Counterbalancing Beam-Type Pumping Units

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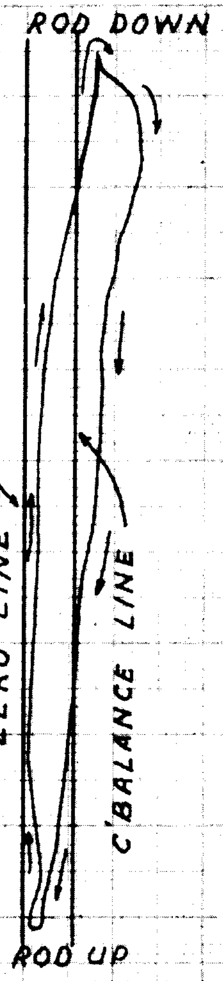
Since the early days of artificial lift of oil, much has been said and written about the importance of proper counterbalance of the loads involved. Unfortunately, little has been done in the industry toward the systematic checking of pumping units to insure that the best counterbalance possible is being maintained. As a result, the industry loses heavily every year, this loss being in energy expended uselessly and in equipment damaged by overloading. Counterbalancing may be defined as the effort to offset the rod load and the fluid load to the greatest extent possible, so as to minimize the net unbalanced load, thereby minimizing the load on the gear box and the prime mover. Several different systems are used, and the method is not particularly important. For beam-type pumping units, the present most generally accepted methods of counterbalance are using beam weights, crank-type weights, and compressed air.

For most companies, counterbalancing of units will be a duty of a pumper or a maintenance man. Therefore, for the achievement of proper counterbalance the most important methods must be those that do not require special equipment and, in the interest of economy, those that do not require involved calculations, with resulting loss of time while calculations are being made. The most widely used method of counterbalancing a unit without special equipment is that of listening to the sound of the prime mover. This is particularly good if the prime mover is an electric motor, in which case the intensity and extent of the whine of the motor, on the up-stroke as compared to the down-stroke, can be used as a gauge by a skillful operator, with good results. For gas engines, this method is not as reliable, but if the operator is familiar with the characteristics of the particular engine and if that engine does not have an extremely large flywheel effect involved, then fairly good results may be obtained. With electric motors, an indicating ammeter may be used to show the peak current being required on the up-stroke as compared to that required on the down-stroke. By that means, the operator may determine, with reasonable accuracy, whether the unit is overbalanced or underbalanced. However, equal peak currents on the up-stroke and on the down-stroke do not necessarily mean that the well is balanced so as to require minimum power requirements.

The most widely used method of counterbalancing, without use of special equipment, is a combination of listening to the prime mover sound and achieving a fairly close counterbalanced condition and then of allowing the unit to coast to a stop and observing where it stops and what action the beam takes once the cranks have come to a complete stop. This method requires patience and skill on the part of the operator, but it is the most accurate and reliable of all methods that do not require special equipment. After the operator has listened to the prime mover and has determined that the well is underbalanced or overbalanced, he moves the weights in the appropriate direction to correct the condition; then he operates the unit again, listening to determine whether he has moved the weights in the proper direction. Once he has the weights placed in a position so that he cannot detect any difference between the sound of the prime mover on the up-stroke and that on the down-stroke, he cuts off the motor, or disengages the clutch, and lets the unit coast to a stop. He repeats this process four or five times, and he notes the position of the cranks when the unit has completely stopped. A properly balanced unit should stop at any position around the clock. Then after the cranks have been stopped, with the brake left free, the cranks should move, very slowly, to a twelve-o'clock position, indicating that the rod-and-fluid load is slightly greater than the counterbalance. If the cranks move to a six-o'clock position, the unit is overbalanced, as there will be slightly more effect at normal pumping speed than at zero speed; hence the counterbalance should be slightly less than the wieght of the rods and fluid, under static conditions.

Perhaps the greatest single mistake made in the counterbalancing of beam-type pumping units is that of attempting to counterbalance the unit under certain conditions as the operator finds them at the time, yet the well may be one of the type that tends to vary considerably throughout its pumping period each day. When a new unit is started, the counterbalance weights should be placed in such a position that the unit will operate satisfactorily without overloading the prime mover, yet no attempt should be made to achieve perfect counterbalance. After the well has pumped long enough to settle down to fairly uniform conditions, accurate and close counterbalancing may be attempted. Even then, the well should be checked three or four times per day for the first thirty days of operation, in an attempt to determine whether or not the fluid level is dropping or whether other conditions are present that would affect the counterbalance requirements. Many wells may be perfectly counterbalanced when started up, yet at the end of an eight-hour pumping period the unit may be so badly balanced that the prime mover is on the verge of stalling. Such a well cannot be counterbalanced throughout the pumping period, but it must be overbalanced at the beginning, with the result that it will be perfectly balanced about midway through the pumping period and definitely underbalanced by the end of the period. There are thousands of such wells, and very probably they cause the bulk of the economic losses mentioned above.

For the determination of the actual loads at the polished rod, a special instrument, the dynamometer, is being widely used; by means of information gained from the dynamometer cards, it may be determined whether the unit is counterbalanced or not, and the exact amount of counterbalance that should be added, or subtracted, may be found. However, this analysis of each well is expensive and time-consuming, and it is not the object of this paper to attempt to convince members of the industry that each well must be weighed and analyzed frequently in order to be operated in an economical and efficient manner. But there are some conditions under which there is no substitute for the use of the dynamometer. Some wells seem to be perfectly counterbalanced when all the regular means of checking them are used, yet when the well loads are calculated and compared with the actual horsepower required to pump the well, the wide variance is puzzling. For such wells the dynamometer will determine whether the unit is overbalanced or underbalanced and whether there are certain peculiar loadings present that could not be calculated. It must always be remembered that the dynamometer merely measures what is happening to the polished rod as it is loaded with varying loads throughout the pumping stroke cycle. By use of dynamometer cards, torque calculations may be made and a torque curve may be drawn. From the peaks of this torque curve, it may be determined whether the unit is underbalanced or overbalanced and whether either of the conditions is causing a torque in excess of the peak torque capacity of the gear box. In such torque calculations, it must always be remembered that the dynamometer card is a record of what is happening at the polished rod, <u>not</u> in the gear box; therefore a factor



Lufkin TC-33ALBBTR-18B, Serial No. 31U

LeRoy A-288 Engine

Well Depth - 2530', Pump Depth 1425'

Plunger 2-1/4", Tubing 2-1/2"

Rods - 7/8" for 125', 3/4" for 1300'

Polished Rod - 1-1/4", Stroke 86", SPM - 24.8

6460R Cranks, No. 5R Counterweights, 24" From End

Peak P.R. Load - 7264#, Average Horsepower - 14.2

J. F. Dynamometer Constant = 11,350#/In.

Pumping Unit Efficiency Assumed = 85%

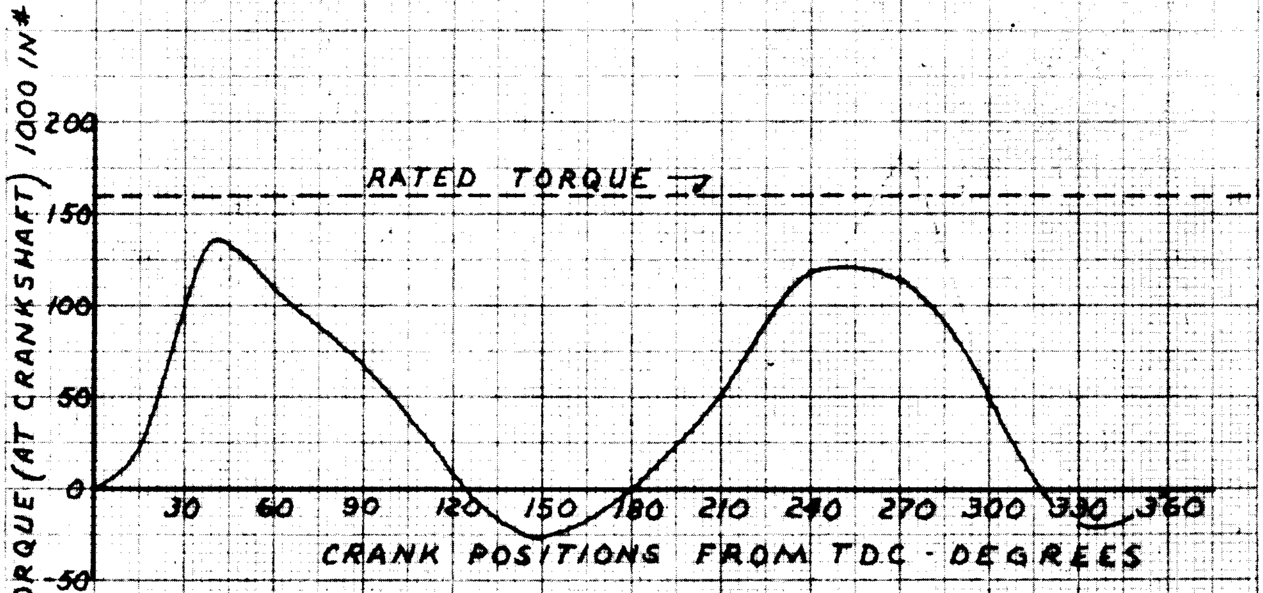


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Figure 1

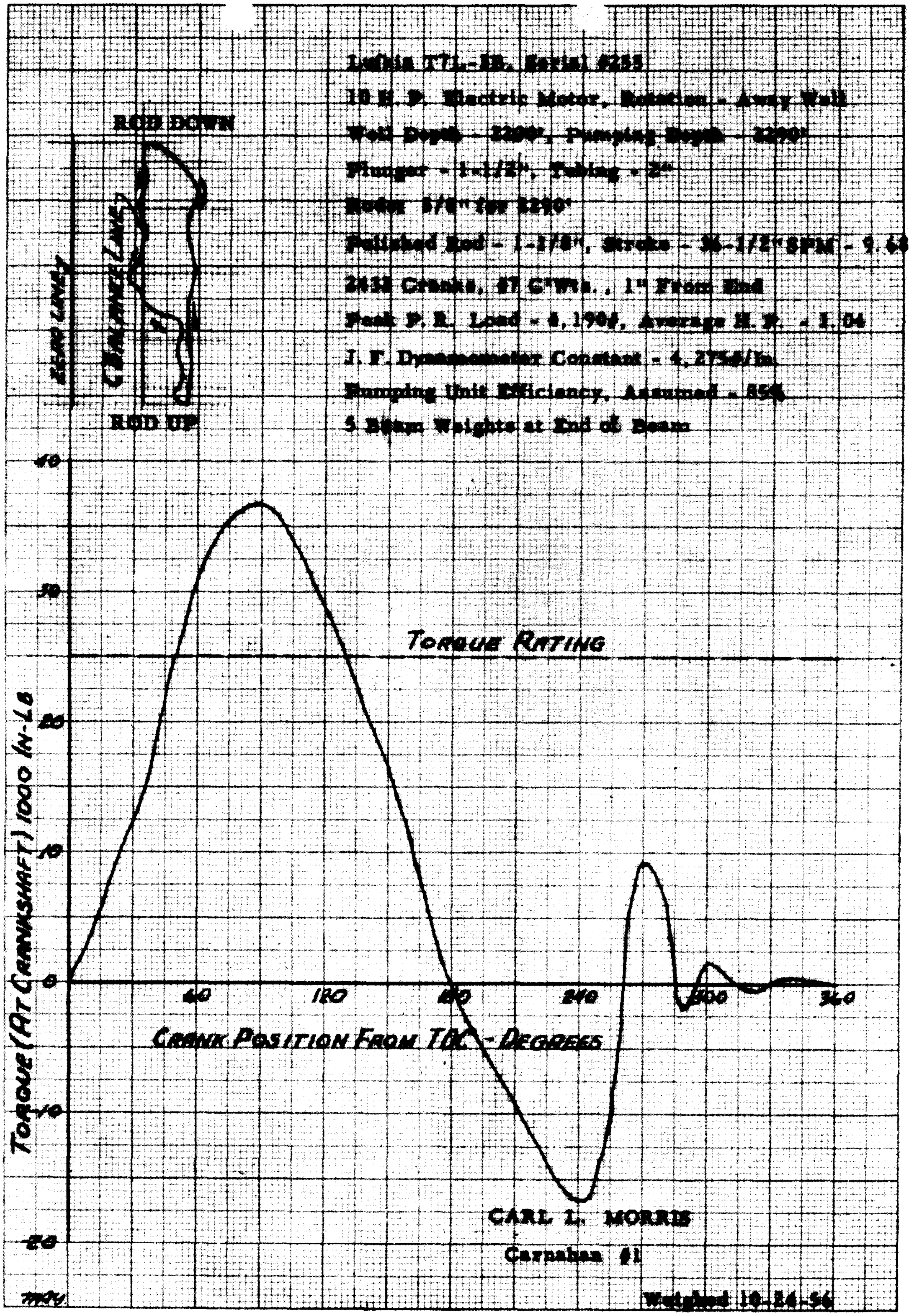
ROD DOWN
ROD UP
ZERO LINE
COUNTERBALANCE LINE
40
30
20
10
0
-10
-20
60
120
180
240
300
360
TORQUE RATING
CRANK POSITION FROM TDC - DEGREES
TORQUE (AT CRANKSHAFT) 1000 IN-LB
CARL L. MORRIS
Carpahan #1

Figure 2

should be introduced to take care of the losses between the polished rod and the gear box. This factor is generally assumed to be 0.85, which consequently gives larger torque values than would be obtained by using the exact measurements of the dynamometer card. Instantaneous torque at any point, which we shall call "X", is equal to A x B x D x Stroke Length divided by L x 0.85. These symbols are defined as follows:

A is measured from the card and is the vertical distance from the counterbalance line to point "X" on the card.

B is the vertical height (on a semi-circle made from using the length of the card divided by 2 as a radius) at position of "X".

D is the dynamometer constant.

Stroke Length is the length of the stroke in inches (measured at the polished rod).

L is the length of the card.

All dimensions are in inches.

Figures 1 and 2 show actual dynamometer cards and torque curves.

Two trends make the proper counterbalance of pumping units increasingly important. One of these is the increasing use of purchased electric power. If counterbalance is not properly maintained, the industry pays for doing needless work, and lifting costs will be unnecessarily high. The second trend is the tendency toward the purchase of units without adequate margin of peak torque capacity, so that even a slight unbalanced condition means that the gear box is overloaded, with resultant damage to the equipment or unduly shortened life of the pumping unit. A proper program of checking counterbalance of all pumping units is just as important as checking the condition of the oil or any other standard point of maintenance. Toward instituting and maintaining such a program, it is suggested that each company have a training program for the personnel responsible for the operation of the pumping units, this training program to be such that all personnel involved will become skilled in determining whether or not a unit is properly balanced and in knowing what to do to bring it into balance. Each pumping unit in a field should have a "static counterbalance effect chart," which is available to the pumper or maintenance man who is to check counterbalance. From the chart he can determine exactly what the counterbalance effect is when the weights are in a particular position. This chart is valuable when an operator starts new units, as it will enable him to determine, by calculations, approximately where to put the counterbalance weights initially. These charts may be obtained from the pumping unit manufacturer.

The majority of pumping units now in use are of the crank-weight type. For the achievement of correct counterbalance, a "trial-and-error" system must be used. With air-balanced units, the counterbalance effect can be changed by turning a valve while the unit is in operation; hence counterbalancing the unit in a short period of time and to a fairly close degree is relatively simple. Here again, however, it must be borne in mind that counterbalance requirements may change from time to time throughout the pumping period; hence the same instructions would apply to the air-balanced unit that would apply to the weight-balanced units, in that it might be necessary to have the unit underbalanced at one time and overbalanced at another, in order to achieve the best possible average balance. For air-balanced units, where the counterbalance requirement varies to an extreme degree, an automatic counterbalancer that will change the air pressure as well conditions make necessary a change in counterbalance effect is available.

In the operation of beam-type pumping units, proper counterbalance is more important than any other factor in its effect on the length of the life of the equipment and on the direct lifting cost involved. For that reason, it is very important that the industry institute programs to accomplish the following:

1. To train pumpers and/or maintenance men to recognize unbalanced condition of pumping units and to teach them proper procedure to currect such condition
2. To institute counterbalance checks of all units as a part of their regular maintenance program

Such effort will pay tremendous dividends by lowering lifting costs and by increasing the salvage value of pumping units.