Application, Maintenance And Trouble Shooting On Beam Pumping Unit Hook-Ups

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Introduction

The average person driving down the highway past a pumping unit working away in the adjoining field has no conception of the many problems involved in the selection of this unit for its particular job and the constant continuing care that must be expended to keep it doing its assigned task year after year. All of this falls into the province of the oil business with the major responsibility on the production department of each company to keep the pumping units going and the oil coming.

This discussion is intended for those production personnel who have experienced trouble in keeping the pumping units going and who desire further information that may help them avoid or solve pumping troubles with a minimum of expense and down time.

Pumping Unit Sizing

Many slide rules, formulae, and charts have been presented from time to time to help production personnel size the pumping unit installation correctly and thereby eliminate a large percentage of the ensuing troubles. These aids require a background of mathematics that is disconcerting to most people. With this in mind, a set of simplified pumping unit selections tables have been developed that involve only simple multiplication to determine the three main factors in pumping unit sizing; peak torque, counterbalance and polished rod load.

Under a variety of plunger sizes, stroke lengths and sucker rod strings, tables have been developed that give these three factors on a per-foot-of-well-depth basis. It is then a simple matter to multiply the well depth times the appropriate three numbers to size a pumping unit of any manufacture or to check an existing pumping installation. The peak rod loads were derived considering the fluid level to be at the bottom of the hole, using the net plunger area for the fluid load, and using Slonneger's acceleration factor formula. These three factors give excellent results for wells up to depths of, say 8,000 feet, and are somewhat conservative for wells deeper than this, resulting in too large a unit on occasion.

Pumping Unit Maintenance

After the pumping unit, prime mover, bottom hole pump and rod string have been chosen and installed at the well, it is then the job of the production department to institute a program of maintenance to most economically operate the equipment and obtain the allotted production. And since any trouble with the production machinery directly affects the oil production, it is advantageous that the operator be familiar with some of the primary ills that production installations fall heir to. With this knowledge he may often avoid the troubles that severely hamper production schedules. Your author, having spent several years in trouble-shooting on pumping unit installations, has found that several common troubles are experienced by many operators; and it is felt that a better understanding of these will help to eliminate them from many installations.

Counterbalance

The one most troublesome, and, at the same time, most important pumping unit factor is the counterbalance. It can make or break the pumping unit, a fact that some operators disregard. Its prime function is to protect the heart of the pumping unit, the gear box, by smoothing out the torque peaks it experiences on each pumping cycle. And strange to some, is the fact that too much counterbalance is just as damaging to the gear box as not enough.

It has been found that the counterbalance effect should be equal to the weight of all the rods and half the fluid column. With anything more or less than this the result is an increased torque load on the gear box. The question is sometimes asked, "Why not counterbalance all of the polished rod load and eliminate the net gear torque?" As stated above this would only increase the torque load excessively and make the job of the prime mover more difficult.

The old controversy of beam counterbalance versus rotary balance will not be discussed here other than to note the present trend in their respective directions. The very small units will obviously continue to have beam balance weights since no space is available on their small cranks; and the very large units for deep wells will probably gradually eliminate their beam weights as the cranks are made large enough to accommodate the total amount of counterbalance required. Oil company safety departments are beginning to frown on beam weights as they present unnecessary safety hazards to operating personnel who must work with them. The rest of the units already have easily adjustable rotary balance.

Correct Counterbalance

Frequently the operator is found who "knows" his unit is balanced because he can stop the cranks at any position and they will stay there. He does not realize he has only enough counterbalance effect to match the weight of the rods. He lacks the weight of one-half the fluid column. If the well is of considerable depth with a low fluid level this weight is sizeable. Therefore, if no other means are available to check the counterbalance, then it will be more nearly correct, if, after stopping the cranks horizontal and the brake is released, that the cranks will fall to the down position. By the same token, any well on which the rods will fall and raise the cranks to the vertical position is considerably underbalanced.

Another method of checking the counterbalance which is inadequate at times is the tachometer. It is supposed to show by the engine speed variations whether the counterbalance is heavy on up or down stroke. The pitfall comes on a single cylinder engine drive when the engine is somewhat large for the unit and is running close to top speed. Then it has enough power and stored energy in its flywheel to pull the counterbalance thru with little change in speed, regardless of whether the counterbalance is too high or too low. When this condition exists, the gear box can be destroyed while the operator is satisfied everything is fine.

The ammeter for checking counterbalance on electrical installations is only as good as the observer's ability to quickly catch and compare the swings of the pointer. An ammeter with a stop hand which can be advanced until the pointer swings are only small pips is much better. Many feel that the ammeter affords the best counterbalance check since it can be used while the counterbalance weights are in motion and thereby includes their momentum effect. An occasion arose to check this recently. An operator, insisting on the above, proceeded to prove his point. He knew the fluid level of the well and first calculated what the counterbalance should be. Then a polished rod dynamometer was installed and an ammeter attached to a motor lead. When he was satisfied the counterbalance was correct by equal pointer swings, the unit was stopped and the counterbalance weighed by the dynamometer. He was greatly chagrined to find that on comparison all three methods agreed exactly as to the proper counterbalance. The momentum effect of the rotating weights is not as much as some would expect at normal pumping speeds as the well load is constantly acting to damp out this effect. This momentum becomes important only on beam balanced units carrying considerable beam weights and pumping at a rapid rate.

The polished rod dynamometer is the surest means of correctly determining the proper counterbalance and should be used where at all possible. It will show the counterbalance line cutting the dynamometer card in the center when correct and cutting the card too high or too low if not.

Some operators insist on staggering the counterbalance weights on the cranks to "help the prime mover on the upstroke." Opinions differ, however; with some insisting on leading counterbalance and others on lagging counterbalance. Actually if two crank weights are staggered the maximum counterbalance effect will fall at their combined center of gravity which is somewhere between them. So to get the maximum counterbalance effect for as much of the stroke as possible, it is only logical to keep the weights together no matter what their chosen position.

Wells that flow by heads are impossible to counterbalance correctly for any period of time. This should be recognized and the unit watched at frequent intervals for any drastic pumping condition changes that would require counterbalance readjustment until the well settles down to a full time pumper. At that time proper counterbalance may be attained.

Pumping Unit Geometry

To successfully apply pumping units to all pumping jobs it is important to understand something of the aspect of unit geometry. The first of these is direction of rotation. The present pumping units on the market can be rotated in either direction, but some of them and many of the older models have different net gear box torques with each direction of rotation. These units can easily be recognized as the ones with the slow speed shaft directly under the tailboard bearing, with the tailboard and saddle bearings on different levels. In these units clockwise rotation of the cranks will afford less counterbalance and higher net torque than when rotated in the other direction. Direction of crank rotation is determined by standing at the side of the unit with the well on the right and prime mover to the left. With the majority of prime mover drives being left hand, the units rotate clockwise with usually not enough counterbalance when the operator does not realize that direction makes a difference. A simple counterbalance adjustment for direction of rotation will save many a gear box from damage.

The best present day units offset the reducer crank shaft with respect to the tailboard bearing or have the tailboard and saddle bearings at the same level, making the geometry the same in either direction, and resulting in the same counterbalance effect and the same net torque.

Another important geometry factor that is coming into prominence is the pumping unit with unequal working centers designed to obtain a long stroke with no geometry change other than extending the front working center. Waterflood projects have largely been the origin of these units where the operator desires a long stroke to produce ever increasing amounts of fluid. This long-stroke, long-front-center feature is pure murder on gear boxes. The idea seems to exist that because a unit has a long stroke, it has no limit to the amount of fluid it can produce. In reality these units are very limited because the long front working center quickly imposes excessive torque on the gear box. Waterfloods at present are in shallow formations resulting in small rod loads and consequently small counterbalance requirements on the one hand, while large plungers and fast long strokes requiring much torque are applied on the other. The gear box is the ultimate victim! All who use these units should realize their definite limitations and apply them with the utmost care.

Fatigue Breaks

A problem that frequently confronts the trouble shooter is the fatigue break. It usually shows up in broken sucker rods and broken hanger wire lines. They occur on high volume wells where large plungers, fast strokes and short rod strings are employed. Often a fluid pound is also present. A dynamometer card will reveal the peak load to be small and the minimum load to be close to zero. The two hanger wire lines will have a combined strength some 20 times that of the peak well load and the rods a strength of 3 or 4 times; yet one or the other will break under these conditions. It must be remembered that a pumping unit running 20 strokes per minute will make 1,728,000 strokes in two month's time. The hangers and rods frequently cannot withstand this loading under the above operating conditions. A smaller plunger and a longer slower stroke will cure this condition. If it is felt that a fluid pound must be continued some sort of shock absorber hanger bar should be used.

Slow Engine Speeds

It is a hard matter to convince some that a pumping unit gear box can be destroyed from two ends; the well end and the prime mover end. Time and again we have weighted a pumping unit with badly pitted gear teeth only to find the counterbalance correct and the gear torque well within the API rating with no fluid pound present. There is usually only one answer; look to the prime mover. A single cylinder engine that is too lightly loaded or running too slowly can do untold damage to a gear box. The uneven flow of power from the prime mover works to alternately speed up and slow down the cranks due to the cyclic pumping load. With the engine running too slowly these speed ups are exaggerated as it attempts to meet the load and also to store energy in the flywheel. The cranks are heavy, possessing a great mass moment of inertia that will not let them speed up easily, so when a speed up power surge comes from the engine it is absorbed to a great extent by the gear teeth. When this surge is excessive the compressive strength of the gear tooth face is exceeded and pitting results. When these power surges are so great that the cranks jump slightly, you can be sure the gear teeth are suffering. The whole condition is often aggravated by a one-to-one V-belt drive or one close to this ratio. Remedial steps include a smaller engine sheave and a faster smoother running engine or a smaller, more fully loaded engine.

Engine Sizing

A comprehensive field survey would probably show that most pumping unit installations have the prime mover sized too large for the job being done because it was chosen to meet the maximum possible production conditions. Production allowables prevent these conditions from being encountered and the engines loaf along on much lighter loads. Maximum anticipated horsepower requirement is the standard used, but, since horsepower and torque are not the same, a better method of prime mover sizing is needed. This method is afforded in the engine torque curve and is not too difficult to apply. This simple formula can be used:

$$\text{Engine torque required} = \frac{\text{Gear Box API Torque (in-lb.)}}{12 \text{xGear reduction ratioXdrive ratio.}}$$

For example: Suppose an 80D unit is to be run at 20 spm. The reducer has a reduction ratio of 25.1 and a V-belt drive ratio,

$$\frac{\text{Driven Sheave Diameter}}{\text{Driver Sheave Diameter}}$$

of 2 to 1 is to be used. Then the engine torque required would be =

$$\frac{80{,}000}{12 \times 25 \times 2} =$$

133 ft. lb. If the engine torque curve shows it can deliver this torque at the chosen speed it will be sufficient. This method would prevent oversizing an engine that might later destroy the gear box.

Phase Converters

We once had a call that the pumping unit was "pulling too hard!" This would naturally arouse the trouble shooter's curiosity. Further questioning revealed that this unit did indeed require a larger motor than other wells in the vicinity doing approximately the same pumping job. Investigation showed the unit to be equipped with a phase converter. Now phase converters in themselves are not bad as they permit the use of three phase motors on a single phase power source resulting in a more economical drive and simpler conversion to three phase power if it becomes available later. But as any other piece of equipment, they have certain limitations which should be understood. With the converter the motor efficiency is approximately 80 percent, so, a 5 horsepower motor cannot be expected to deliver much more than 4 horsepower under these conditions. If a 5 horsepower single phase motor, loaded close to capacity, is replaced by a 3 phase motor and converter then certainly a larger motor will be necessary. This was the case above.

Identical Wells

A ticklish problem arises when one pumping unit in a group of 'identical wells" develops trouble. The task is to determine why this particular unit should be having trouble when the rest do not. A group of wells can be drilled to the same depth but there the exact sameness stops. A close check of all installations will reveal different engine speeds, different plunger sizes, well loads, counterbalance, different conditions of maintenance, etc. The problem unit is usually one where several adverse operating conditions are concentrated and these can be determined by close study. The claim of faulty equipment should not be entertained until the operator is sure his operating conditions are above question.

Operational Maintenance

This discussion has been pointed toward troubles that arise with pumping units which operating personnel should know. Without pointing a finger at any one it should be noted that operational discrepancies are frequent in the field. Many damaged gear boxes are found where the operating personnel have not looked in the boxes from time of installation. Some companies have organized maintenance crews that service units at regular intervals, but in between these intervals the pumper will not "turn a tap" and a unit may develop serious trouble which he will not correct because it is not his responsibility. This is specialization to the detriment of the pumping unit! A more versatile pumper is to be desired; one who knows his units from top to bottom and is ready at all times to administer needed routine maintenance.

Operator Integrity

The final most distressing problem that confronts the equipment trouble shooter is the withholding of facts by the operator in times of equipment failure. All too often the operator stands silently by while the trouble shooter has the job of finding out what happened, if he can. The experienced investigator can often sense that something is amiss because the conditions of failure as presented do not quite ring true. But if he bears in too hard revealing exactly what happened to the detriment of the operator, he is faced with the dilemma of winning an argument but losing a customer.

Further exasperating is the operator who will not believe any of the trouble shooter's findings if his operating practices are challenged. He will stoutly maintain the equipment is faulty, having nothing to lose and maybe new equipment to gain. Often a faulty equipment claim is hanging on just at the time new eqquipment is to be bought, but the operator will not allow the manufacturer a chance to quote until a "satisfactory" adjustment is made on the claim. These stalemates result in costly policy adjustments by the manufacturer for the sake of future business.

Conclusion

The operator who best knows the pumping unit installations from the standpoint of its application, its possibilities, its characteristics and its inherent troubles will always obtain, with proper care, the most trouble free service and most economical oil production.