Dec. 22, 1959 A. G. BODINE, JR 2,918,127

METHOD OF CLEANING OUT WELL PUMP TUBING AND THE LIKE

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Fig. 2

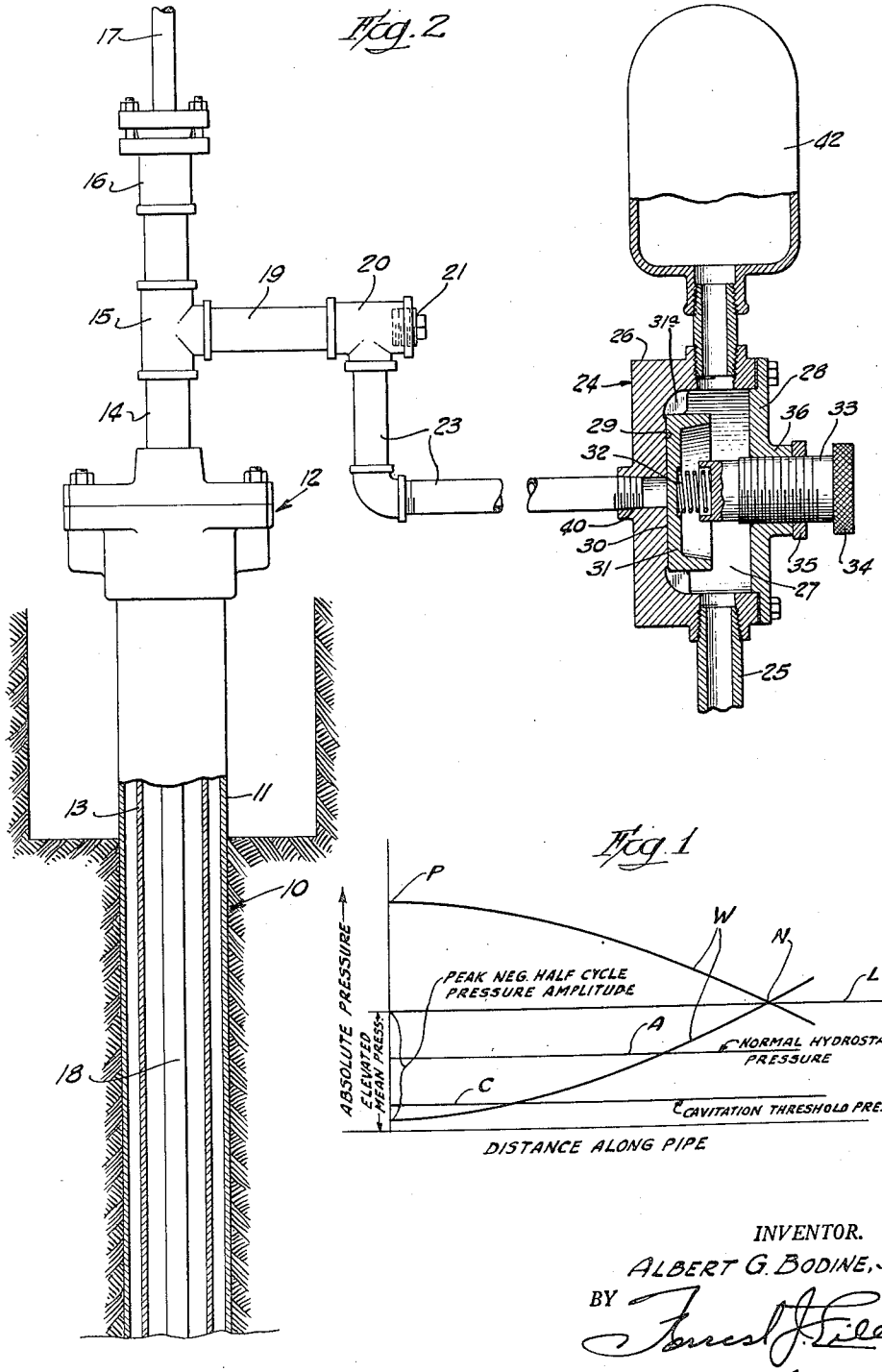


Fig. 1

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METHOD OF CLEANING OUT WELL PUMP TUBING AND THE LIKE

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Fig. 3

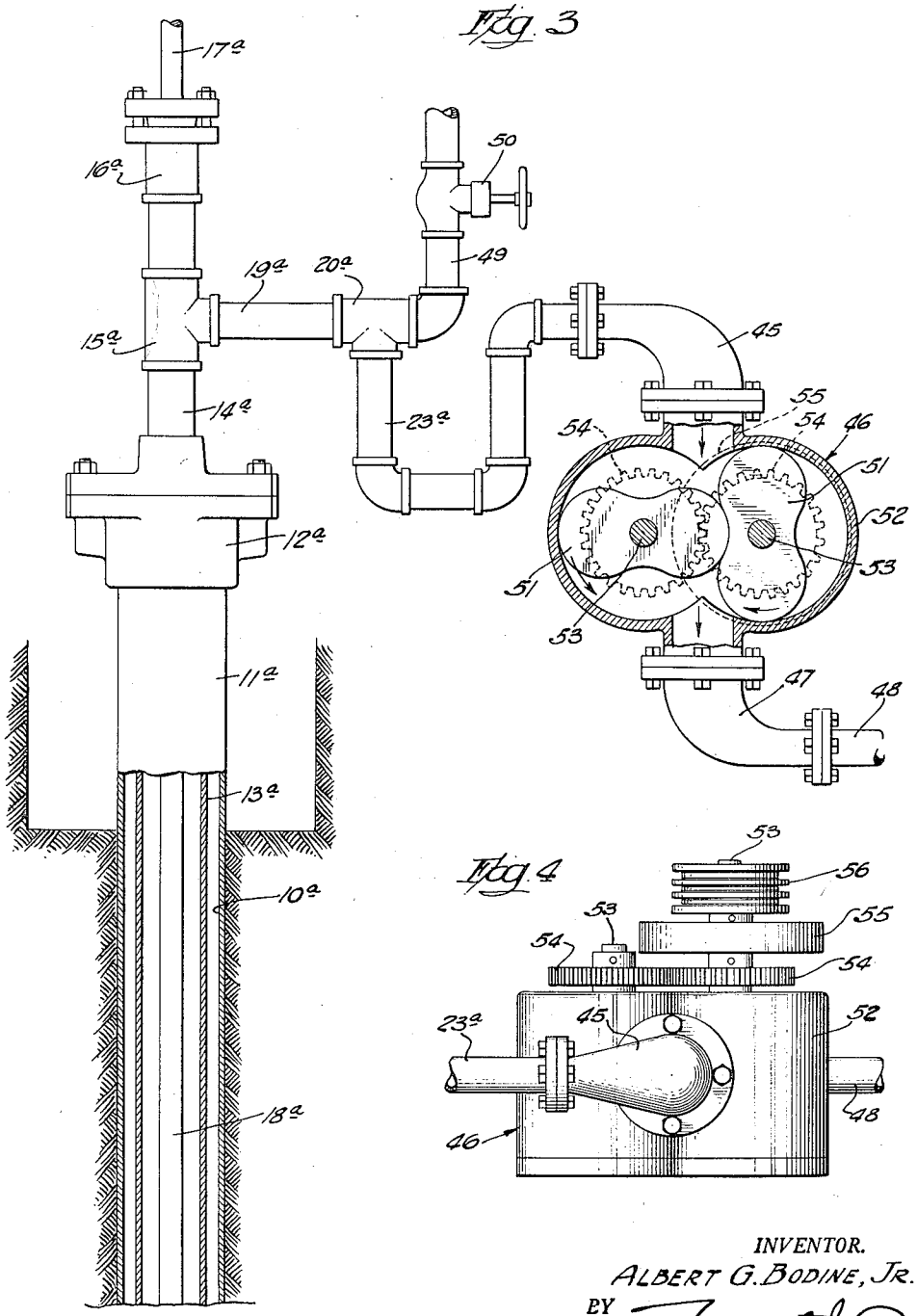


Fig. 4

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METHOD OF CLEANING OUT WELL PUMP TUBING AND THE LIKE

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Fig. 5

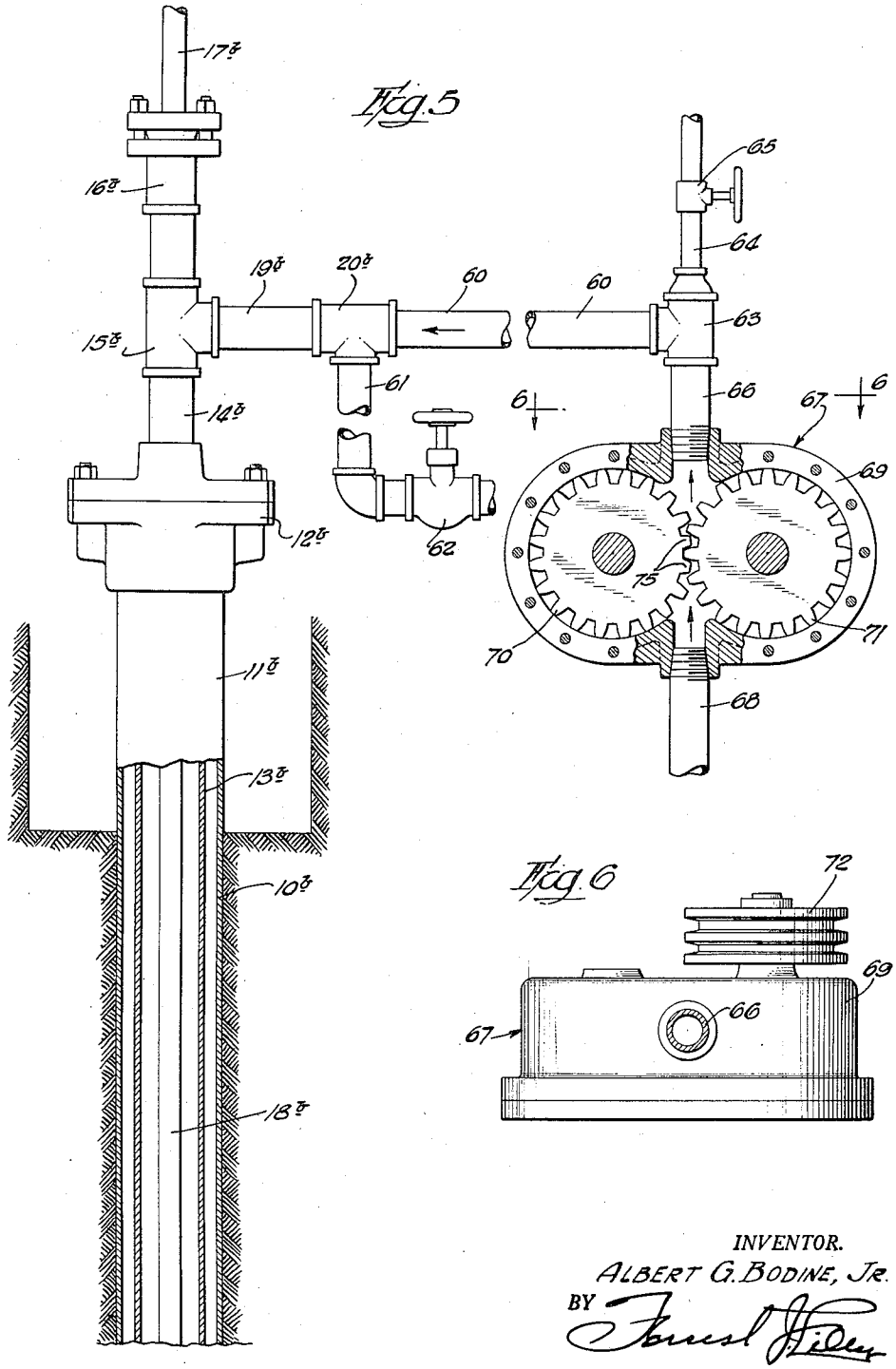


Fig. 6

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METHOD OF CLEANING OUT WELL PUMP TUBING AND THE LIKE

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Fig. 7

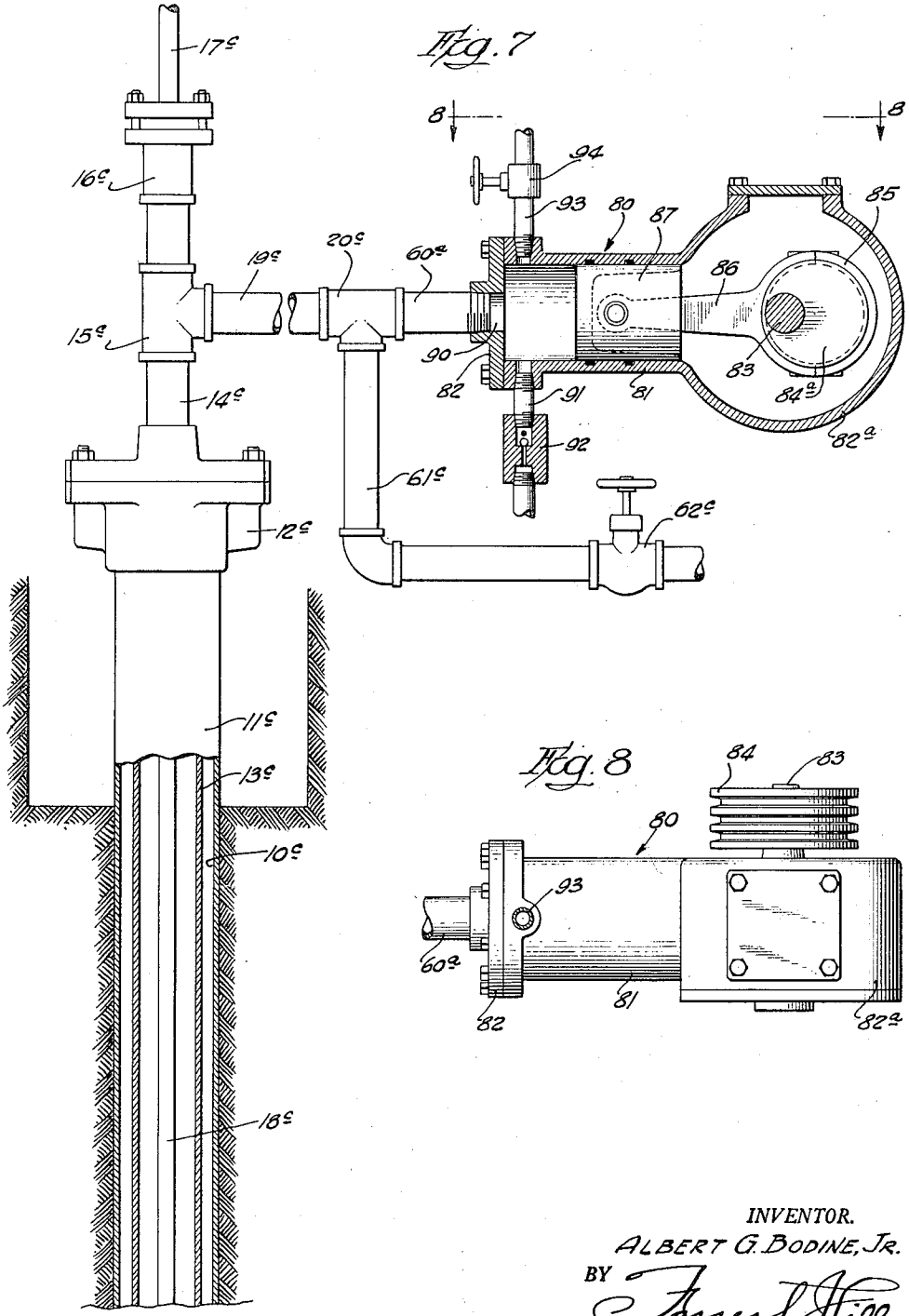


Fig. 8

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METHOD OF CLEANING OUT WELL PUMP TUBING AND THE LIKE

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Fig. 9

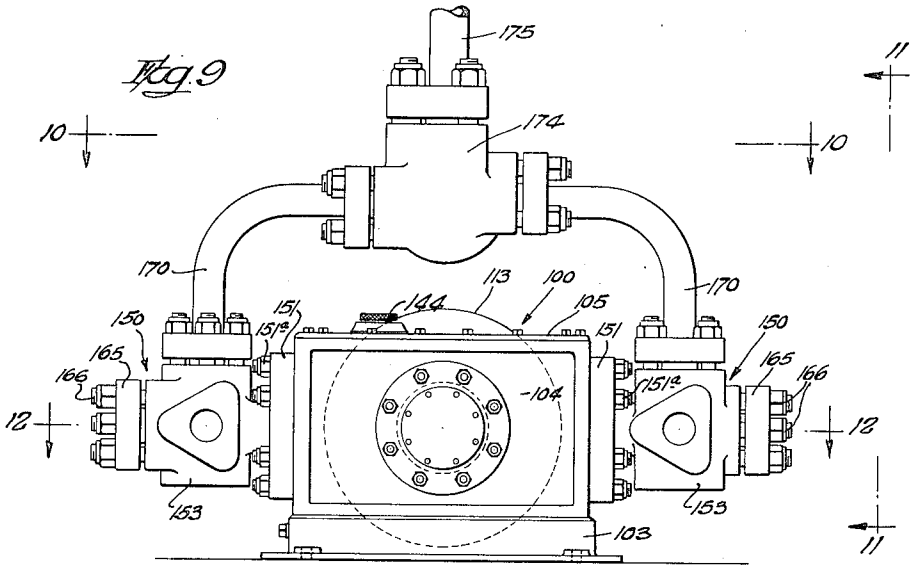


Fig. 10

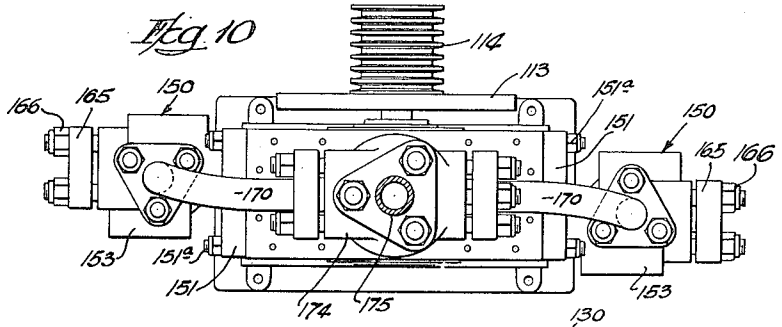


Fig. 11

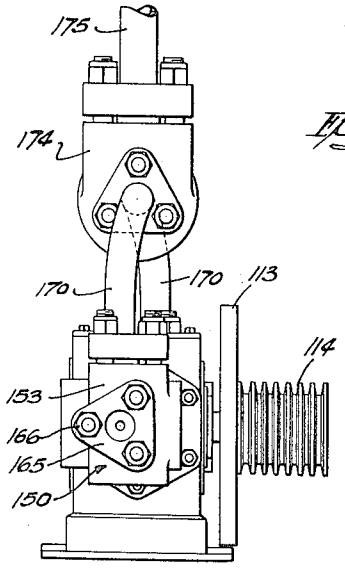
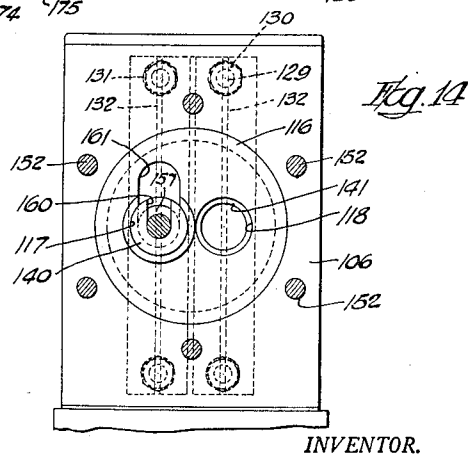


Fig. 14



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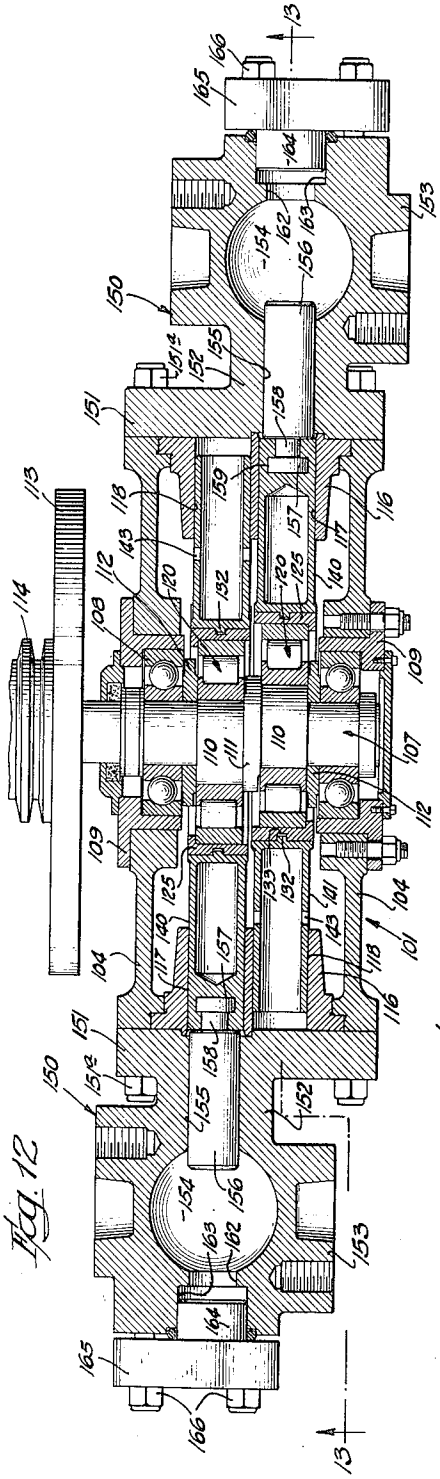


Fig. 12

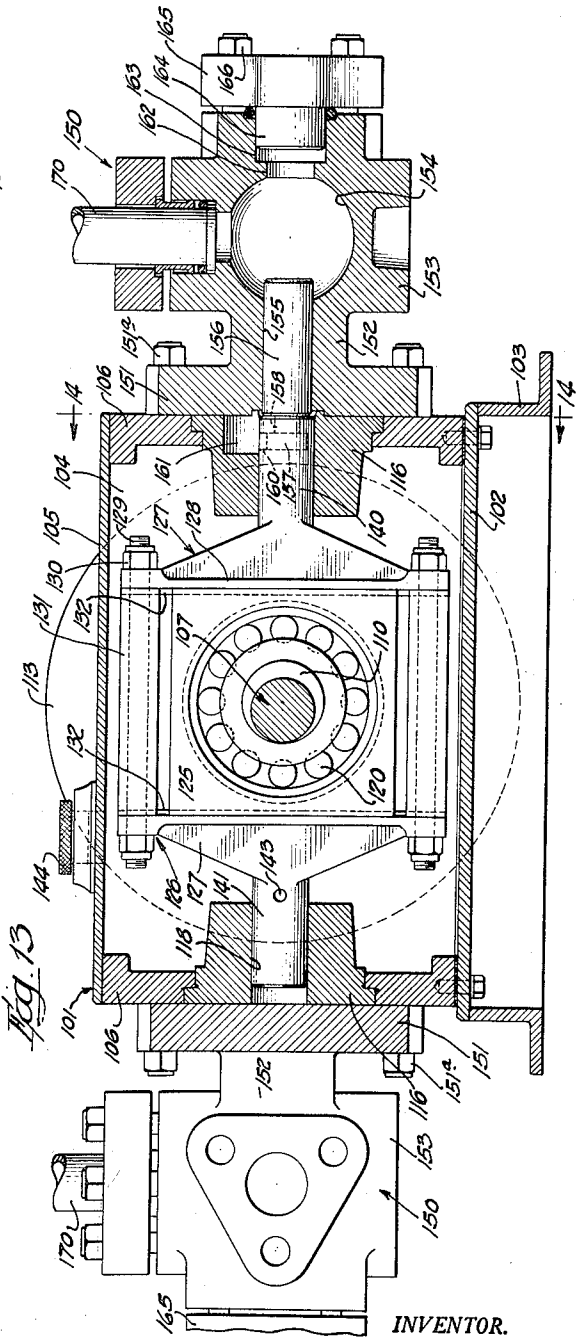


Fig. 13

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United States Patent Office 2,918,127 Patented Dec. 22, 1959

2,918,127

METHOD OF CLEANING OUT WELL PUMP TUBING AND THE LIKE

Albert G. Bodine, Jr., Van Nuys, Calif.

Application August 2, 1956, Serial No. 601,709

6 Claims. (Cl. 166—43)

This invention relates generally and illustratively to systems for cleaning oil well pump production tubing of accumulations of dirt, scale, wax, etc. The invention has especial present utility as applied to oil well pumps because of the existence of large oil production areas presently noted for their waxing problems, but has broad application to clean out of pipe whether in a well, or above ground.

A primary object of the invention, generally stated, is accordingly the provision of a novel and effective system for effective removal of dirt, scale and wax from pipe, and a further and more specific object is the provision of a system by which oil well production tubing may be readily cleaned of accumulations of such materials while installed in a well, even, in some cases, without interrupting production.

I have discovered that pipe whose interior surfaces are laden with dirt, scale, wax, and the like, may be very rapidly cleaned through application of sound waves of sufficient amplitude to produce cavitation at the interface between the dirt or wax laden pipe and a contained liquid in which the sound waves are transmitted. The cleaning action becomes exceedingly violent and effective when the negative half cycles of the sound pressure wave swing low enough to cause cavitation.

It is known in the oil industry that many oil wells are literally choked off from production by deposition of wax over a period of time. The present invention deals with this problem by use of sound wave generating devices which transmit sound waves down the production fluids in the well tubing. These sound waves are preferably generated at frequencies to resonate the column of well fluid, and at amplitudes to induce cavitation. To increase the violence of cavitation, the column of well fluid is preferably held under an elevated mean static pressure.

The invention is applicable to conventional sucker rod pumps wherein the inside of the pump tubing, and the sucker rod itself, become coated with wax which is deposited from the production fluid. In some wells the wax deposition takes place at a particular region some substantial distance up the tubing where the oil has cooled off to the critical wax depositing temperature. That is to say, the oil entering the bottom of the tubing is often sufficiently hot that the wax stays in solution in the oil until it has traveled some distance up the tubing and has reached the critical deposition temperature; but in this region, and above, wax accumulation is a common problem of considerable seriousness. The invention is equally applicable to flowing wells.

The invention is capable of embodiment in two general physical forms, one involving application of sound wave generating equipment permanently installed in connection with the output flow line from the oil well and designed to operate continuously to transmit sound waves down the production tubing to keep the tubing clean at all times, and the other consisting of a portable, high powered sound wave generator designed for

temporary installation in connection with a well on a service treatment basis.

A feature of the invention is that either flowing or sucker rod pump installations can be treated without disturbing the existing equipment, i.e., the pump and all of its parts can be left in place, and in many instances the well can continue to pump without interruption. In most instances the sound wave generator is connected to the output flow line from the well so that sound waves can be directed back down the well, and these sound waves travel down the well column regardless of whether or not there is an upflowing current of oil.

In most instances it is desirable to maintain a back pressure on the liquid column in the tubing to maintain the liquid column under a substantial degree of compression. This compression greatly assists the transmission of sound waves down the liquid column. According to one practice of the invention, the compression can be maintained or established by allowing the well to flow or to be pumped against a constriction in the flow line obtained by use of a back pressure valve installed downstream, beyond the location where the sound waves are introduced into the liquid in the flow line. In those practices of the invention in which oil production is interrupted during the treatment, it is usually desirable to employ a small pump at the ground surface, connected to maintain an elevated pressure head on the oil in the flow line by pumping oil in the reverse direction in the flow line, i.e., back into the well. This is found necessary in some instances because of the evolution of gas within the liquid column as a consequence of the sound waves being transmitted down the column. Thus, by injecting "make-up" oil back into the column, there is accommodation for the volume adjustment required as a result of the evolution of gas bubbles owing to the sound wave transmission through the column. In the case of treatment during production from the well, the gas bubble problem is normally non-existent because the production of oil against the back pressure will prevent gas evolution.

Various forms of sound wave generator are possible within the scope of the invention. One simple form comprises a differential pressure periodic valve which automatically opens and closes at a pre-set frequency as a result of the flow of liquid therethrough. The action of this valve is such as to generate and transmit sound waves back down the well column, and it will be seen that this type of generator operates by the flow of the production oil, so that the energy for generating the sound waves is extracted from the flowing oil column, which in turn is derived from well energy in the case of a flowing well, or from pump energy in the case of a pumped well.

Other forms of generator applicable require an external energy source such as an engine or an electric motor. A suitable sound wave generator can be arranged by use of an engine driven reciprocating piston of fairly high frequency (e.g., 60 cycles per second) having a relation of displacement and driving force such that its mechanical output impedance is comparable to that presented by the oil filled production tubing going down into the well.

The invention will be better understood by referring now to the following detailed description of several illustrative embodiments thereof, reference for this purpose being had to the accompanying drawings, in which:

Fig. 1 is a diagram representing operating conditions in accordance with the invention;

Fig. 2 is a view, partly in medial section, and partly in elevation, showing one present illustrative embodiment of the invention;

Fig. 3 is a view similar to Fig. 2, but showing a modification;

Fig. 4 is a plan view of the hydraulic motor of Fig. 3;

Fig. 5 is a view similar to Fig. 2, showing another modification;

Fig. 6 is a plan view taken as indicated by line **6—6** of Fig. 5;

Fig. 7 is a view similar to Fig. 2, showing another modification;

Fig. 8 is a plan view taken on line **8—8** of Fig. 7;

Fig. 9 is a side elevational view of another embodiment of the invention;

Fig. 10 is a view taken in accordance with line **10—10** of Fig. 9;

Fig. 11 is a view taken in accordance with line **11—11** of Fig. 9;

Fig. 12 is a section taken on section line **12—12** of Fig. 9;

Fig. 13 is a section taken in accordance with broken line **13—13** of Fig. 12; and

Fig. 14 is a view taken in accordance with section line **14—14** of Fig. 13.

Reference is first directed to Fig. 1, which is a diagram representing sonic pressure wave amplitude established along the liquid filled tubing under conditions of standing wave resonance for any given depth in the tubing, and showing also the threshold pressure level for cavitation. The normal hydrostatic pressure level is indicated at A, and the pressure level coinciding with the threshold for cavitation is indicated at C. Cavitation is explained by authorities on different theories, either as vapor bubble formation when the liquid pressure is depressed to or below the vapor pressure of the liquid at the prevailing temperature, or as the pressure level equal to the dynamic tensile stress of the liquid. Whatever the correct theory may be, when a fluctuating pressure in a liquid swings periodically into a certain low pressure region, certain violent phenomena occur which have disruptive effects on adjacent solid materials. In accordance with the present invention, the peak value of the negative half cycle of the sonic pressure wave is made great enough that the pressure in the liquid is periodically fluctuated below the threshold level for cavitation, represented by the line C.

Fig. 1 shows a pressure standing wave at W, and the mean hydrostatic pressure level L is preferably elevated substantially above normal hydrostatic pressure A, as shown. The wave W has an anti-node at P and a node at N. The amplitude of the negative half cycle of pressure wave W is made large enough to periodically depress the pressure in the liquid to or below the threshold level C for cavitation, as clearly represented. The advantage of an elevated mean pressure level for the wave W is that an increased total pressure swing is thereby made possible, and there is correspondingly greater energy transmission, and also greater rate of change of pressure with respect to time,

$$\frac{dp}{dt}$$

with consequent greater disruptive forces of cavitation. The more violent these forces, of course, the faster the cleansing action. The aim with all of the following described forms of the invention is the carrying out, to greater or lesser extent, of the preferred and idealized conditions depicted in Fig. 1.

With reference to the illustrative embodiment shown in Fig. 2, numeral **10** designates generally a well bore containing casing **11** surmounted by casing head **12**, a usual pump tubing, which is the pipe to be cleaned, being designated at **13**. The tubing **13** will be understood to be set into casing head **12** in the usual manner, and to deliver its flow of petroleum through the casing head to a tubing **14** containing T-fitting **15** and having at its upper end a stuffing box **16** for polished rod **17**, the latter being understood to operate the conventional string of sucker rods **18** carrying at the lower end thereof the plunger of a conventional oil well pump, not shown.

Into the side of T-fitting **15** is connected flow pipe **19** leading one end of a T-fitting **20**, the other end of which is plugged, as indicated at **21**, and to the side connection of which is coupled flow line **23**. The latter leads to a periodic, differential pressure valve **24**, beyond which is delivery line **25**.

Valve **24** comprises a main body part **26** having an interior chamber **27** and a closure plate **28**. At the bottom of chamber **27** is a finished face **29** forming a seat for the bottom face **30** of a check valve element **31**, the latter being edge guided by guide ribs **31***a*, and backed up by coil spring **32** seating in a cup on the end of a member **33** screw-threaded into a central bore end closure plate **28**. Member **33** has a knurled end portion **34** by which it may be conveniently rotatably adjusted. A nut member **35** on member **33** may be set tightly against boss **36** on plate **28** to fix the member **33** in adjusted position. Flow pipe **23** is coupled into threaded bore **40** in the center of valve body **26**, and this bore communicates with chamber **27**, opening to the center of valve element **31**, as shown. A surge chamber **42** is connected into valve chamber **27**, and final delivery line **25** is also connected into chamber **27**.

In operation, production fluid from the well, either under pump pressure, or well pressure, if the well flows naturally, acting on the face **30** of valve element **31** opposite inlet bore **40** first slightly unseats the valve element from the face **29** against the force of spring **32**. Immediately that valve element **31** separates from face **29**, fluid pressure from the production line acts over the entire area of valve face **30**, the total force exerted on the valve element then being sufficient to displace the valve element a substantially distance against spring **32**. Upon this occurrence, a quantity of oil flows freely from line **23** into chamber **27**, and of course out of the latter by way of delivery line **25**. As a result of this flow, the pressure in line **23** drops momentarily to the point such that the total force acting on valve element **31** is less than that exerted by the compressed spring **32**. Accordingly, valve element **31** returns to its seated position, as shown in the figure. Pressure in line **23** then builds up again, and very shortly, acting again on an area of valve **31** equivalent to the area of port **40**, slightly displaces the valve element against spring **32**, thus completing the cycle. Thus a pulsating flow is established in line **23**, and this pulsating flow generates sonic pressure waves of high amplitude, which are propagated via line **23**, pipes **19** and **14**, and thence down the oil column contained within tubing **13**. Since pulsations will also occur within chamber **27**, it is advantageous, in order to relieve pulsations in delivery line **25**, to provide the aforementioned surge chamber **42**, which will be understood to contain a body of air which alternately compresses and expands with pressure changes occurring inside chamber **27**.

The frequency or periodicity of the described reciprocation or vibration of the valve element **31** depends upon the mass of the valve element, the constant of the spring **32**, and the pre-compression of spring **32** as set by adjustment member **33**. By this adjustment, the periodicity of the generated sonic wave can be made such as will establish standing wave resonance in the tubing **13**. The occurrence of resonance can be easily ascertained by those familiar with resonance phenomena from the sound radiated, or can be indicated by a pressure gauge, not shown, set, for example, into the casing head and communicating with the upper end of the tubing **13**. The back pressure exerted by spring-urged valve element **31** in the flow line compresses the fluid column and raises its pressure fairly substantially, as to a mean pressure level such as suggested in the diagram of Fig. 1. Such a valve as here described, connected in the flow line

from the well, either a pumped well or a flowing well, establishes high amplitude sonic pressure waves in the column of liquid within the tubing, and when resonance is established, as is preferred, a sonic standing wave is set up in the tubing as represented in Fig. 1, as previously indicated. The amplitude of the pressure waves thus transmitted down the liquid column in the tubing is such that the peak value of the negative pressure half cycles depresses the pressure in the oil column to, or below, the pressure level for cavitation, thereby creating conditions of such violence as to rapidly cleanse the inner surfaces of the tubing of foreign material such as dirt, scale and wax.

The principal cleansing action will tend to occur, as may be gathered from an inspection of Fig. 1, in the regions of the tubing corresponding to pressure anti-nodes. These may be shifted somewhat by adjustment of the pressure wave frequency, which is, in turn, under control of valve adjustment member **33**. In order to carry the cleansing action up and down from the pressure anti-node regions encountered at resonance, the wave frequency can also be adjusted to be off resonance to an extent, under which conditions traveling waves of substantial amplitude can be produced, and while these will normally not attain amplitudes as great as standing waves under resonance conditions, they are nevertheless powerful enough to accomplish material cleansing action. Also, of course, a material degree of standing wave action, at substantial amplitude, is achieved even though the periodicity of the wave produced by the vibrating valve is not precisely equal to the natural resonant frequency of the oil-filled pump tubing, and strong wave action, easily powerful enough to accomplish cavitation, can be obtained under such conditions. Finally, resonant operation can be established at higher frequency modes, in which case the pressure anti-node regions are more closely spaced, as well as located at different positions.

Reference is next directed to the embodiment shown in Figs. 3 and 4, showing a system generally like that of Fig. 2, excepting for the substitution of a pulsating type of hydraulic motor for the periodic valve of Fig. 2. The well bore is indicated at **10***a*, casing at **11***a*, casing head at **12***a*, pump tubing at **13***a*, and other parts are as in Fig. 2, as will be clear from the drawings, including T-fitting **20***a* and flow line **23***a* communicating with the liquid column in tubing **13***a*, all as will be readily understood. Flow line **23***a* has coupled thereto the inlet fitting **45** of a pulsating hydraulic motor **46**, here shown as of the Root's or lobar rotor type, numeral **47** designating the outlet fitting of the motor, and connected thereto is final delivery line **48**. To the end of T **20***a* is coupled by-pass line **49** having adjustable by-pass valve **50**.

Motor **46** has two conventional lobed, interengaging rotors **51** working within casing **52**, and mounted on rotatable shafts **53** connected by meshing gears **54**. The shaft for one of the gears carries flywheel **55** and pulley **56**, and the latter is preferably connected by suitable belts to any suitable loading device, such as an adjustable brake, not shown. The operation of such a motor is too well known to require description herein, and it will be sufficient to point out that such a motor delivers a pulsating output, and has a correspondingly pulsating intake, when held to a substantially constant r.p.m. by the inertia of flywheel **55**. The pulsating flow characteristics of this motor create sonic pressure waves in flow line **23***a* leading thereto and in the liquid column within the pump tubing **13***a*, and by speed regulation of the motor, which is accomplished by adjusting the by-pass valve **50**, these pulsations may be established at such frequency as will resonate the liquid column in the pump tubing **13***a*, in the general fashion explained heretofore. The loading factor afforded by the motor, augmented, if desired or necessary, by the additional load, such as a brake, connected to one of the rotor shafts, as described above, sets up a back pressure, and establishes the desired elevated hydrostatic mean pressure in the liquid column in the well tubing. It will be understood without further description that this form of the invention establishes the type of wave conditions characteristic of the invention, as heretofore fully explained.

The embodiment of Figs. 5 and 6 shows, first, a novel pulsating pump, and second, a modified form of the invention in which the pump is arranged to pump against the liquid column in the pump tubing, i.e., in a direction back down the production column. The well bore is indicated at **10***b*, casing at **11***b*, casing head at **12***b*, pump tubing at **13***b*, riser pipe from the casing head at **14***b*, flow pipe at **19***b*, and T-fitting **20***b* is shown as coupled at one end to pipe **19***b*, at the other to a pipe **60**, and the side outlet of T-fitting **20***b* is coupled to delivery line **61** containing control or shut-off valve **62**.

Line **60** is coupled to the side port of T-fitting **63**, to the upper port of which is coupled gas vent pipe **64** containing control valve **65**, and to the lower port of which is coupled pipe **66** leading from the outlet of a special pulsating pump **67**. Oil is supplied to pump **67** from a separate source, not shown, via inlet line **68**.

Pump **67** is a modified gear pump, having housing **69** containing meshing pump gears **70** and **71**, the shaft of the latter being provided outside casing **69** with pulley **72** by which the pump is driven, suitable belting and prime mover, not shown, being provided. One or more teeth **75** of one of the pump gears are made undersize, so as to provide clearance through which a predetermined leakage will occur. That is to say, in the operation of the pump, each time the undersized teeth mesh with the normally sized teeth of the other pump gear the positive flow characteristics of the pump are temporarily interrupted, with the result that the output pressure of the pump drops temporarily. This pressure drop results in the propagation through the line of liquid leading from the output side of the pump of a negative pressure wave.

As will be seen from Fig. 5, the pump **67** pumps oil through line **60** in opposition to the outflow from the well normally taking place from production tubing **13***b* and flow line **19***b*.

The system of Fig. 5 can be operated while the well is being pumped, or, in the case of a flowing well, while fluid is flowing from the production tubing through outlet pipe **19***b* and flow line **61**. In this case, the fluid delivered from pump **67** acts to maintain a back pressure on the column of liquid in the production tubing. In order to adjust this back pressure, it may be desirable to close valve **62** to some extent. Or, in the event that the well pumping operation is shut down, valve **62** may be further closed, so that it passes only the flow delivered by the pump **67**. In addition to maintaining the said back pressure on the column of liquid in the production tubing, the pressure pulsations caused by the pump **67** create a sonic pressure wave which is propagated down the pressurized column of liquid in the tubing. Again, as in earlier embodiments, control of the speed of the pump enables the establishment of resonance, and a standing sound wave, in the liquid column in the tubing. As in the earlier cases, the pulsations are generated at sufficient amplitude to bring about cavitation.

Figs. 7 and 8 show a system generally similar to that of Figs. 5 and 6, excepting for substitution of a piston type of pump or pulsator for the gear pump of the preceding embodiment. For convenience, parts in Figs. 7 and 8 similar to parts in Figs. 5 and 6 are identified by like reference numerals, but with the sub letter "*c*" replacing the sub letter "*b*" of Figs. 5 and 6. Thus the well bore is indicated at **10***c*, casing at **11***c*, casing head at **12***c*, pump tubing at **13***c*, riser at **14***c*, flow pipe at **19***c*, and T-fitting at **20***c*.

The pump or pulsator of Figs. 7 and 8 is generally designated by numeral **80**, and comprises cylinder **81**, cylinder head **52**, and crank case **82** in which is journalled

shaft 83 driven by pulley 84 and carrying eccentric 84 around which is eccentric strap 85 on connecting rod 86 connected to piston 87. Pressure line 60*a* is connected at one end to T-fitting 20*c* and at the other into port 90 extending through cylinder head 82, and an oil supply line 91, containing check valve 92, is connected into the head end region of cylinder 81. Preferably, a gas vent pipe 93, containing control valve 94, is also connected into the head end region of cylinder 81. To the side outlet of T-fitting 20*c* is coupled delivery line 61*c* having control or shut-off valve 62*c*.

The operation of the system of Figs. 7 and 8 is similar to that of Figs. 5 and 6, excepting for differences brought about by the piston type of pump, which is capable of developing high amplitude pressure waves superimposed on a high level of back pressure. The check valve 92, in the case here illustrated, will be seen to have a relatively small fluid passage therethrough, and accordingly, the pump does not deliver a substantial flow volume. It may accordingly be considered as essentially a pulsator, delivering high amplitude pressure waves, but small flow volume. Of course, a larger bored check valve could be substituted, and a substantial flow volume delivered, more as in Fig. 5. As with the system of Figs. 5 and 6, in the event that the well is a flowing well, or pumping is continued, flow continues through delivery line 61*c* during the operation of the pulsator. Valve 62*c* may be partially closed in order to hold the necessary back pressure. And in the event that the pumping operation is shut down, valve 62*c* may be further closed, so as to pass merely the flow delivered by the pump or pulsator 80; or, such flow may go down the production column.

Figs. 9 to 14 show a practical design of powerful, short stroke, twin piston type pulsator 100 which may be substituted for the pump or pulsator in the system of Fig. 7. This pulsator 100 has no intake fluid line, and hence pumps no net fluid flow, its function being solely that of delivering high amplitude pressure pulses. This unit may be used with a flowing well, or with a pumped well while the well is being pumped. Alternatively, a small auxiliary pump may be coupled to the flow line from the well, between the well and the pulsator, to maintain the desired elevated back pressure.

The pulsator includes a crank case 101 made up of base plate 102, mounted on support 103, side plates 104, top plate 105, and end plates 106. A crank shaft 107 extends transversely through this crank case, being supported in bearings 108 carried by bearing housings 109 mounted in suitable openings in side plates 104, as best shown in Fig. 12. Crank shaft 107 has a pair of 180° opposed eccentrics 110, separated by a spacer flange 111, and spacer discs 112 are placed between the outer sides of the eccentrics 110 and the bearings 108. Outside of crank case 101, crank shaft 107 carries a flywheel 113 and a pulley 114 through which the shaft is adapted to be driven by multiple belts from a suitable prime mover, not shown.

Received in end plates 106 are inserts 116, each having a pair of bores 117 and 118 aligned with the two eccentrics 110. The inner race ring of a ball roller bearing assembly 120 is fitted onto each of the eccentrics 110, and the outer race ring thereof is mounted in a suitable opening in the vertically reciprocable slide plate 125 of a Scotch yoke assembly 126. Each Scotch yoke 126 has a cross head 127 including a pair of spaced end plates 128, connected by threaded tie rods 129 and nuts 130, and spaced by sleeves 131. The inner faces of these cross head end plates 128 are formed with vertical splines 132 received in corresponding spline-ways 133 formed in the aforementioned slide plates 125.

Projecting outwardly in opposite directions from each cross head are a cylindrical piston drive rod 140 which is slidably received in bore 117 in the insert 116 at one end of the crank case, and a cylindrical guide 141 which is slidably received in bore 118 in the insert 116 at the opposite end of the crank case. It will be noted that the piston drive rods 140 of the two cross heads project oppositely. The guides 141 are preferably hollow, and furnished with ports 143 to avoid entrapment of liquid therebehind. The crank case is partially filled with oil through a threaded port normally closed by a filler plug 144.

Mounted against each of the end plates 106 of the crank case is a piston chamber member generally designated by the numeral 150. This member 150 includes a plate or flange portion 151 mounted against end wall 106 and secured thereto by studs such as indicated at 152. Projecting outwardly from flange 151, in alignment with bore 117, is a neck portion 152, leading to an enlarged body part 153 formed with a central chamber 154. A bore 155 aligned with bore 117 extends through flange 151, neck 152 and into chamber 154 of body part 153, and fitted into this bore 155 is a cylindrical piston 156 which is reciprocated by the aforementioned piston drive rod 140. An operative connection is made between the outer end of the drive rod 140 and the adjacent end of piston 156, and comprises, in this instance, a disc-like head 157 connected to the end of piston 156 by a reduced neck 158, said head and neck being received in a correspondingly shaped cavity 159 in the end of rod 140. This cavity 159 is slotted out at the top, as indicated at 160, in order that the head 157 and neck 158 may be moved laterally into position, the insert 116 being formed with a pocket 161 immediately above the formations described in order to provide clearance to accommodate assembly and disassembly of the coupling device with the piston drive member 140.

The body 153 is formed, in alignment with piston 156, with a bore 162 and counterbore 163 to provide access into chamber 154 and the counterbore 163 receives a closing pin 164 on a head 165 which is secured to body 153 by suitable studs and nuts, as indicated at 166. A suitable sealing ring may be employed around pin 164, as indicated.

Coupled into each of chambers 154 is a pressure pulse delivery tubing 170, suitable seals being provided, as indicated. The tubings 170 lead to a T-fitting 174, from which leads a single pressure pulsation delivery line 175. It will be understood that the latter may be connected, for example, to the pressure line 60*a* of Fig. 7 in place of the pump 80 there shown. Assuming a pumped or flowing well, the valve 62*c* of Fig. 7 would then be closed down to maintain the necessary back pressure, as previously described; and in the event that the pumping operation is shut down, a small auxiliary pump, not shown, may be connected to the delivery line 61*c* downstream from the control valve 62*c* and operated to pump in the upstream direction, such pump being employed to maintain necessary back pressure.

In the operation of the pulsator of Figs. 9–14, the two pistons 156 simultaneously move into and are then retracted from the chambers 154. The stroke will be seen to be short, and the frequency of operation is made relatively high, as, for example, 20 revolutions per second of the crank shaft, giving a pressure pulsation in the chambers 153, twin pressure pulse lines 170, and single line 175 leading to line 60*a* (Fig. 7) of 20 c.p.s. The pressure pulses thus delivered by the pulsator are exceedingly powerful, i.e., of high amplitude, capable of generating a strong sonic wave in the column of production fluid in the pump tubing, in the general manner previously described in connection with the preceding embodiments. The advantage of such a pump as disclosed in Figs. 9–14 is its capability of generating pressure waves of extremely high amplitude. Resonance in the pump tubing may again be accomplished by speed regulation of the pulsator.

The several embodiments of the invention now described have in common the capability of generating sonic pressure waves in the column of liquid in the pump

tubing of high amplitude, such as will produce cavitation at the interface between the liquid column and the inside surface of the tubing. Under such conditions, accumulations of dirt, scale, wax and the like are rapidly loosened, and the pump tubing surfaces scrubbed clean. Highest amplitude for these pressure waves is attained at resonance. As has been explained, however, under conditions of resonance, localized pressure anti-node regions are established, at which pressure amplitude is maximized, while between such regions, pressure pulsations are lower. Accordingly, I generally prefer to operate not only at resonance, but at frequencies above and below resonance, as well as at different resonant frequencies, in order to subject all regions of the pump tubing to the action of the pressure waves. It will be understood that when operating off resonance, the pressure waves will not be at maximized amplitude, but they may still be of sufficiently high amplitude to accomplish an effective cleaning action. Moreover, as will be apparent, at the order of wave frequency characteristic of the invention (stated in connection with the embodiment of Figs. 9–14 to be 20 c.p.s., which is typical), a wavelength along the pipe is relatively long, and calculates to be 150 feet for 20 c.p.s., assuming a velocity of sound in the well liquid of 3,000 feet per second. Accordingly, a substantial number of feet of pipe are simultaneously subjected to cavitation on each half-cycle of the wave. It will further be evident that at the wave frequencies indicated, the waves generated will be relatively high harmonics of the fundamental resonant frequency of the liquid column in the pump tubing. Thus, assuming a pump tubing of 6000′ in length, and a velocity of sound of 3000 feet per second, the fundamental wave frequency would be one-half cycle per second. The typical resonant operating frequency of 20 c.p.s. suggested hereinabove would then be the 40th harmonic of the fundamental. Operation may then be, for example, as suggested hereinabove, at higher frequency modes, i.e., at higher harmonics (multiples of the fundamental one-half c.p.s.), with resulting shifting of the locations of the pressure antinodes where cavitation is maximized.

The invention has now been described in connection with a number of present illustrative embodiments. It will be understood, of course, that various modified forms of equipment may be employed to carry out the principles of the invention, and it will further be understood that such modifications are within the spirit and scope of the broader of the appended claims.

I claim:

1. The process of cleaning the interior surfaces of a string of pump tubing or the like in an oil well while filled with a column of liquid, that comprises: installing adjacent the well at the ground surface an acoustic wave generator adapted for generating a high amplitude acoustic wave in a pressurized liquid, acoustically coupling said wave generator to the upper end of said column of liquid through wave-transmitting coupling liquid filling a pressure-holding liquid condit communicating both with said wave generator and with the interior of the upper end portion of said string of pump tubing, holding a mean pressure on said column of liquid which is at a level above atmospheric at the upper end of said liquid column, and operating said acoustic wave generator to generate in and transmit through said coupling liquid and down said column of pressurized liquid acoustic pressure waves of negative pressure amplitude periodically reaching the cavitation pressure of the pressurized liquid column at the interface between the liquid column and the pipe surface to be cleaned.

2. The subject matter of claim 1, wherein well flow from said liquid column is continued through a delivery line while said acoustic waves are being generated, and elevated mean pressure is obtained by holding a back pressure on said column by restricting said flow through said delivery line.

3. The subject matter of claim 2, wherein said flow through said delivery line is maintained by continued operation of a well pump at the lower end of said string of pump tubing.

4. The subject matter of claim 1, wherein well flow from said liquid column is continued through a delivery line while said acoustic waves are being generated, and said acoustic waves are produced by said generator by periodically choking said flow through said delivery line.

5. The subject matter of claim 1, wherein elevated mean pressure on the liquid column is obtained by pumping liquid from a surface source of supply against said column of liquid while said acoustic waves are being transmitted down said column of liquid.

6. The subject matter of claim 1, wherein the cleaning process is performed while production of oil continues from the well, and wherein elevated mean pressure on the liquid column is obtained by pumping liquid from a surface source of supply against the column of rising liquid while said acoustic waves are being transmitted down the rising column of liquid.

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