# Determining Net Lift And Bottom-Hole Pressure With A Dynamometer

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With the production of oil coming from increasing depths and the cost of lifting oil continuing to rise, it is essential that maximum efficiency be obtained in the operation of pumping wells. This requires the full utilization of personnel, equipment, and technical advances. The operation of a pumping well, simple as it may seem, is in reality a rather complex thing. In order to fully understand the problems involved, it is essential that all the many and varied factors be viewed as a complete picture. In the past few years, the dynamometer has become an impartant tool with which to make this picture more complete. This tool has wide application in solving pumping troubles and in promoting efficient lifting operations. The purpose of this paper is to expand the use of the dynamometer to making a determination which is often desired but seldom available. The use of net lift and bottom-hole pressure can be a valuable aid with many advantages. With this knowledge, a better design and selection of equipment can often be accomplished, the application of equipment and production practices can be improved, and very frequently the solving of pumping problems can be made easier. This information is also quite valuable to the reservoir engineer in his efforts to obtain maximum production from a reservoir. These are but a few of the many uses of these data. It is beyond the scope of this presentation to fully explore all these various applications of dynamometer data but rather to suggest possible adaptation of these data to determine fluid levels.

In determining the net lift and bottom-hole pressure in a pumping well, the first thought that comes to mind is, "What equipment is necessary?" The dynamometer and its related equipment (polish rod clamps, wrench, etc.) are the only tools required. The dynamometer test data necessary are the traveling valve check and the standing valve check. Although this sounds simple enough, it should be pointed out that there are several precautions which should be observed in taking these valve checks. In taking the traveling valve check, it is possible to get an indication of the condition of the traveling valve and/or the plunger without measuring the weight of the rods and fluid accurately. As you may know, this test is accomplished by stopping the rods at a position just past midway on the upstroke and observing the load. As fluid passes through the traveling valve or by the plunger, this load decreases as the weight of the fluid is transferred from the rod string to the tubing string. The load measured immediately after motion has ceased is the weight of the rods and fluid. If the rods are stopped suddenly thus causing excessive vibration, error in determining this load will be introduced. To obtain the best results, the motion should be stopped at a minimum deceleration rate, thus reducing the impulse to a minimum. Also, it is good practice to perform this test at least two times to insure that a representative determination has been made.

The standing valve check is taken by stopping the rods just before the end of the downstroke. In a well that pounds fluid or is in a pumped-off condition, it is especially important that the motion be stopped near the end of the downstroke in order to insure that the traveling valve is open. Should fluid be leaking past the standing valve, the traveling valve will close and the load will begin to increase. This initial load, with the traveling valve open, is the weight of the rods submerged in the well fluid. Here again, it is important that the motion be stopped at a minimum deceleration rate, therefore reducing the impulse to a minimum. Performing the test at least two times will again insure that a representative determination has been made.

From the foregoing tests, there are two things which have been determined (1) the measured weight of the rods and the fluid, and (2) the measured weight of the rods immersed in the well fluid. Using this information, it is a simple matter to determine the measured weight of the fluid.

The first step in determining the net lift and bottom-hole pressure is to find the average or effective gradient of the fluid in the tubing. This will be a variable factor since the tubing may be filled with a heterogeneous mixture of salt water, oil, and gas. However, by using Archimedes principle, the average gradient may be determined from the actual buoyancy of the rods. Steel immersed in water has buoyancy equal to the weight of the steel times the ratio of the densities of water and steel. Thus the buoyancy of a string of sucker rods immersed in water is determined by the equation:

(1) $B_{rw} = W_{ra} \times 0.125$

WHERE:
$B_{rw}$ = Buoyancy of rods in water, lb.
$W_{ra}$ = Weight of rods in air, lb.
0.125 = Ratio of density of water and steel.

The buoyancy of the rods immersed in the well fluid would be:

(2) $B_{rf} = W_{ra} - W_{rm}$

WHERE:
$B_{rf}$ = Buoyancy of rods in well fluid, lb.
$W_{rm}$ = Weight of rods measured, lb.

Using equations (1) and (2), the average gradient of fluid in the tubing may be calculated by:

(3) $G = 0.434 \times B_{rf}/B_{rw}$

WHERE:
G = Average gradient of fluid in the tubing, psi/ft.
0.434 = Gradient of water, psi/ft.

Using this information, it is possible to determine the calculated fluid load, which assumes the annulus fluid level to be at the pump or the formation pressure to equal zero at pump depth.

(4) $W_{fc} = D \times G \times A_{pn}$

WHERE:
$W_{fc}$ = Calculated fluid load, lb
D = Depth to pump, ft.
$A_{pn}$ = Net area of pump plunger, sq. in.

The measured fluid load which is the calculated fluid load less any assistance from formation pressure, is determined by taking the difference between the measured weight of the rods and fluid and the measured weight of the rods.

(5) $W_{fm} = W_{rf} - W_{rm}$

WHERE:
$W_{fm}$ = Measured fluid load, lb.
$W_{rf}$ = Measured weight of rods and fluid, lb.

The difference between the calculated fluid load and the measured fluid load would be equal to the force applied to the system by the formation presssure. This force divided by the full area of the plunger would be the bottom-hole pressure at the pump depth.

(6) $BHP = W_{fc} - W_{fm}/A_p$

WHERE:
BHP = Bottom-hole pressure at the pump, psi.
$A_p$ = Full area of plunger, sq. in.

The net lift would be determined by:

(7) $L_n = W_{fm} \times D/W_{fc}$

WHERE:
$L_n$ = The net lift, ft.

The following table shows a comparison of this method with sonic or bomb measurements on several wells in the West Texas Area.

It should be pointed out that the net

| Well | Pump Depth Feet | G psi/ft. | Dynamometer Ln Feet | Dynamometer BHP at pump Depth, psi | Sonic BHP at pump Depth, psi |
|---|---|---|---|---|---|
| A | 4,025 | .3825 | 3,325 | 268 | 271 |
| B | 6,000 | .3310 | 3,040 | 841 | 847* |
| C | 2,850 | .4020 | 2,605 | 97 | 127 |
| D | 2,925 | .4070 | 2,790 | 56 | 81 |
| E | 2,935 | .3400 | 1,100 | 539 | 698 |

*Determined with a pressure bomb.

lift or apparent fluid level is not necessarily the same as the fluid level in the casing-tubing annulus. This is due to the fact that the average fluid gradient in the annulus is not necessarily the same as that in the tubing. The liquid column in the annulus could be considerably gas-cut and thus very foamy or it could be heavily water-cut. Therefore, the determination of an average gradient for this liquid column would be impossible using surface data. With this thought in mind, the accuracy of results obtained by sonic measurement in pumping wells are questionable due to the inadequacy of determining this average fluid gradient.

The preceding method of determining apparent fluid level and bottom-hole pressure is presented as a new application for the dynamometer, and due to its limited use it has not been developed to a standard recommended practice. However, it does have sufficient merit to deserve further investigation and is presented with that thought in mind. There are several limitations or reasons that explain the erroneous results sometimes encountered. It is essential that the exact number and size sucker rods are known. Also, the pump size, its depth, and its characteristics are equally important and should be accurately known. Excessive friction, caused by slack in the tubing, paraffin, or a pump galled with sand and scale, will introduce error. As previously stated, it is also possible to obtain a false reading when taking the valve checks due to improper technique.

From the above factors, it may be seen that the best results would be obtained if a dynamometer test were taken shortly after a new or repaired pump was installed. This would reduce to a minimum the possibilities of error introduced by leaking valves, paraffin, scale, and incorrect information as to equipment installed in the well. Should this method prove reliable, a fieldwide program could be set up to take a dynamometer test each time a new or repaired pump was installed. With proper application, the information obtained from such a program would be a valuable aid in promoting better production practices, and hence reduce the cost of lifting oil.

Further development of this method of determining bottom-hole pressure could best be accomplished by comparing the results obtained in this manner with those obtained by bomb measurement. There are a number of operators who have wells with facilities to determine pumping bottom-hole pressures by running a pressure bomb in the casing annulus. It is hoped that this paper will encourage these operators to investigate further the possibilities of this method proving reliable as another tool with which to improve the efficiency of producing oil.