Why Spend Money to Counterbalance a Pumping Unit ?

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INTRODUCTION

Several papers have been written on the subject of counter-balance in the past. The subject has been discussed for years and all evidence points to the fact that more will be said and written about it in the future. Why then does counterbalance present such a problem? The problem is one of application, which is caused by the lack of knowledge on the part of the operating personnel as to the importance of proper counterbalance, and/or a program to assure proper application of this counterbalance. Further, the probelm and need is present in each beam type sucker rod pumping system. The magnitude of these problems are realized when you consider that in excess of 80% of the world's pumping systems are of the beam type. Eventually, each person concerned with production of oil will be forced by necessity to solve in some manner his individual needs in relation to counterbalance.

The unit manufacturer has a definite role in relation to counterbalance. His first and primary function is to supply the demand of the oil industry. In keeping with developments over the past few years, the units being supplied today are actually of lighter structural material than of those in the past. This is a result of more knowledge of pumping systems, gained by better methods of interpretating and measurements of well conditions and loadings. Certainly the industry can thank the men who have accomplished this.

Another function of the manufacturer is to offer to the industry pumping units that incorporate the best engineering fundamentals and principles at an economical price. Also, to continually search for methods, materials and devices that will enable the industry to perform its function . . . produce oil at lowest possible cost.

ACCOMPLISHMENTS OF MANUFACTURERS

One of the accomplishments of manufacturers over the years, with relation to counterbalance, was the introduction of the adjustable crank weights. This was done to encourage proper use of counterbalance and to minimize cost of changing balance and operating cost of the unit. Another important introduction by some manufacturers was that of offering air balanced units. Certainly here the simplicity of changing counterbalance is at its best form.

Another step along this line is the incorporation of automatic counterbalancing controls in conjunction with air balanced units. These controls constantly keep check on the effective counterbalance and adds or takes away counterbalance as needed. With the air balanced unit, the necessity of maintaining proper counterbalance is the same as that of the conventional beam type unit. These functions of the manufacturer have provided the industry with the proper tools to reduce the problems imposed by counterbalance. Counterbalance is a device that is an integral part of each unit. Proper use of this device dictates the degree of success of the complete pumping system.

Lever Principle

Many centuries ago, man, using his intellect, incorporated a simple lever into his work of moving objects. In Fig. 1, showing a simple lever, load L is to be moved. The lever is resting on fulcrum point "F", a distance "A" from the load. At the other end of the lever, at a distance of "B" from the fulcrum, man applies a force or push downward of "P".

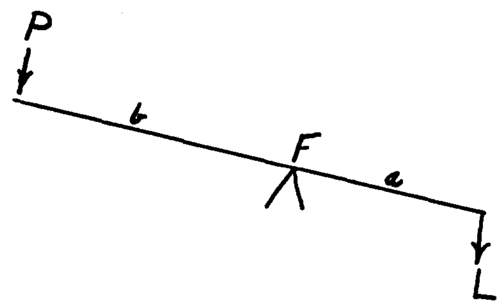


Fig. 1

Assuming that the distance "B" is 10 times distance "A", then the man has a mechanical advantage of 10 to 1 and can exert "P" pounds of push and move a load 10 times greater than "P". This basic principle of levers still prevails in our present day beam operated units. A beam type pumping unit uses levers to perform its job of transmitting power from the prime mover, or source of power, to the polished rod that is connected by rods to the oil lifting plunger. The pumping unit has the same features found in any simple lever. A load is applied at one point and is transferred to another point through a distance where a counterload is applied.

However, here it is necessary to change rotary motion to reciprocating motion. The speed reducer, as its name implies, reduces the rotary speed of the prime mover through other mechanical advantages to a speed desired at the cranks that can be used to obtain the reciprocating speed needed. It is assumed that the circular motion transferred from the cranks through the levers of the units to the polished rod results in approximate simple harmonic motion at the polished rod. The approximations of simple harmonic motion in a conventional type beam pumping unit is governed by the ratio of the pitman to the crank. That is, the longer pitmans the shorter cranks approach the desired harmonic motion.

It is necessary to bring out some of the above points in simple unit geometry and to show the functions of some of the components, in order to establish the effect of counterbalance weights. The rig geometry establishes the effect of the counterbalance weights regardless of their location. For the conventional beam type unit, the counterbalance weights are normally located on either the beam or the crank.

Beam & Rotary Counterbalance Weights

Beam counterbalance weights are normally placed on a beam extension beyond the tailboard or yoke. The effective balance created by beam weights is in proportion to the operating speed since the mass of weights has to be accelerated and decelerated with each reversal of the stroke.

In this case, effective balance is equal to the weight of the beam weights plus or minus the vertical acceleration in ft/sec^2 times the counterbalance in pounds divided by acceleration of gravity. ($Ce = Cw \pm \frac{Cw}{g} a$).

Beam weights do not impose adverse stresses in the pumping rig, since the manufacturer overcomes any such stresses that might be set up by design. However, the use of beams weights does introduce shock loads to the reducer at the 0° and 180° crank positions.

Rotary counterbalance effect, unlike beam weights, is not dependent on operating speed. Its counterbalance effect is the product of the counterbalance in pounds, dead weight, and its radius of rotation of the center of gravity of the weights divided by the radius of rotation of the wrist pin ($Ce = \frac{Cw \times D}{R}$). Rotary counterbalance creates a centrifugal force that is a function of operating speed. This force exerts bending moments on the low speed shaft and also changing moments on the reducer itself.

The use of beam and rotary counterbalance, in combination, can be strongly recommended. The advantages of each are utilized and the adverse conditions of one tends to offset that of the other. This can be accomplished by placing a determined amount of counterbalance on the beam and then adjusting the counterbalance to that needed by use of the rotary counterbalance. In many instances, an actual savings in operating cost has been experienced by the use of this combination.

Fig. 2 illustrates what is called the unit geometry of a conventional unit. The following important facts should be noted from the figure. The distances z, p, o, r, & n are always fixed and when these distances are known, it is possible to determine the variables m, y, v, & s for any position of the crank. M, y, v, & s will equal p, o, r, & n, respectively, twice during each pumping cycle.

For any position of the crank the torque applied by the well load F to the crankshaft is:

$$T_f = F \times \frac{z}{y} \times v$$

Torque applied by the counterbalance weights C & B is:

$$T_{cb} = C \times s + B \times \frac{m}{y} \times v$$

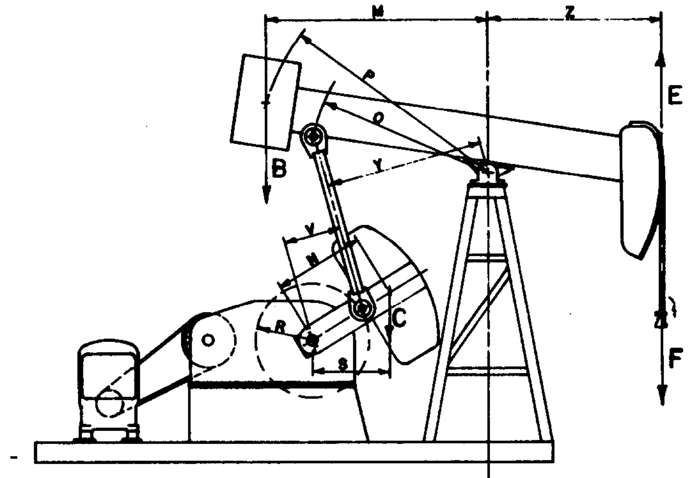


Fig. 2

Because the torques applied by the well load and counterbalance weights are opposite in sense the net torque on the crankshaft is:

$$T_n = T_f - T_{cb} = F \times \frac{z}{y} \times v - (C \times s + B \times \frac{m}{y} \times v)$$

$$T_n = \frac{v}{y}(F \times z - B \times m) - C \times s$$

Counterbalance effect E at the polished rod is obtained by the following formula:

$$E = C \times \frac{s}{v} \times \frac{y}{z} + B \times \frac{m}{z}$$

Fig. 3 illustrates the geometry of a pneumatic pumping unit. The distances z, p, o, & r are fixed and when these distances are known it is possible to determine the variables y, s, & v for any position of the crank. Y, s, & v will equal o, p, & r, respectively, twice during each pumping cycle. For any position of the crank the torque applied by the well load F to the crankshaft is:

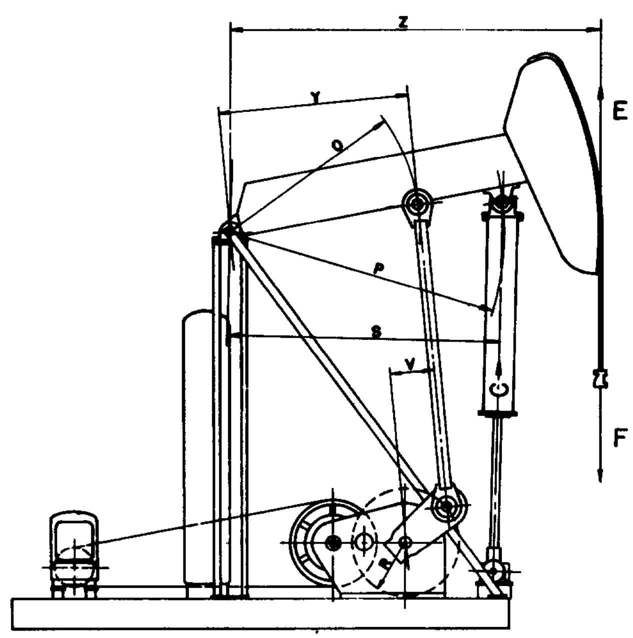


Fig. 3

$$T_f = F \times \frac{z}{y} \times v$$

Torque applied by the counterbalance cylinder is:

$$T_c = C \times \frac{s}{y} \times v$$

Because the torques applied by the well load and counterbalance cylinder are opposite in sense, the net torque on the crankshaft is:

$$T_n = F \times \frac{z}{y} \times v - C \times \frac{s}{y} \times v$$

$$T_n = \frac{v}{y} \left(F \times z - C \times s\right)$$

Counterbalance effect E at the polished rod is found by the following formula:

$$E = C \times \frac{s}{z}$$

The above formulas are used to establish the effective counterbalance as rated by the manufacturer.

Reducer Torque

There has been considerable importance placed on reducer torque, and rightly so. Today engineers and other people who design pumping installations take into careful consideration all existing factors that determine the size of the unit to be used. Consideration is given to the rod string, well depth, fluid to be produced at stages of well depletion, and reservoir characteristics. Care also is given to water flood possibilities and any other influencing information available is considered and incorporated. This has brought on our optimum pumping conditions and sizing of units for individual wells.

This program has no doubt lowered the cost of installations of new equipment in many instances. There are several formulas and interpretations of formulas used to design the pumping system. In selecting the system, peak polished rod loads, counterbalance effect required, net load, and finally peak torque requirements are calculated. Sometimes this sizing is so close to the limitations of the unit selected that a small amount of incorrect counterbalance will greatly effect the torque limitations of the reducer and exceed the rated design.

We now come to our question "Why spend money to counterbalance a pumping unit?" The obvious reason is to save money. Fig. 4 illustrates the reducer torque requirement with no counterbalance and with counterbalance. With proper counterbalance, the peak torque is about 40% of that required when no counterbalance is used.

We can conclude then that proper counterbalance will require a smaller prime mover, a smaller reducer box and a lower operating cost. With this, the operator is making best use of tools at hand to accomplish the most efficient operation.

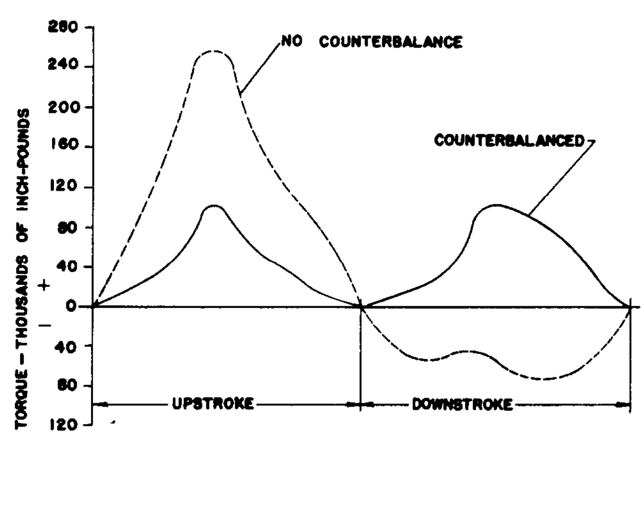
Equalize The Net Load

The objective of correct counterbalance is to equalize the net load on each part of the stroke. This ideal effective counterbalance should equal the weight of the rods plus one half the weight of the fluid. If we have this arrangement, then the net load on the upstroke equals the polished rod load less the counterbalance effect. The static PRL consist of the weight of the rods plus the weight of the fluid. If our ideal counterbalance condition exists, then the net load is half the fluid weight. On the down stroke, the net load is the counterbalance load less the falling rod load. Again the net load is half the fluid weight and ideal effective balance is achieved.

There are several methods used to determine when proper counterbalance exists in a pumping installation. These methods can be divided into two categories. The first category would be to check the conditions of counterbalance by visual methods. These include listening to the engine exhaust or the whine of an electric motor; watching the crank rotation for variances in speed; slipping of the clutch to determine peak load slip points; and by listening to the reducer.

The other category makes use of instruments. These include the use of a tachometer to determine variations in engine speeds; in the case of electric motors, the use of an ammeter to determine peak torques on the motor and then the use of a dynamometer. Of the above methods, the dynamometer is considered the most accurate but is also the most expensive. Regardless of which method is used, some method should be used regularly to maintain proper unit balance. There are definite times when balance should be checked and changed. The balance certainly should be set on a new installation after normal pumping conditions are obtained.

Any change in operation of the unit will necessitate a change in the balance. Such changes are: change in strokes per minute; when an adjustment of stroke length is made; when an alteration is made in the rod string or plunger; and at any apparent changes in well conditions. Possibly a good general program, that could be instituted by a producing company, would be a program of visually checking the counterbalance by the pumper and periodically, as governed by conditions, to check the counterbalance by instruments. This would



EFFECT OF COUNTERBALANCE ON TORQUE

Fig. 4

exclude certain problem wells that cannot be properly balanced.

The importance of correct counterbalance has been emphasized many times before, as mentioned previously. The reason for this emphasis is that something like 90% of all material failures in pumping units can be attributed to units operating improperly balanced. It has been said that the reducer is "the heart of the pumping system". The degree of over or under balance directly affects the life expectancy of this "heart". Proper care and proper balance will extend the life of the "heart" or reducer.

Other advantages for maintaining proper balance are: more economical operations as far as power requirements; smoother operated equipment; less trouble with other component parts of the unit such as bearings, foundations and other points of juncture. Other than operating cost, there also should be a certain amount of pride in each individual to operate the equipment at his disposal to the best advantage possible.

CONCLUSION

To answer the question posed by the title, it is necessary to spend money for counterbalance to obtain an efficient beam type system to artificially lift oil. The counterbalance effect itself is dependent on unit geometry as supplied by the manufacturer. The final affect of the counterbalance and its influence on the efficient operation of the pumping system is then dependent on, and governed by, the operator.