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METHOD OF DETERMINING FLUID DENSITY, FLUID PRESSURE,
AND THE PRODUCTION CAPACITY OF OIL WELLS
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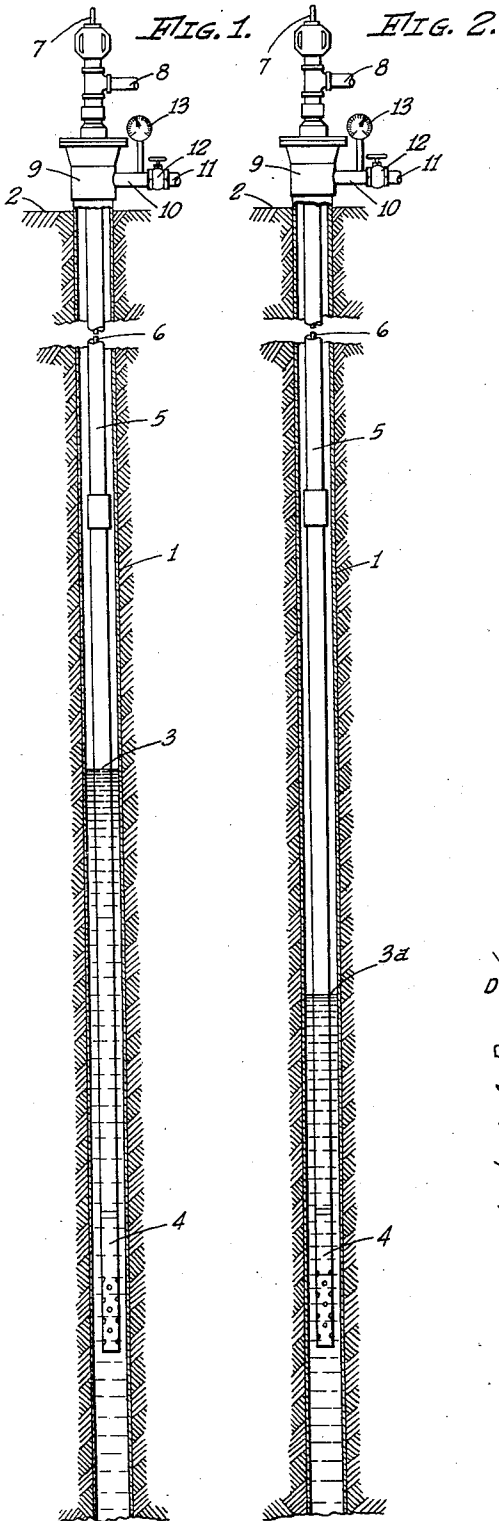


FIG. 3.

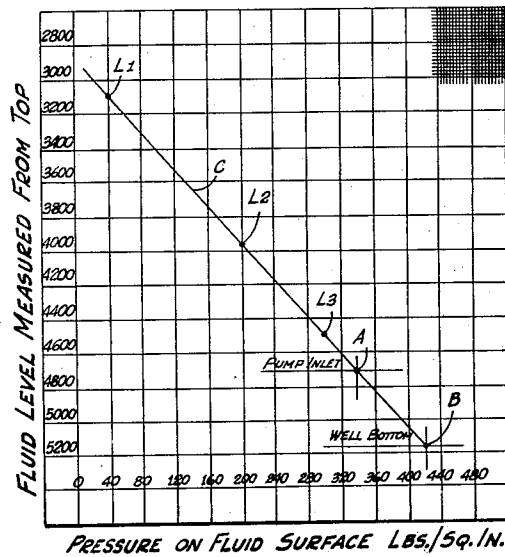
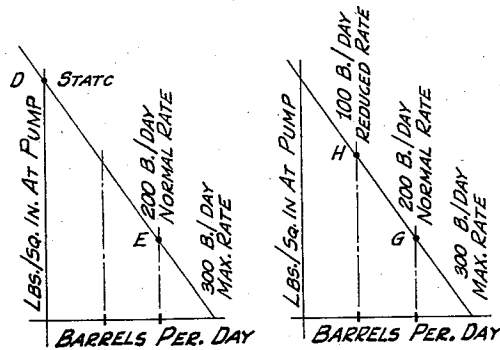


FIG. 4.

FIG. 5.

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METHOD OF DETERMINING FLUID DENSITY, FLUID PRESSURE, AND THE PRODUCTION CAPACITY OF OIL WELLS

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Continuation of application Serial No. 171,170, October 26, 1937. This application April 19, 1939, Serial No. 268,805

REISSUED

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8 Claims. (Cl. 73—51)

My invention relates to methods of determining the fluid density, fluid pressure and potential production capacity of oil wells and has particular reference to methods of determining the most desirable character of pumping equipment and manner of operating the same to permit an efficient production of oil from a given well.

This application is a continuation of my co-pending application Serial No. 171,170, filed October 26, 1937.

It is the common practice in oil well production activity to permit an oil well to produce as a flowing well, that is, to permit the oil to flow out at the ground surface due to the pressure in the oil formations, until the production rate reaches a considerably low value or ceases, after which gas lifting is usually attempted and continued until the production rate with gas lifting reaches a relatively low value or the production entirely ceases. At this time, and in some instances prior to any attempt to gas lift the oil, mechanical pumping devices are usually installed to lift the oil by mechanical means to the surface, these pumps usually comprising a pump barrel located at a considerable depth in the well, usually 50 to 150 feet below the surface of the liquid in the well while it is producing, plungers or other reciprocating devices being employed in the barrel and operated from the ground surface by means of sucker rods.

Usually the selection of the size and character of the pumping equipment is determined by the production of the well during its flowing or gas lifting life by estimating from this production the type or character of pump which appears to be most suitable. In many fields, however, the type, size and character of the pump installed is usually one determined as "standard" for that particular type of well in the particular field. In other words, it is one having the same dimensions as pumps in other wells producing from the same horizon. Frequently, such well receives no further attention until the field as a whole has declined to a point where it becomes necessary to increase the production from the wells, as for example, by the encroachment of water, necessitating the lifting of greater quantities of fluid in order to obtain the desired amount of oil. When this condition occurs, it is customary to increase the capacity of the pumping equipment.

Also, the production from a given well may be believed to be less than the character of the well and the character of the pumping equipment employed should indicate, as for example, the pump

may be operating at a relatively low volumetric efficiency.

In order to determine whether or not any change in the size, character, operating characteristics or location of the pumping apparatus should be made, it is desirable that the location of the liquid surface, the character of the liquid in the well, its density and the fluid pressure at any given point below the surface of the liquid and the maximum potential production capacity of the well should be determined.

For example, if the pumps in a particular field are operating at good volumetric efficiency, much can be determined from the quantity of oil produced and the volumetric displacement per stroke of the pump, and if the pumps are operating at their maximum capacity, the fact that the fluid level is at a considerable distance above the pump inlet may indicate that the operator is justified in making a change in the size or character of the pumping equipment. Again, if the volumetric efficiency of the pump is found to be low, as for example, when the pump appears to be taking in a comparatively large quantity of gas upon each stroke of the pump, the operator should know whether or not the inlet of the pump is located at a point too near the liquid surface so that he may determine how far below the liquid surface he should lower the pump in order to allow it to receive liquid for the full stroke.

Frequently in wells where the quantity of gas produced by the well is relatively small, an increased production of the pump may be obtained by raising the pump to a point nearer the liquid surface so that a better separation of the gas takes place prior to the entry of the liquid into the pump, while if the well is making a large quantity of gas, it may be better to lower the pump to a point below where the gas is separated from the liquid so that upon each stroke of the pump, dense fluid will be picked up. However, in many instances, it is dangerous to lower the pump too close to the bottom as sand is likely to be pumped into and foul the pump.

In wells where the fluid level is so low that the pump is not completely submerged and hence does not receive a full cylinder or barrel of fluid upon each stroke, a pounding at the pump is created which may be heard or determined at the ground surface. This same character of pounding, however, may be produced by the pump even though the liquid surface is at a considerable distance above the pump inlet, occasioned by the inflow into the pump of large quantities of free gas.

Hence, simple tests to determine the fluid level relative to the pump inlet will not produce the desired information to the operator as to the desirable character or location of the pumping mechanism.

If, however, the fluid pressure at different levels below the surface of the fluid is determined, this information may be employed to determine the most desirable location of the pump and whether or not a change should be made in the size, operating characteristics or character of the pumping equipment employed in a given well to produce an increased or maximum production from the well.

The determination of the fluid pressure at different points below the surface of the well may be determined by instruments known as pressure recorders, which must be either attached to the pump or lowered into the well to the desired level, or must be lowered into the well on wires, cables or other supporting devices and left at the desired levels for a predetermined length of time necessary to permit the recorders to make a chart or record of the pressures encountered. All of these methods, however, require the stopping of the pumps and the stopping of production while the test is being made and further required the removal of the pumps and sucker rods and sometimes the tubing and other apparatus from the well in order to insert the pressure recorders or pressure measuring devices, which entails considerable labor and time and holds up the production of the well for a considerable period of time.

It is therefore an object of my invention to provide methods for determining the fluid pressure at any given point below the surface of the standing column of liquid in the well, determining the density of the liquid in such column and the production index of the well without interrupting or interfering with the production of the well by the usual pumping apparatus employed therein.

Another object of my invention is to provide a ready means for determining the fluid pressure at any level below the surface of the standing column of liquid in the well and for determining the density of the liquid in any particular well without necessitating the removal or replacement of any of the usual pumping apparatus, flow tubes, sucker rods or other mechanism found in a well being produced by a mechanical pump.

Another object of my invention is to provide information to aid in the determining of the proper location of a pump in an oil well to achieve the maximum volumetric efficiency of the pump in handling the particular character of fluid found in the particular well.

Another object of my invention is to provide a ready method for determining the potential production capacity of an oil well with a minimum of expense, delay or interruption of the production activities of the well.

Another object of my invention is to provide a method of determining the density of the fluid in a well by measuring the amount of recession of the level of the liquid surface under two conditions of pressure upon the liquid surface and computing from the facts thus obtained the density of the fluid in the well. Fluid densities in producing wells range all the way from less than .04 pound per square inch to over .4 pound per square inch per 100 feet of fluid in the well. Therefore, a simple fluid level determination without a density or pressure determination gives very little information.

Another object of my invention is to provide a ready method for determining the potential production capacity of a well by measuring the pressure at the pump inlet under two conditions of operation of the pump and computing therefrom the maximum potential production obtainable from the well.

Another object of my invention is to provide a ready method for determining the potential production capacity of a well by determining the liquid pressure at some point below the liquid surface in the well, either at the pump inlet or any other location, under two conditions of production from the well (one of which may be zero production), and by comparing the pressures so determined with the production rates, determining the maximum potential production obtainable from the well.

Other objects of my invention will be apparent from a study of the following specification read in connection with the accompanying drawing, wherein

Fig. 1 is a diagrammatic, cross-sectional view of a typical oil well, illustrating the level of the liquid surface as being located a considerable distance above the inlet of the pumping apparatus employed.

Fig. 2 is a view similar to Fig. 1 but illustrating the effect on the liquid surface of gas pressure allowed to build up in the casing.

Fig. 3 is a diagrammatic view illustrating a chart or graph which may be employed in the practice of my method for the computation of fluid density and pressures at different locations or levels within the well;

Fig. 4 is a diagrammatic view illustrating a chart or graph which may be employed to compute the maximum potential capacity of a well from a comparison of the pressure at the pump while it is idle with the pressure at the pump while it is operating normally; and

Fig. 5 is a view similar to Fig. 4 illustrating the manner in which a more accurate computation of the potential capacity of a well may be obtained by comparing the pressure at the pump under two production rates of the pumping apparatus.

Referring to the drawing, I have illustrated in Fig. 1 a typical oil well which includes a casing 1 extending down through the well bore from the ground surface 2 into the oil producing sands, the oil flowing from the sands or oil formation into the casing and rising in the casing to some level indicated at 3. Pumping apparatus employed to remove the oil from the well usually includes a suitable pump 4 located upon tubing string 5, constituting the flow tubing through which the oil is raised to the ground surface, the pump 4 including usually some reciprocating mechanism operated by reciprocal movements of a string of sucker rods 6 extending down through the tubing 5 and connected to reciprocating power apparatus at the ground surface, as indicated at 7. The flow tubing 5 is provided with an outlet 8 communicating with a suitable oil line through which the oil pumped from the well is conveyed to any desired location.

The casing 1 is closed at its upper end as indicated at 9, an outlet 10 being provided communicating with the casing 1 to permit gas escaping from the oil to pass into a suitable gas line 11, a control valve 12 being usually provided to control the flow of gas into the gas line.

By properly selecting the size, the stroke and

the speed of the pump 4, the pump may be made to remove the oil from the well at approximately the same rate at which the oil flows into the well from the surrounding formation, and if so selected, the well will be operated at its maximum capacity. However, oil coming from the formation contains relatively large quantities of gas which, due to the pressure of the oil, cannot readily escape but which when the oil enters the pump tends to expand in the pump, reducing the volumetric efficiency of the pump. If now the pump is so located relative to the liquid surface that the greater portion of the gas within the well has been permitted to escape prior to the entry of the oil into the pump, it follows that upon each stroke of the pump, the pump will be operated upon relatively dense fluid and will hence operate at relatively high volumetric efficiency.

I have discovered a ready means for determining not only the pressure existing at the pump without requiring the removal of the pump or any of its apparatus but also I have discovered a ready method for determining the density of the fluid at the pump entrance, the information so obtained being used in the location of the pump at the most desirable level to obtain the maximum volumetric efficiency of the pump.

To obtain the information required, I measure or determine the stable location of the liquid surface of the "standing column" of liquid within the well when the pump is operating at its normal production capacity and with the pressure of gas within the casing at the usual or normal value maintained during the usual or normal pumping operations at the well. The expression "standing column" as used herein is intended to mean the column of liquid which stands in the well as distinguished from the pumped liquid column which is being lifted to the ground surface by the pump, such standing column being known in the oil industry as the "dead" liquid column and with the usual type of pumping apparatus this standing column lies in the annular space between the tubing 5 and the casing 1. This location of the fluid level may be readily accomplished by employing the methods and apparatus disclosed in United States Letters Patent No. 2,047,974, issued to Harold T. Wyatt and Paul E. Lehr. July 21, 1936, and in my copending applications Serial No. 162,699, filed September 7, 1937, and Serial No. 164,534, filed September 18, 1937. While the methods and apparatus are completely disclosed in the said patent and applications, the method may be stated briefly as including the introduction into the annular space between the tubing 5 and the well casing of a sudden change in pressure in the well casing and measuring the length of time elapsing between the production of this pressure impulse and the return to the ground surface of the echo thereof from the surface of the fluid. By noting the distance from the ground surface of the fluid level under these conditions and by noting the pressure of gas at the casing head, as by means of a pressure gauge 13, the pressure on the liquid surface may be computed as follows: to the casing head pressure is added the effect of pressure on the liquid surface exerted by the weight of the column of gas between the liquid surface and the casing head. A gravity test may be made of the gas at the casing head which will determine the pressure exerted by each foot or hundred feet of height of the gas column. This

information may be computed by the following formula which is by Dice:

$$\text{Log}_{10} Pb = \frac{SD}{122.82T} + \text{Log}_{10} Pt$$

Where

Pb = Lbs./sq. in. absolute at bottom of gas column.

Pt = Lbs./sq. in. absolute at top of gas column.

S = Specific gravity of the gas (air is considered 1).

D = Depth from casing head to liquid surface.

T = Mean temp. of the gas column in degrees F. absolute.

This information may then be plotted upon a graph or chart as illustrated in Fig. 3 in which the conditions existing in the particular well under measurement are assumed to be such that with a pressure of 36 pounds per square inch at the casing head, the liquid surface is found to lie at 3100 feet below the casing head. The specific gravity of the gas in this instance may be found to be such that the effect will be to produce 4 pounds per square inch pressure on the liquid surface. Thus, the addition of 36 pounds and 4 pounds produces a total pressure on the liquid surface of 40 pounds per square inch. By arranging the chart shown in Fig. 3 with the ordinates representing the fluid level measured from the ground surface and the abscissae representing pressure on the liquid surface in pounds per square inch, the point L1 determined from the preceding formula may be plotted on the chart shown in Fig. 3.

Now, the valve 12 is closed or a suitable pressure regulator is placed in the gas line 11 and the pressure within the casing is allowed to build up to any predetermined value. As the pressure builds up, the oil level 3 tends to recede. By continuing the operations of the pump during the building up of this pressure, preferably for a period substantially equal to three times the length of time required for the pump to remove the column of fluid between the original fluid level and a new fluid level to which the pressure depresses the liquid surface, represented at 3a (Fig. 2), it will be found that a stable condition will be achieved at which the fluid level will become constant and the production by the pump will be approximately the same as before the pressure was allowed to build up in the casing. When this stable condition is reached, a second measurement of the fluid level is obtained by the level measuring methods and apparatus hereinbefore described.

Having determined the new location of the liquid surface, the pressure exerted thereon may now be calculated as follows: Assuming that the casing head pressure in this instance was adjusted to 170 pounds, to this should be added the pressure due to the weight of the column of gas above the new fluid level. The determination of the effect of the weight of the column of gas upon the fluid level may be obtained either by calculation or may be plotted out and obtained from suitable charts prepared for this purpose. In this instance, it may be assumed that the pressure due to the gas column is 30 pounds per square inch, making a total of 200 pounds per square inch on the fluid. Now, assuming that the level to which the standing column of liquid mixture of oil and gas has receded is 3966 feet from the top of the well, the new point L2 on the chart shown in Fig. 3 representing the new level and the pressure on the liquid surface may be placed upon the chart. From an exhaustive series of actual tests, it has been discovered that the relation between the pressure on the liquid surface

and the distance through which the fluid will recede in any given well having a uniform cross sectional area is constant, so that a line drawn on the chart shown in Fig. 3 intersecting the points L1 and L2 will truly represent the fluid level at any of the pressures which may be placed upon the fluid column. Thus, by merely extending the line C downwardly on the chart until it crosses the ordinate representing the location of the pump inlet indicated on the chart as A, a direct reading of the fluid pressure required to cause the surface of the column to recede to the pump inlet is obtained. On the chart this is represented as 336 pounds per square inch, which is the pressure at the pump for the normal rate of production, assuming that the rate of production was normal during the tests.

The actual pressure in the column of liquid at the pump inlet may, however, be calculated from the information received by the two fluid level tests described above. That is, by subtracting the original fluid level from the new fluid level, the total difference in level will be found, in this instance 866 feet. Then, by subtracting the original pressure on the liquid surface from the new pressure on the liquid surface, a difference of 160 pounds per square inch is found to have been necessary to cause the liquid column to recede 866 feet. By dividing the difference in fluid pressure by the difference in surface level, the density of the liquid mixture of oil and gas in the well (that is, the pressure exerted by this mixture per unit of height of the column of liquid mixture) may be found. In this instance, the column receded a distance between 3100 feet and 3966 feet or a total distance of 866 feet, while the pressure difference is 160 pounds. The density of the liquid is such therefore as to exert 0.185 pound per square inch per foot of height of the column.

Hence, knowing the pressure on the fluid surface at any level thereof and knowing the distance below this surface at which the pump inlet is located, a direct calculation of the fluid pressure at the pump inlet may be obtained by the following formulae:

The pressure at any point below the normal fluid level in a well at which the level can be maintained by means of gas pressure in the casing is

$$PL1 = Pc1 + Pg1 \text{ and } PL2 = Pc2 + Pg2$$

The density of the fluid for the rate of production during the tests is

$$D = \frac{PL2 - PL1}{L2 - L1} = \text{density of the fluid in lbs. per sq. in. per ft. of fluid.}$$

The pressure at the pump is

$$Pa = D(La - L2) + PL2$$

Where

Pc1=gage casing pressure to maintain fluid at level L1.

Pc2=gage casing pressure to maintain fluid at level L2.

Pg1=pressure exerted upon fluid surface by weight of gas above it at level L1.

Pg2=ditto for level L2.

PL1=pressure on the fluid surface at level L1.

PL2=pressure on the fluid surface at level L2.

L1=fluid level corresponding to Pc1.

L2=fluid level corresponding to Pc2.

La=pump location in feet from ground surface.

Pa=pressure at the pump.

In the example shown in Fig. 3, assuming the

inlet to the pump is located at the 4700 foot level, the pressure of the oil at this point would be equal the sum of the gas pressure at the casing head for level L2, the pressure exerted by the column of gas above the liquid surface corresponding to this level and the pressure exerted by the column of oil above the pump inlet. In this instance, the pressure at the casing head is assumed to be 170 pounds per square inch, the effect of the column of gas at this pressure with the fluid level at 3966 feet from the surface being 30 pounds per square inch and the effect of the column of liquid above the pump inlet being 734 feet at .185 pound per square inch per foot, or 135.5 pounds per square inch exerted by the column of liquid, the result being 335.5 pounds per square inch pressure at the pump entrance. This result is clearly illustrated in Fig. 3 by the point A, the point A being located at the 335.5 pound mark on the abscissae of the chart. If desired, an estimation of the bottom hole pressure may also be made by continuing the line C downwardly on the chart to intersect the ordinate representing the bottom of the well, such point being indicated at B, or the pressure at any other level in the well below the surface of the liquid for the rate of production at which the tests were made may be located along the line C. I have discovered that in wells employing mechanical pumps for any given production rate by the pump, the density of the oil and gas mixture is constant throughout the height of the standing column of liquid in the annular space between the tubing and casing so that the line C once established continues as a straight line, the effect in pressure per unit of height of the column being constant throughout the height of the column.

Knowing the density of the oil and the pressure exerted at the pump inlet, the operator of any particular well may determine whether or not it is practicable to increase the amount of fluid being produced. If the volumetric efficiency of the pump is low and the tests indicate considerable pressure at the pump, he may raise the pump to a level indicated upon the line C at which better separation of gas will usually occur prior to entry of fluid into the pump.

The utilization of the information obtained by the foregoing method will also accurately produce the information of the maximum potential production of the well as by comparing the pressure of the fluid at the pump under two or more different operating conditions of the pump. For example, the static fluid pressure at the pump when the pump is not operating may be measured and compared with the fluid pressure at the pump when the pump is operating at its normal rate of production or at any other rate of production, a comparison of the two values so obtained will produce a constant, indicating the ratio between the rates of production and pressure at the pump inlet, so that by employing this constant at a theoretical zero pump inlet pressure (which would represent the fluid being removed from the well at the rate it flows into the well from the formation) the maximum potential capacity of the well may be found.

Employing the method of determining fluid pressure at the pump hereinbefore described, the static liquid pressure may be readily obtained without necessitating the use of pressure recorders or other devices requiring the removal of or alteration of any of the pumping mechanism and the measurement may be made in

wells which have been shut down as readily as in wells which are actively producing.

To obtain the fluid pressure at any point at or below the liquid surface when the well is not producing fluid, the casing should be closed in and the gas escaping from the liquid should be allowed to build up pressure in the casing until a suitable condition is reached, that is, a point is reached at which no more gas is made by the well (no more gas escapes from the liquid).

When this point is reached, the remaining fluid in the well may be considered as dense fluid. Now, by determining the height of the liquid surface under these conditions by my method, the pressure on the liquid surface may be readily determined and by adding thereto the effect of the weight of the column of fluid above any given level, the fluid pressure at that level may be found. This information alone is extremely useful to the operators of producing wells.

The information thus obtained may be plotted on a graph or chart such as that shown in Fig. 4, wherein the ordinates represent fluid pressure at the pump inlet in pounds per square inch and the abscissae represent rate of production of oil from the particular well under consideration, and the static pressure may be plotted at zero production, as indicated by the point D in Fig. 4.

The casing pressure may now be reduced and the pump started and allowed to assume a predetermined rate of production, preferably its normal rate. Assuming this rate is 200 barrels of oil per day, a new determination of the fluid pressure at the pump is made at this rate of production. That is, the pump is started and allowed to operate until the fluid level in the well reaches a stable condition. The location of the fluid level and the pressure in pounds per square inch at the pump inlet under these conditions are determined by the method hereinbefore described and the fluid pressure at the pump is plotted against the production rate on the chart shown in Fig. 4. Assuming that this new pressure at 200 barrels per day is found to be at the point indicated in Fig. 4 at E, a straight line drawn between the points D and E will intersect the zero pressure ordinate at a point representing the maximum potential capacity of the well. In the diagram shown in Fig. 4, this maximum potential production capacity is found to be 300 barrels per day. In other words, if a pump of sufficient capacity is installed in this well and operated in such manner as to remove 300 barrels per day, the oil will be removed at the same rate at which it flows into the well from the formation.

A more accurate determination of the maximum potential production capacity of the well may be made by comparing the fluid pressure at the pump under two different operating conditions of the pump, such as by measuring the fluid pressure at the pump when the pump is operating at one production rate, for example its normal rate, and then changing the rate of production of the pump as by slowing the pump down or changing the stroke of the pump and plotting the relation between the new production rate and the fluid pressure measured by my method, as set forth herein, it will be found that a line intersecting these two points will also represent the relation between production rate and fluid pressure at the pump at any rate of production by the pump. As shown in Fig. 5, the normal production rate of 200 barrels per day plotted against the fluid pressure at the pump in pounds per square inch may be represented upon the chart

by the point G while at a reduced rate of production at the pump, say to 100 barrels per day, it will be found that the fluid pressure at the pump is increased so that by determining the fluid pressure under these conditions, the relation between the reduced production rate and the fluid pressure at the pump may be plotted by the point H. A straight line interconnecting the points H and G will intersect the zero pressure ordinate at a point therealong, indicating a maximum possible production of 300 barrels per day. In making such determinations, however, it is desirable that the rate of production of the pump be reduced to at least two thirds of its normal production rate and preferably to 50% of its normal production rate in order to obtain substantially widely separated points H and G.

Again, it will be noted that all of the necessary calculations to determine the maximum production possible of the well may be made without interrupting the normal production conditions at the well and without requiring the laborious efforts of removing and replacing any of the pump mechanisms.

It will therefore be observed that I have provided a ready method for determining the density of the fluid in any particular well and also for the determination of the fluid pressure at the pump without requiring the removal or alteration of any of the usual mechanism found in the well. It will also be noted that I have provided a ready method for graphically determining the fluid pressure at the pump by first determining the amount of recession of the fluid level due to changes in gas pressure exerted upon the fluid surface and plotting this information upon a graph or chart and extending a straight line intersecting the two or more points so located to a point on the chart representing the level of the pump inlet. It will also be noted that I have devised a ready means of utilizing the information obtained with respect to fluid levels and gas pressures at the casing head for mathematically determining the fluid pressure at the pump and also for utilizing this information to determine accurately the potential production of any well measured. It should also be noted that all of the measurements necessary to provide for the computations and calculations explained herein may be accomplished without interrupting the operation of the pump except for the measurement of the static pressure as described herein.

While I have illustrated and described the preferred embodiment of my invention, I do not desire to be limited to any of the detail illustrated or described herein, except as defined in the appended claims.

I claim:

1. The method of determining the density of the standing column of liquid in a well, which comprises measuring the stable level of the liquid column under one condition of gas pressure, changing the pressure of gas within the well to move the surface of the liquid column to a new stable level, measuring the new stable level and dividing the change in pressure on the liquid surface required to achieve the new level by the difference in height between the two levels.

2. The method of determining the density of liquid in a well having a casing and a pump suspended therein on tubing and without requiring removal of pump parts, which consists in determining the liquid level in the annular space between the pump tubing and the casing under one condition of pressure, changing the pressure

of the gas within the well to move the liquid surface to a new stable level, measuring the new level and dividing the change in pressure on the fluid surface required to achieve the new level by the difference between the two levels.

3. The method of determining the density of the standing column of liquid in a well having a casing and a pump suspended therein, which consists in measuring the level of the standing column of liquid in the well while the pump therein is operated at a given rate of production and under a known condition of gas pressure on the surface of the liquid column, changing the gas pressure on the liquid column, continuing the operation of the pump at the same production rate until the level of the standing column becomes stable at a new location, measuring the new level and comparing the difference in the pressures exerted on the liquid surface at the two levels with the difference in height of the two levels.

4. The method of determining the density of the standing column of liquid in a well having a casing and a pump suspended therein, which consists in measuring the stable level of the surface of the standing column of liquid under one condition of pressure of gas released by the well, measuring the pressure on said liquid surface under said one condition of gas pressure, regulating the flow of gas from the well to increase the pressure of said gas to a different value to depress the surface of said standing column to a new stable level, measuring the new level, measuring the pressure on the liquid surface at the new level, and comparing the difference in the pressures exerted upon the liquid surface under the two conditions of gas pressure with the difference in height of the levels of the liquid surface under the two pressure conditions.

5. The method of determining the density of the standing column of liquid in an oil well having a casing and a mechanical pump suspended therein upon pump tubing and without requiring the removal of pump parts which consists in the steps of operating the pump under one stable condition of gas pressure in the casing until the liquid level becomes stable, measuring the distance between the casing head and the surface of the liquid under this stable condition, altering the casing pressure to a new condition, operating the pump at the same rate of production under the new condition of gas pressure to again stabilize the liquid level, measuring the distance between the casing head and the new level of the liquid surface under said new stable condition, and measuring the casing head pressures under the two stable conditions, whereby the pressure exerted by the liquid per unit of height of the liquid is represented by comparing the difference in height of the liquid surface levels and the difference between the pressures on the liquid surface required to maintain the liquid surface at the two levels.

6. In a well having a casing and a pump suspended therein, the method of determining the unknown pressure exerted in the standing column of liquid in the well at any desired level below the normal surface of said column and without requiring the removal of any of the pump parts, which comprises measuring the actual stable level of the liquid column under one known condition of gas pressure in the casing, determining the pressure on the liquid surface at that level, changing the pressure of gas in the well to move the surface of said column to a new actual stable level, measuring the new level of the

liquid surface, determining the pressure on the liquid surface at the new level, determining the density of the liquid by dividing the change in pressure on the liquid surface required to achieve the new level by the difference in height of the two levels and computing the unknown pressure at the desired level by adding to the pressure on the liquid surface at either of the levels the effect in pressure of the column of liquid of the density so determined between the selected actual level and the desired level.

7. In a well having a casing and a pump suspended therein, the method of determining the unknown pressure exerted by the standing column of liquid at any desired level below the normal surface of said column while the pump is operating to remove liquid from the well, which comprises measuring the actual stable level of the liquid under one known condition of gas pressure in the well by sonic sounding method, determining the pressure on the liquid surface at that level, changing the pressure of the gas in the well to move the surface of the column to a new actual level, continuing to operate the pump at the same production rate as for the first condition of gas pressure in the well until the liquid level again becomes stable, measuring the new stable level and determining the pressure upon the liquid surface at this new level, determining the pressure exerted per unit of height of the liquid column by dividing the change in gas pressure on the liquid surface required to effect the change in the liquid level by the difference in height of the two levels, and computing the unknown pressure at the desired level by adding to the gas pressure upon the liquid surface at either of the actual levels the effect in pressure of the liquid column between the selected actual level and the desired level.

8. The method of determining the potential production capacity of a well having a casing and a pump suspended therein, which comprises measuring the stable level of the surface of the standing column of liquid in the well at one known rate of production and under one known condition of gas pressure in the well, determining the pressure on the surface of the liquid column at that level, changing the gas pressure in the well to move the surface of the liquid column to a new stable level, measuring the level of the liquid surface under the new gas pressure condition and determining the pressure on the liquid surface at the new level, dividing the change in pressure on the liquid surface by the difference in height between the two levels to thereby determine the density of the liquid in the column at that rate of production, determining the pressure at some predetermined desired point below the normal liquid surface for that rate of production by adding to the pressure on the liquid surface for either of the measured levels the effect in pressure of the column of liquid between that level and the predetermined desired point, then changing the rate of production by the pump and repeating the liquid level change and gas pressure determinations to determine the density of the liquid in the column and the pressure of the liquid at the said predetermined desired point for the new rate of production and then dividing the difference in the two production rates by the difference in the corresponding liquid pressures at the desired point and using the ratio thus found to determine the maximum rate at which the well is capable of being produced.