the temperature thereof, producing the well at a rate sufficiently slow that the temperature of the well fluid at said zone increases to a predetermined value, and then increasing the rate of production relative to the rate of introduction of said heated fluid to a value maintaining said predetermined temperature.

6. Well apparatus comprising a vertically elongated body adapted to be lowered into the production zone of a well and within the well fluid therein, said body containing a vertically extending passage and a pair of openings placing said passage in communication with the well at a pair of vertically spaced locations both deep within the well, whereby said body and the well bore wall form together at said production zone an endless circulation path which extends in a first vertical direction within said body passage, in a reverse vertical direction along the outside of said body, and between the inside and outside of the body at said vertically spaced locations, and means including a nozzle discharging along said path and in the direction of a portion of the path a stream of an additive fluid brought down from the surface of the earth to mix with the well fluid and produce an endless circulation of the well fluid and additive fluid together along said path.

7. Apparatus as recited in claim 6, in which said last mentioned means comprises an aspirator discharging said additive fluid in said first vertical direction within said passage.

8. Apparatus as recited in claim 6, in which said body has an open upper end adapted for connection to the lower end of a production string and through which said passage is communicable upwardly with the string.

9. Apparatus as recited in claim 6, in which said last mentioned means includes a conduit extending downwardly into the well and delivering said additive fluid to said nozzle, and a pump at the surface of the earth forcing said additive fluid under pressure through said conduit.

10. Apparatus as recited in claim 9, including a heater at the surface of the earth heating said additive fluid before its delivery to said conduit.

11. Apparatus as recited in claim 10 in which said means including a nozzle comprise an aspirator discharging said additive fluid in said first vertical direction, said body having an open upper end connectable to a production string and through which said passage is communicable with the string.

12. Well apparatus comprising a well production string for extending downwardly within a fluid containing well, a production pump carried at the lower end of said string and within the well fluid, a vertically extending body carried by the string beneath said pump at the production zone of a well, said body containing a vertically extending passage and a pair of openings placing said passage in communication with the well at a pair of vertically spaced locations both deep within the well, whereby there is formed at said production zone an endless fluid circulation path extending in a first vertical direction within said body passage, and in a reverse vertical direction along the outside of said body, a conduit extending downwardly into the well to conduct an additive fluid thereinto, and means including a nozzle discharging a stream of said additive fluid along said endless path and in the direction of a portion of said path to mix with the

well fluid and produce an endless circulation of the well fluid and additive fluid together along said path.

13. Apparatus as recited in claim 12, in which said body has an open upper end through which said passage communicates with said pump.

14. Apparatus as recited in claim 12, in which said conduit extends vertically alongside said production string.

15. Apparatus as recited in claim 14 in which said means including a nozzle comprise an aspirator within said body discharging a jet of said additive fluid in said first vertical direction, said apparatus including a pump at the surface of the earth forcing said additive fluid under pressure through said conduit, and a heater at the surface of the earth heating said additive fluid before its delivery to said conduit.

16. The method of treating a well that comprises forming at a production zone deep within the well a defined endless well fluid circulation path which is elongated vertically along said zone, conducting an additive fluid downwardly within the well from the surface of the earth, and discharging a jet of said additive fluid into the well fluid along said endless path at a location to cause circulation of the well fluid and additive fluid therealong.

17. The method of treating a well that comprises forming at a production zone deep within the well a defined endless well fluid circulation path which is elongated vertically along said zone, conducting a heated oil downwardly within the well from the surface of the earth, and discharging a jet of said heated oil into the well fluid along said endless path at a location to mix with the well fluid and cause circulation of the well fluid and said oil along said path.

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