Dynamometer Fundamentals As Applied To Water Flood Operations

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It is the purpose of this paper to review certain dynamometer fundamentals and show how these are being applied to water flood operations. Due to space limitations many points will require further study for full comprehension. However, we hope to present a sufficiently clear picture to illustrate the economic advantages obtained by using the dynamometer for operational control of water floods.

After the initial studies and decisions have been made and the flood is started, it is then a matter of continuous checking and adjusting of volumes of input water in order to attain optimum results at the producing wells. In order to show how the dynamometer fits into the picture, we will use illustrations of actual cases. However, in the discussion of fundamentals, we shall briefly explain what the dynamometer is and what it does.

Some 30 years ago the Bureau of Standards in Washington was presented with the problem of developing a device for calibrating tensile machines. It had to be small enough for easy transport, several times more accurate than a tensile machine, and one which would repeat to within 1/10th of 1 percent. After extensive investigation and research, a steel ring was developed to meet these requirements. It was called a proving ring. Figure 1. It was through the application of this ring principle that the Johnson-Fagg Dynamometer is installed on a pumping well in such a manner that the weight of everything below polished rod is transmitted thru the ring. This weight is recorded with respect to polished rod position. A timer stylus also records the instantaneous polished rod velocity. Inasmuch as the load on a pumping well continuously changes throughout the pumping stroke, we need an instantaneous load record at each point in the stroke if we are to properly analyze the pumping problem. In order to accomplish this, the dynamometer rides on the hanger bar below the polished rod clamp. In this manner it sees down to the pump and back to the prime mover. Figures 3 and 4. The record made by the dynamometer is called a dynamometer card and may be defined as the resultant of all the forces acting at the polished rod at any particular instant of time throughout the pumping stroke. A detailed discussion of dynamometer card interpretation becomes too involved for the scope of this paper. As a review, we would suggest reading "Dynamometer Card Interpretation" in the "Sucker Rod Handbook" published by Bethlehem Steel Company, pages 144 to 171, Second Edition.

We shall now take a look at what the dynamometer sees looking down to the pump and looking back to the prime mover. Looking down, we first see the load at the polished rod on the sucker rod string at each position in the pumping stroke. When analyzing the record, we can know the peak load, the range of load, and the minimum load at the top of the sucker rod string. Experience has shown that certain load limits should not be exceeded for given pumping conditions. (Ref. Bethlehem Sucker Rod Handbook, page 23). The importance of range of load is also illustrated in the Goodman Diagram page 23 of the

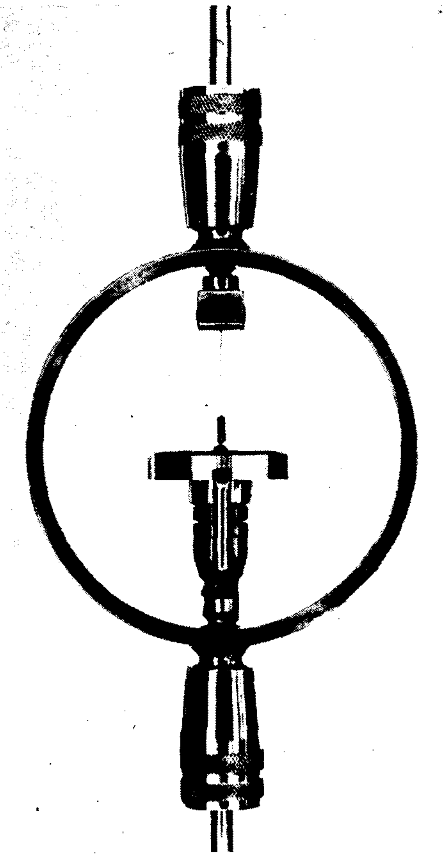


Figure 1

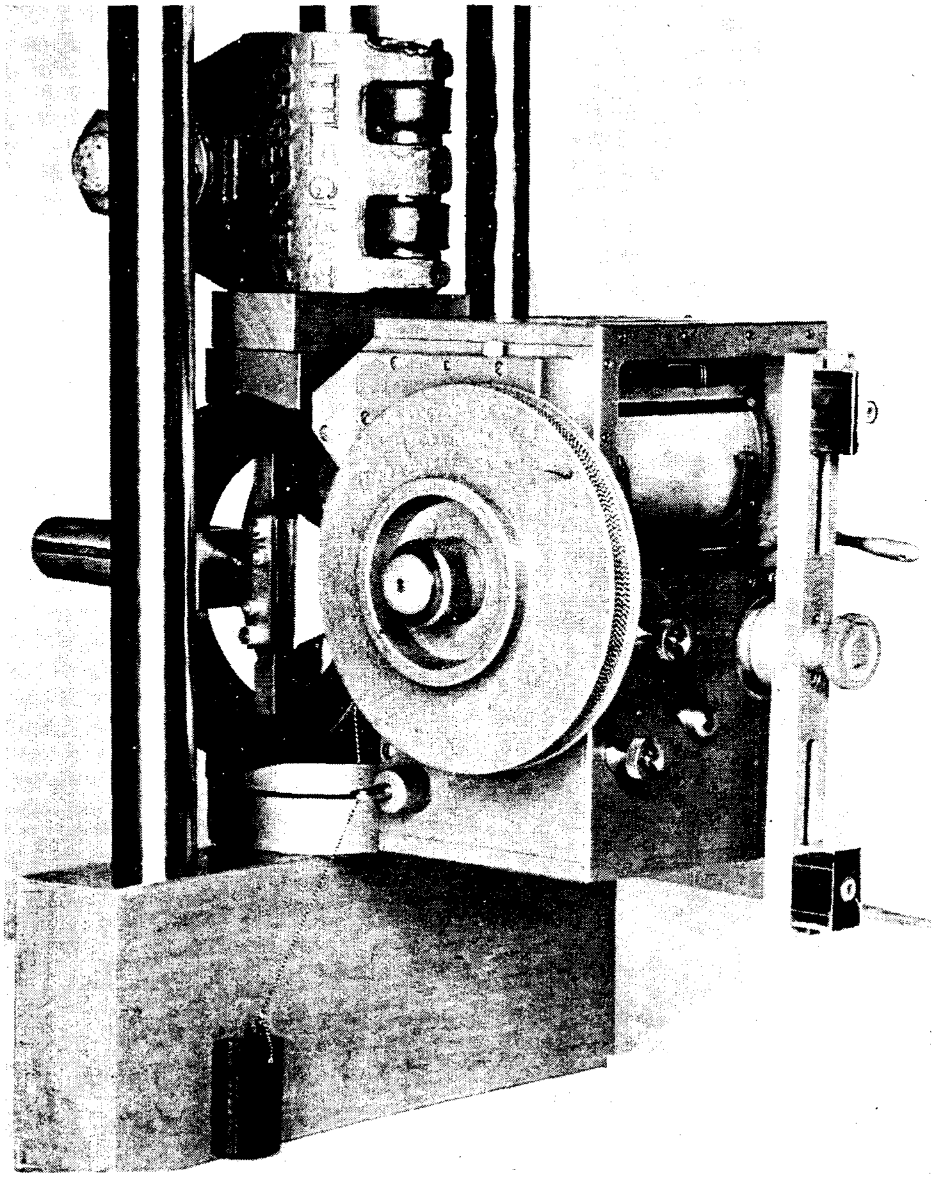
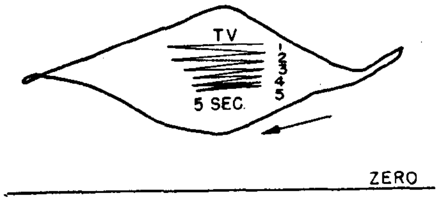
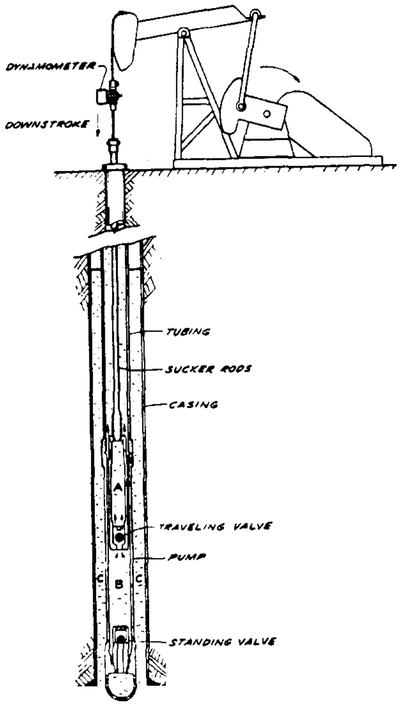


Figure 2

same book. Now when considering the pump, we remember that the purpose of the entire pumping system is to actuate the pump. It is important to know when the traveling valve opens and closes; how far the plunger is traveling, (overtravel or undertravel); and the condition of the pump as to wear. It is easier to check the fluid slippage past the plunger when the pump is in the well and in actual operating conditions, than it is to check it at a pump shop. For this reason, a check as to the condition of the pump will save many unnecessary pulling jobs as well as show worn pumps that are not operating in a satisfactory manner.

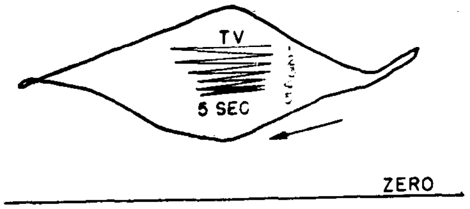
Now looking back toward the prime mover, the peak load tells us the load on the structure. After measuring the counterbalance effect, we can determine the approximate peak torque on the gears from the dynamometer data. This, of course, tells whether the unit is properly counterbalanced and whether it is operating within its load range capacity. The input horsepower might be compared with the polished rod horsepower to obtain the overall efficiency of the prime mover and the pumping unit. When these things are considered, it becomes apparent that wells should not be operated in a pumped-off condition, or when very little useful work is done.

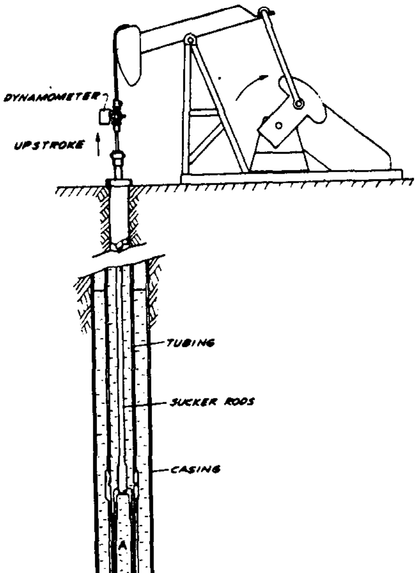




WHEN THE PUMPING UNIT IS STOPPED ON THE DOWNSTROKE THE LOAD ON THE DYNAMOMETER REPRESENTS THE WEIGHT OF THE SUCKER ROD STRING IN FLUID. IF THE STANDING VALVE IS HOLDING, THE LOAD SHOULD REMAIN CONSTANT. FLUID PRESSURES A AND B ARE EQUAL AND THE PRESSURE INVOLVED IS DETERMINED BY THE HYDROSTATIC HEAD OF THE FLUID COLUMN IN THE TUBING.

Figure 3





WHEN THE PUMPING UNIT IS STOPPED ON THE UPSTROKE THE STATIC LOAD AS SEEN BY THE DYNAMOMETER IS EQUAL TO THE WEIGHT OF THE SUCKER RODS IN FLUID PLUS THE WEIGHT OF THE COLUMN OF FLUID ABOVE THE PUMP, PLUS FRICTION, MINUS THE FORCE EXERTED BY THE WORKING FLUID LEVEL--OR PUMPING BOTTOM HOLE PRESSURE.

Fogure 4

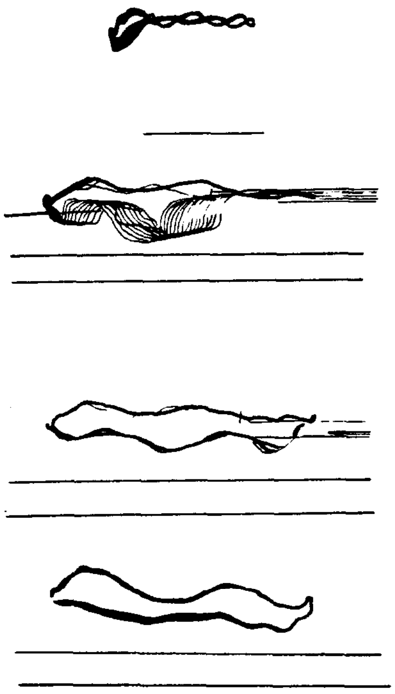
Now let us see how the dynamometer is used in water flood operations. To begin with, the most anxious waiting period is the time necessary for the input water to exert its influence on the producing wells. Figure 5 shows four wells in a flood. These represented a cross-section of the field. "Well A" is the most remote from the injection wells. It is a part-time pumper, operating at a slow speed, a short stroke, and with a small bore pump. It pounds fluid shortly after starting and produces only three barrels per day. "Well B" which at one time was similar to "Well A" is making no water but is getting a reaction from the reservoir pressure build-up. The rapid pump down as shown by the dynamometer card indicates that this well is also a small producer. The card on "Well C" was taken at the beginning of a pumping cycle. It is still a part-time pumper, but production has increased considerably. "Well D" is a full-time pumper. It is adjacent to a line of input wells.

Figure 6 shows a full body card when taken at the beginning of the pumping cycle. However, its rapid pumpdown indicates a low productivity. As the flood develops, the pumping time will be increased, but the pumping cycle decided upon here should be good for three to four months.

Figure 7 shows a progressive pumpdown condition, which illustrates how the polished rod horsepower decreases as the well pumps off. Although the input horsepower to the motor will not change in a corresponding amount due to the work necessary to turn the unit. The close regulation of pumping cycles resulted in a saving of $700.00 per month on one lease in the power bill alone. The corresponding saving in pump life and other equipment was no doubt substantial but could not be evaluated.

Figure 8 is the case history to date of a pilot flood which has several unusual aspects. When considering a water flood project, it is often advantageous to put in operation a pilot flood to help avoid the risk of a major loss. This is the case of the following example. It is a five spot pilot flood in the Sprayberry formation; depth approximately 7500 feet. Inasmuch as we are primarily concerned with the mechanical aspects of the problem, our discussion will be confined to those phases. To begin with, the major pieces of well equipment consisted of the following: casing, 5-1/2" O. D.; tubing, 2" EUE set on a compression type tubing anchor; 1875' or 7/8" sucker rods; 5025' of 3/4" sucker rods; and a 1-1/4" pump. Production was 51 barrels of oil and 17 barrels of water operating at 11.5 - 84" strokes per minute.

The initial set of dynamometer cards showed excessive friction and an abnormally high peak load. From previous experience, it was decided



WELL "A" IS MOST REMOTE FROM INJECTION WELLS IN A NEW FLOOD. PRODUCTION 3 BARRELS PER DAY.

WELL "B" DURING PUMP DOWN CYCLE. IT IS MAKING NO WATER- BUT IS GETTING A REACTION FROM THE RESERVOIR PRESSURE BUILD-UP.

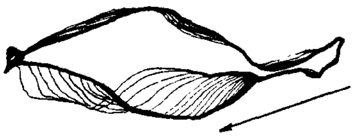
WELL "C" IS STILL A PART TIME PUMPER BUT PRODUCTION HAS INCREASED CONSIDERABLY.

WELL "D" IS A FULL TIME PUMPER. IT IS ADJACENT TO A LINE OF INPUT WELLS

CROSS SECTION OF WELLS THRU FIELD

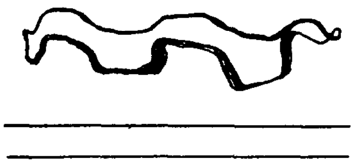
Figure 5

CARDS TAKEN AT TEN MINUTE INTERVALS TO DETERMINE PUMP-DOWN TIME

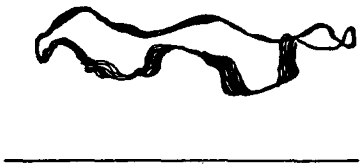


TIME CYCLE SET AT 30 MINUTES ON AND ONE HOUR OFF

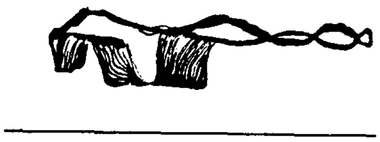
Figure 6



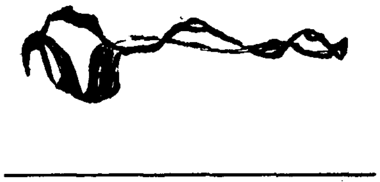
CARD NO. 1 WAS TAKEN 5 MINUTES AFTER INSTRUMENT WAS INSTALLED. NOTE TRAVELING VALVE OPENS NEAR BEGINNING OF DOWNSTOKE. TIME 9:30 A.M.



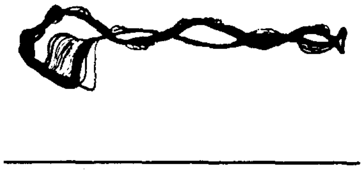
NO. 2 AFTER 10 MINUTES, THE DOWNSTROKE SHOWS A PROGRESSIVE PUMP DOWN CONDITION IS DEVELOPING. TIME 9:40 A.M.



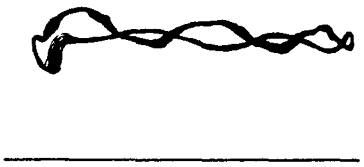
NO. 3 WELL IS PUMPING DOWN QUITE RAPIDLY. TIME 9:50 A.M.



NO. 4 PUMP OFF CONDITION CONTINUES. TIME 10:00 A.M.



NO. 5 ALMOST PUMPED OFF TIME 10:10 A.M.



NO. 6 WELL PUMPS DOWN UNTIL A VERY SMALL PORTION OF THE PUMP BARREL IS FILLED ON EACH STROKE. THE INPUT HORSEPOWER HAS DECREASED SOMEWHAT BUT THE POLISHED ROD HORSEPOWER HAS DECREASED SUBSTANTIALLY. TIME 10:20 A.M.

Figure 7

that slack in the tubing was the probable cause of these unusual conditions. In order to eliminate this, a tension type tubing anchor was installed. A comparison of the before and after cards show a reduction in peak load, a normal slope to the dynamometer card, and a decrease in polished rod horsepower. By 9-19-55, approximately two months later, production had increased to 230 barrels of oil and 72 barrels of water. Shortly thereafter, the following equipment changes were made: A 320,000 inch pound pumping unit replaced the 228,000 inch pound unit; 2-1/2" tubing replaced the 2"; 1725' of 1", 1975' of 7/8" and 2325' of 3/4" sucker rods replaced the 7/8" and 3/4" sucker rod string. The pump was raised approximately 900'. A 2" bore pump replaced the 1-1/4" bore. The pumping speed was increased to 16 - 84" strokes per minute. Pumping fluid level was approximately 2300' from surface. Dynamometer cards taken 10 - 27 - 55 show operation under these conditions.

By December 22,1955, production had increased to 256 barrels of oil and 100 barrels of water per day. It was then decided that pumping equipment was too small and a hydraulic 30' stroke unit with a 125 horsepower electric motor was installed. Production increased to 284 barrels of oil and 162 barrels of water, operating with a 2" bore pump. During the interim between December 26 and March 7, a number of adjustments were made in the surface equipment in order to obtain smoother operation. Fluid conditions were also changing in the reservoir so rapidly that it was a continual problem to maintain smooth operation and maximum production. It will be interesting to see where the economic limit will be reached, since the water increase appears to be quite rapid.

It is realized that the foregoing illustrations and discussions are limited in scope, however, we believe that sufficient examples have been given to illustrate the importance of applying dynamometer fundamentals to the control of water flood operations.

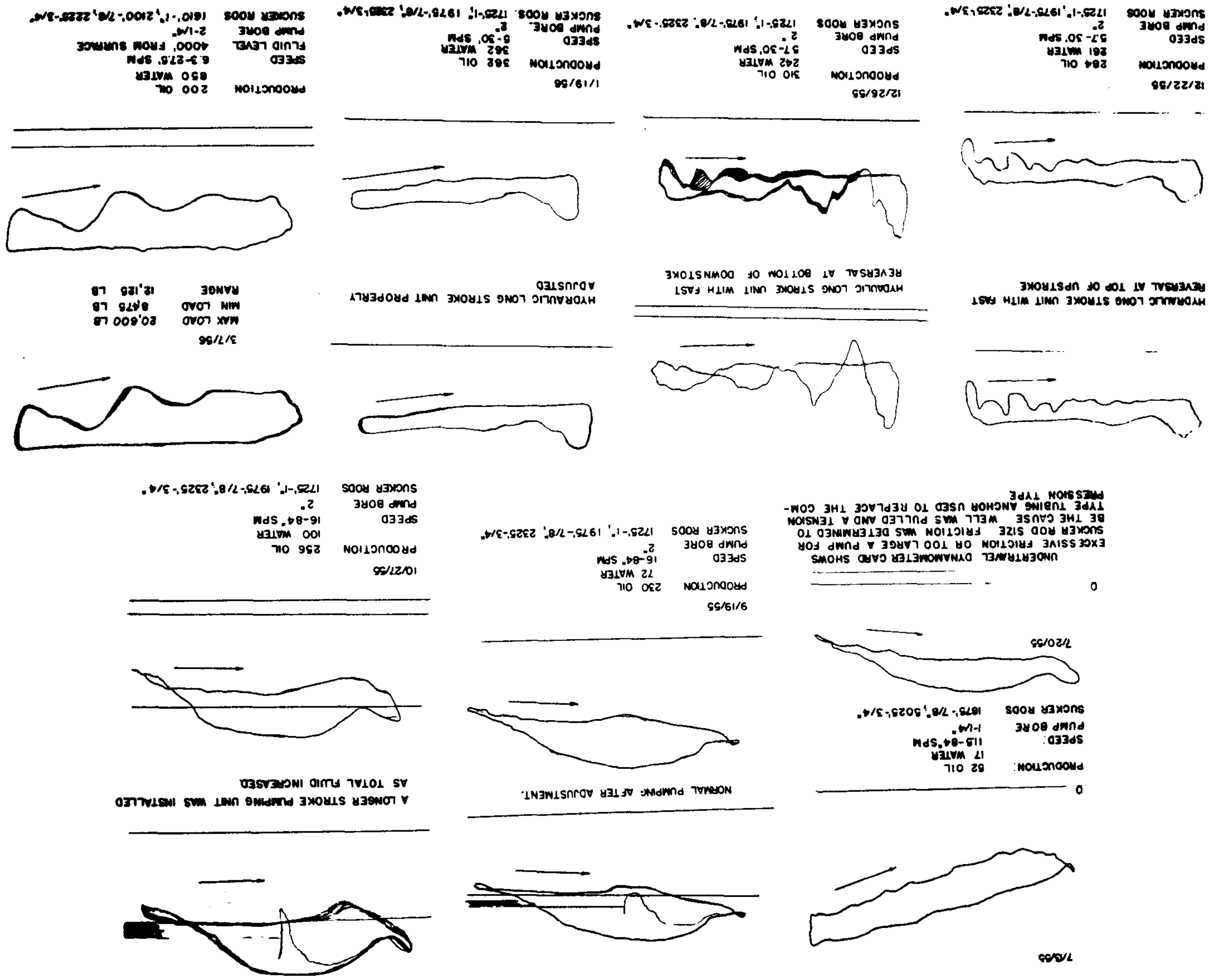


Figure 8