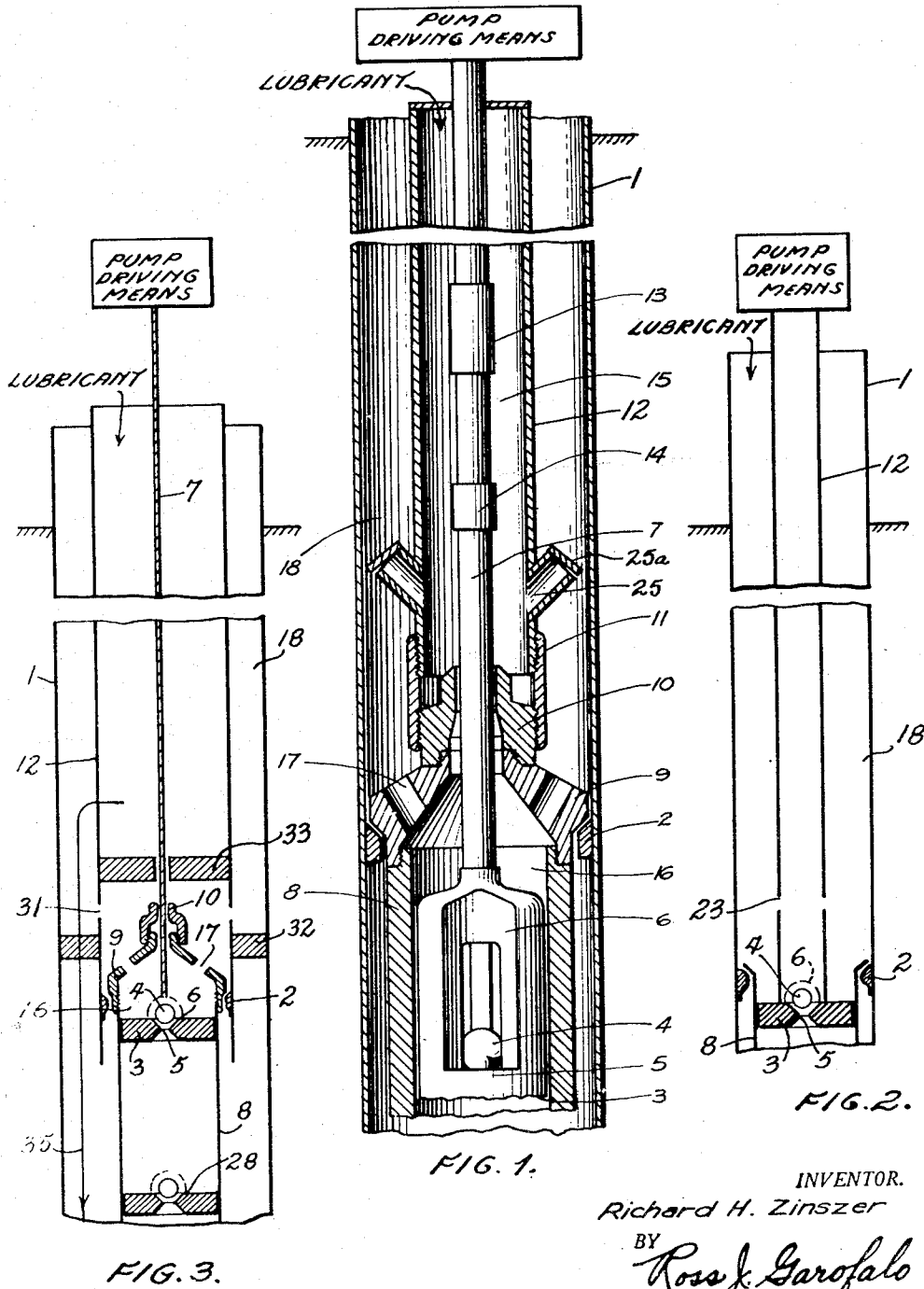


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PUMPING VISCOUS FLUIDS

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PUMPING VISCOUS FLUIDS

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This invention relates to the pumping of viscous fluids and especially to a method for producing heavy viscous crude oils from wells by means of a reciprocating pump.

In the production of petroleum a well is drilled into a producing formation and if there is sufficient pressure on the formation, upon removal of the drilling fluid from the well the oil will flow to the surface of its own accord. If there is insufficient pressure on the formation, or if this pressure has been depleted by extensive production from the well, it becomes necessary to resort to artificial means of supplying pressure such as pumping.

In the usual pumping procedure a reciprocating pump is located near the bottom of the well in the producing zone and this pump is driven by a shaft, such as a string of sucker rods which extends from the pump all the way to the surface of the earth where the driving mechanism is located. Thus the reciprocating shaft extends through the entire depth of the well and the oil being pumped from the producing zone is in contact with it for the entire distance. When the crude oil is of moderate or low viscosity the power required to overcome the frictional resistance with which the oil opposes the motion of the rod is negligible in comparison with the power required to lift the combined weight of the oil, the pump plunger and the long string of sucker rods. However, when the crude oil is extremely viscous the resistance it offers to the motion of the shaft results in difficulties in driving the shaft which are almost prohibitive. These highly viscous oils are generally of very low A. P. I. gravity or high density and this aggravates the condition. The motion of the shaft must be very slow or there is great danger that the shaft will bend or buckle and scrape on the walls of the surrounding tubing or twist or break. Consequently the rate of production is limited by the fact that the pumping speed must be extremely slow. Rapid movement of the shaft through the viscous oil would set up dangerous stresses and strains in the shaft.

As an illustration of the difficulties that are encountered, some time ago a survey was made of the power requirements of the pumping wells located in various fields in California. These requirements were actually measured and also were calculated, expressing the results in terms of horsepower required per given volume of fluid raised to the surface. The calculations were made by the use of the conventional formula recommended by the American Petroleum Institute for this purpose. It was found that the

actual requirements corresponded to the requirements calculated according to the formula, for substantially all of the fields which were producing oils having normal viscosities, such as less than about 10,000 Saybolt Universal seconds at 100° F. For those wells which were producing oils of higher viscosities however the actual H. P. requirements were always in excess of those calculated by the formula. In the case of the wells located in the Santa Maria Valley and Cat Canyon fields, which were producing oils having viscosities in the neighborhood of 100,000 to 500,000 or more Saybolt Universal seconds at 100° F., the actual H. P. requirements were frequently 3 to 4 times as great as those indicated by the formula.

It has been discovered that the above difficulties encountered in pumping these viscous crude oils may be overcome by a method which may be termed lubrication of the shaft. This may be accomplished by surrounding the reciprocating shaft with a stationary jacket or sleeve within which a fluid of lower viscosity is maintained. Thus the reciprocating shaft operates in a relatively non-viscous fluid which provides little resistance to its motion and reduces markedly the power requirements or pumping load. This permits markedly higher pumping speeds resulting in increased economy and increased flow. In this mode of operation the viscous crude is pumped through the well outside of the stationary jacket. Thus it is not subjected to the violent stirring action of the reciprocating shaft and this provides for smoother flow and also less danger of emulsification where water is also present with the crude oil. These heavy viscous crudes are also frequently carriers of rather large amounts of sand which in the ordinary method of pumping has an extremely abrasive action on the relatively rapidly moving reciprocating shaft. By the present method of pumping contact between the shaft and the abrasive sand is avoided. A slight modification of the method of this invention provides further advantages. This modification consists in allowing a portion of the less viscous fluid to escape from the inner jacket near the bottom of the well and commingle with the viscous crude being produced. This tends to reduce the viscosity of the mixture being pumped and still further increase pumping efficiencies and flow rates.

A number of different modes of carrying out the operation of this invention may be employed. In one modification it is only necessary to insert a string of small bore tubing into the conventional pumping well installation so that the inserted tubing surrounds the reciprocating shaft

and lies inside the tubing or casing used for the production stream. In this modification the bottom of the inserted tubing or jacket need not be closed but may be entirely open. The jacket is put in place and the "lubricant," i. e., the less viscous fluid, is forced into the jacket from above so as to displace the viscous crude. If desired, additional lubricant may be continuously added through the jacket so as to mix with the viscous crude being produced and lower its viscosity.

In a specific example of the above type of operation a pumping well, No. 6 of the Bradley Lands Lease No. 2 in the Santa Maria Valley, California, field, was selected for test. The crude normally produced from this well had a viscosity between about 100,000 and 500,000 seconds Saybolt Universal at 100° F. and had a gravity between about 7° and 9° A. P. I. at 60° F., thus being heavier than water. The well was approximately 3,725 feet deep and the casing through which the oil was being produced was principally 5½ inches diameter. A conventional reciprocating pump was located about 15 feet from the bottom of the well and was driven by a string of sucker rods leading to the top of the well. In the ordinary operation of this pumping installation the maximum pumping speed was 8 strokes per minute, since at this rate, in spite of the weight of the sucker rod, the rate at which the sucker rod dropped on the down stroke was so slow, due to the viscosity of the oil being produced, that the rod hung loosely from the bridle by which it was attached to the walking beam. A string of 2½ inch tubing was inserted into this well so as to surround the sucker rod for about 1675 feet, i. e., about the upper half of its length. This tubing or jacket was then filled with Orcutt crude of about 21 gravity and 100 Saybolt Universal seconds viscosity at 100° F. by injecting the latter crude into the upper portion of the jacket so as to displace the viscous crude from the entire length of the jacket. Pumping operations were resumed and it was found possible to increase the rate of pumping to 10 strokes per minute, resulting in an increase in production rate of about 25%, with a marked decrease in the power required per unit volume of production. Even at this higher speed furthermore the rod settled so rapidly on the down stroke as to maintain an appreciable tension on the bridle. Later installations in which the entire shaft has been jacketed and "lubricated" have given even better results. The invention is illustrated in different modifications in the attached drawing.

Figure 1 shows one modification in which a solid pump shaft is used and the viscous oil is produced through the annulus between the outer and inner tubing.

Figure 2 shows a second modification in which a hollow pump shaft is used, and the viscous oil is produced through this hollow shaft.

Figure 3 shows a modification of Figure 1 in which an insert or tubing pump is used instead of a casing pump. Figure 3 also shows that a portion of the lubricant may be diverted to the bottom of the well.

Another modification of the invention is shown in Fig. 1 of the attached drawing if vents 25 are eliminated. This illustrates a means of providing a closed tube as a jacket, i. e., a jacket which surrounds the entire length of the reciprocating shaft and is closed at the bottom to prevent free mixing of the lubricant with the viscous production. Referring to the drawing, 1 represents a conventional casing or tubing of approximately

5 inch diameter in the producing zone of the well. The conventional casing of larger diameter (about 10 in.) which surrounds tubing 1 is not shown. A conventional plunger type pump is suspended in tubing 1 by means of lock shoe 2. The entire pump assembly is then run in and supported on lock shoe 2. The assembly, only the upper portion of the pump being shown, includes plunger 3 with check valve including ball 4, seat 5 and cage 6 attached to sucker rod 7; pump shell 8, adaptor 9, rod guide bushing 10, coupling 11 and secondary tubing or jacket 12. The sucker rod 7 is equipped with automatic attachments 13 and 14, No. 14 being equipped with left-hand threads to permit the replacement of the rod without the necessity of removing the entire pump assembly. Bushing 10 is machined to fit closely to the sucker rod 7 which is a machined or polished rod at this point, so as not to allow excessive passage of oil between inner chamber 15 and cylinder 16. The outside of bushing 10 is screwed to coupling 11 which attaches it to jacket 12. The inner portion of bushing 10 is threaded to receive adaptor 9 which is equipped with ducts 17 allowing free communication between cylinder 16 and annular space 18. Adaptor 9 is also equipped with a shoulder which allows the entire assembly to be supported on shoe 2. The adaptor is also threaded to receive and support pump shell 8.

In operation the inner chamber 15 within jacket 12 is filled with the lubricant and the viscous crude oil is pumped from the bottom of the well up through the cylinder 16 and ducts 17 into shell 18 which conducts it to the surface of the ground. This type of unit is capable of many variations. Bushing 10 may be replaced by a conventional assembly for providing a packing gland around shaft 7 and thus prevent substantially all flow between the inside and the outside of jacket 12. On the other hand if dilution of the viscous oil with the lubricant is desired, the clearance between rod 7 and bushing 10 may be sufficiently large to provide an appreciable flow of lubricant from inside the jacket to mix with the viscous oil production and lower its viscosity. If further such dilution is desired vents 25 may be provided through jacket 12 just above coupling 11 or through coupling 11, or through adaptor 9 and bushing 10. These vents may be provided with check valves 25a if desired to prevent the reverse flow of viscous oil into the jacket. It may also be desirable as shown in Figure 3 to allow the lubricant inside jacket 12 to dilute the oil as it enters the bottom of the well, and suitable means 35 for diverting at least part of the flow of lubricant from inside jacket 12 to the bottom of the well just beyond the stationary valve 28 conventionally employed at this position may be used. Other arrangements of apparatus shown in Figure 3 include employing a small diameter insert type pump designed so that jacket 12 may be first installed into the well and the insert pump thereafter installed through the jacket. Ducts 31 would then be provided through the jacket just above the pump to allow the viscous production to escape through the outer shell while the lubricant filled the jacket down to the ducts. The outer tubing would also be provided with a packer 32 situated just below the ducts to prevent the production from being bypassed to the bottom of the well again. If dilution of the production with lubricant is not desired, a suitable packing 33 may be provided between

the reciprocating shaft 7 and the jacket, just above the ducts.

In another modification of the invention as shown in Fig. 2 the above flows are reversed. In this modification tubing 12 rather than rod 7 is employed as a driving shaft for the pump. The lubricant is then forced from above into the outer annular shell 22 between the casing 1 and the hollow pump shaft 12, and the viscous production is pumped up through the hollow pump shaft. In this modification as in the previous ones additional lubricant may be injected through openings 23 to provide for dilution of the viscous production.

As a lubricant for the purposes of this invention and oil of relatively low viscosity such as below about 1,000 seconds Saybolt Universal at 100° F. may be employed as illustrated in the specific example. However the invention is not limited to the use of crude oil. Thus, various fractions from crude oil may be employed such as fuel oils, gas oils, kerosene, gasoline and the like. Natural gas, natural gasoline, or other light hydrocarbons may also be used. Water may also be employed, as may steam or air, or other gas, or in general any fluid which has a viscosity lower than about 1,000 seconds Saybolt Universal at 100° F.

The invention may also be applied to the pumping of viscous fluids other than crude oil, such as tar, molten sulfur, or the like. It may also be employed in pumping operations in which the shaft has a motion other than the usual reciprocating motion, such as a rotary motion.

Other modifications of this invention which would occur to one skilled in the art are to be included in the scope of the invention as defined in the following claims.

I claim:

1. Apparatus for pumping liquids from wells comprising the combination of, an outer pipe extending from the surface down into the well, a rod-operated pump of the reciprocating displacement member type associated with the outer pipe and adapted to raise a column of well fluid through that pipe to the surface, a pump operating rod extending down within the outer pipe and connected to the displacement member of the pump to operate it by vertical reciprocation, an inner tube immediately surrounding the pump rod throughout a substantial portion of its vertical length, a passage leading from the interior of the inner tube to the interior of the outer pipe and constantly open for passage of fluid from the former to the latter under a differential in the pressures in the tube and pipe, and means for maintaining a body of relatively non-viscous fluid in the inner tube around the pump rod at a pressure which at least substantially balances the pressure of the well fluid at the lower end of the inner tube.

2. An apparatus according to claim 1 in which the less viscous fluid is an oil having a viscosity less than about 1000 seconds Saybolt Universal at 100° F.

3. An apparatus according to claim 1 in which the less viscous fluid comprises water.

4. An apparatus according to claim 1 in which the less viscous fluid is air.

5. Apparatus for pumping liquids from wells comprising the combination of, an outer pipe extending from the surface down into the well, a rod-operated pump of the reciprocating displacement member type associated with the outer pipe and adapted to raise a column of well

fluid through that pipe to the surface, a pump operating rod extending down within the outer pipe and connected to the displacement member of the pump to operate it by vertical reciprocation, an inner tube immediately surrounding the pump rod throughout a substantial portion of its vertical length, the lower end of the inner tube communicating with the interior of the outer pipe to allow discharge of fluid from the inner tube to the outer pipe under control of the pressure differential existing between the tube and pipe and independently of the operation of the pump, and means for forcing a relatively non-viscous fluid down the inner tube around the pump rod under a pressure sufficient to flow out of the inner tube into the pumping column in the outer pipe.

6. Apparatus for pumping liquids from wells comprising the combination of, an outer pipe extending from the surface down into the well, a rod-operated pump of the reciprocating displacement member type associated with the outer pipe and adapted to raise a column of well fluid through that pipe to the surface, a pump operating rod extending down within the outer pipe and connected to the displacement member of the pump to operate it by vertical reciprocation, an inner tube immediately surrounding the pump rod throughout a substantial portion of its vertical length, valvular means independent of the pump forming a communication to pass fluid from the lower part of the inner tube to the interior of the outer pipe and to prevent the opposite passage of fluid, and means for forcing a relatively non-viscous fluid down the inner tube around the pump rod under a pressure, at the valvular means, greater than the pressure of the well fluid at that point.

7. Apparatus for pumping viscous liquids from wells comprising the combination of, an outer pipe extending from the surface down into the well, an inner tube extending from the surface downwardly within the outer pipe in spaced relation therein, a pump barrel carried by the lower end of the inner tube, seal means between the pump barrel and the outer pipe serving to close the space between the barrel and pipe, the inner tube having an opening through its wall above the pump barrel to form communication between the interior of the tube and space surrounding it within the outer pipe, a reciprocable pump plunger in the pump barrel, a plunger operating rod extending from the surface through the inner tube, a seal stopping off the annular space between the rod and the inner tube wall at a point above the opening through that wall, and means at the surface adapted to maintain a body of relatively non-viscous fluid under pressure in the inner tube around the pump rod.

8. An apparatus according to claim 7 in which is also provided means for forcing the relatively non-viscous fluid through the inner tube and means for diverting at least part of said relatively non-viscous fluid from said inner tube to the bottom of the well just beyond the bottom of said pump.

9. An apparatus for pumping a viscous oil having a viscosity greater than about 10,000 seconds Saybolt Universal at 100° F. From a well which comprises a reciprocating pump near the bottom of said well, a reciprocating shaft extending from said pump to the surface of the earth, means for driving said shaft and thereby driving said pump, two stationary concentric tubes surrounding said shaft, a less viscous fluid having a viscosity less

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than about 1,000 seconds Saybolt Universal at 100° F. within the inner tube, means for maintaining said less viscous fluid within the inner tube in contact with said moving shaft while pumping the said viscous oil through the outer space between said inner tube and the outer tube, an opening near the bottom of said inner tube between the inner space thereof and said outer space, and means for continuously introducing the less viscous fluid into the stream of viscous oil through said opening.

10. An apparatus for pumping a viscous oil from a well which comprises a pump located near the bottom of the well, a reciprocating shaft extending from said pump to the top of the well, means for reciprocating said shaft, a first passageway for withdrawing said viscous oil from said pump through said well out of contact with the outside of said shaft over a substantial portion of said shaft, a second passageway containing a less viscous fluid in contact with the outside of said shaft over the said portion of said shaft, an opening between said first passageway and said

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second passageway, means for forcing the less viscous fluid through said second passageway and means for diverting at least part of said less viscous fluid from said passageway to the bottom of the well just beyond the bottom of said pump.

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