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INCREASING PRODUCTION BY THE PRACTICAL APPLICATION OF DYNAMOMETER AND FLUID LEVEL PRINCIPLES

by

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ABSTRACT

This paper presents an approach used by Continental Oil Co. to increase the production of oil by teaching the principles associated with the use of dynamometer and fluid level instruments. Short courses have been presented to foremen, who are responsible for pumping equipment maintenance, and to test engineers, who obtain and analyze basic data and make recommendations to foremen. The paper discusses the teaching of this technical subject to personnel without technical training.

This training has made test engineers more aware of the proper method of operating dynamometer and fluid level equipment and more knowledgeable in analyzing and solving pumping problems. It has instilled in foremen a high degree of confidence in the data obtained by the use of dynamometer and fluid level instruments.

As a result of the present educational program, a climate of cooperation exists between foremen and test engineers. Foremen now take the initiative in requesting the assistance of test engineers in solving pumping problems. This change has been reflected in increased efficiency and additional revenue.

References and illustrations at end of paper.

INTRODUCTION

In 1961, the management of what was then the Southwestern Region of Continental Oil Co. recognized the importance of up-grading the technical and practical knowledge of test engineers, foremen and head roustabouts with respect to the proper use of dynamometer and fluid level sounding equipment in oil producing operations. Two short courses were designed to satisfy this need, one for test engineers and the other for foremen and head roustabouts.

At that time it was found each test engineer and production engineer had his own favorite set of formulae, graphs, tables and pumping unit calculation slide rules. Some of these were incorrect, and others were applicable only to specific areas or situations. It was necessary to divise some means by which the principles could be taught to all personnel concerned with pumping equipment and its operation.

The ideas, training techniques and visual aids presented in this paper represent a combined effort of the instructors who participated in the short courses and not of any one individual.

PURPOSE OF SHORT COURSES

The purposes for which these short courses were designed are:

1. Increase the efficiency of pumping operations.
2. Increase production from pumping wells to the allowed limits.
3. Prevent unnecessary pumping equipment expenditures.
4. Promote a climate of cooperation between test engineers and foremen to carry out the first three objectives.
5. Up-grade the technical knowledge of test engineers. This would enable them to perform engineering calculations associated with dynamometer card interpretation more accurately and make better recommendations.
6. Up-grade the technical knowledge of foremen and head roustabouts. This would afford them a better understanding of the technical assistance they should expect from test engineers and also enable them to evaluate recommendations made by test engineers.

DEVELOPMENT OF SHORT COURSES

Eleven sessions of the short courses have been conducted since Nov., 1961. The first was a four-day course for test engineers and involved the proper use of dynamometer and fluid level sounding instruments and the utilization of data obtained during the operation of those instruments.

The next eight were three-day sessions conducted for foremen and head roustabouts to acquaint them with the use of dynamometer and fluid level sounding instruments and the assistance test engineers can give in solving pumping well problems. They were informed that the test engineer and his equipment were "tools" which should be used just like other tools of the trade and that he should function as an advisory member of the foreman's staff. It was stressed that an environment of cooperation between the foreman and the test engineer would not only increase revenue but would increase the stature of each individual in the eyes of management.

The last two sessions, held in 1963, were for test engineers. The 1961 session was very basic, while the 1963 sessions dealt more with the refinements of dynamometer card interpretation.

The short courses were attended by 208 participants.

OUTLINE OF SHORT COURSES

The 1963 sessions for test engineers covered the following topics:

1. The formulae used in dynamometer card interpretation and various loads encountered during the pumping cycle.
2. Calculation of torque factors by the "perpendicular" method for a miniature pumping unit.
3. Field testing and demonstration of dynamometer and fluid level sounding instruments.
4. Calculation of dynamometer and fluid level sounding data obtained during field demonstration, including the plotting of torque curves.
5. Classification of dynamometer cards and a systematic approach to problem pumping wells.
6. Gas compression problems in sucker rod pumps and discussion of compression ratios.
7. Effect of pump size, speed, stroke length and depth on fluid production.
8. Productivity indices as they affect pump setting depths.
9. Discussion of load vs stress.
10. Purpose and design of tapered rod strings.
11. Standing valve, traveling valve and tubing leak discussion.
12. Dynamometer card interpretation symposiums.
13. Practical pumping problems.

TEXTBOOKS

The basic textbooks used during the courses were "Sucker Rod Handbook", Handbook 489, published by Bethlehem Steel Co., 1958, and "Pumping Well Problem Analysis", by Eubanks, et al, published by Joe Chastain, 1958.

TEACHING METHODS

The following types of teaching methods were used:

1. Conference Leadership
2. Lecture
3. IPAT or Provincial Step
4. Demonstrations
5. Illustrations
6. Group Discussion and Problem Solving
7. Individual Problem Solving

Conference Leadership. This method is based on the principle of participation by all conferees. It involves the extensive use of the following types of questions which are listed in the order of preference:

Overhead Question - This type of question is directed to the group as a whole, not to any one specific participant.

Reverse Question - The conference leader directs the question back to the participant who asked it.

Relay Question - The conference leader directs a question which has been asked by one participant to another participant.

Direct Question - The conference leader directs a question to a specific participant.

Information Question - This type of question is used by the conference leader to ask for information.

Lecture Method. This involves the verbal imparting of knowledge by the instructor.

IPAT or Provincial Step Method.[1] This method is:

I - Introduce the subject.
P - Present pertinent information.
A - Apply the information presented.
T - Test for comprehension.

Demonstration Method. This method involves actual demonstration of a procedure or technique.

Illustration Method. The use of visual aids or other forms of illustrations is employed to present or clarify the point under consideration.

Group Discussion and Problem Solving Method. The class is separated into several groups, and topics to be discussed or problems to be solved are assigned. Each group elects a leader, discusses the topics or solves the problems and then makes a report to the entire class.

Individual Problem Solving Method. Each participant is assigned problems to be solved. The solutions are checked, and the corrected problems are returned to the participant.

The effectiveness of instruction during the short courses were measured in several different ways:

1. Homework problems were assigned, and the solutions checked.
2. Short problem-type quizzes were given daily.
3. Discussion groups were formed, and every morning a leader, designated by each group, reported on the effectiveness of the previous days' instruction. Additional information was requested at that time on any item which was not clear or on which additional discussion was desired.
4. Individual participants were questioned frequently by the instructors throughout the course.

An instructor can be lulled into complacency unless some means of testing the individual participant's degree of comprehension is used. The mere nodding of a head should not be accepted as evidence that a participant understands and comprehends what is being said. A follow-up type of test is essential to assure the instructor of his effectiveness.

The combined teaching methods proved to be highly effective in teaching this technical subject to personnel without technical training.

DEVELOPMENT OF BASIC PRINCIPLES

Visual aids were used extensively throughout the course. As an example, a "building blocks" approach was utilized to develop the basic formula used in dynamometer card interpretation. It is very important to stress the starting point in effective dynamometer card analysis. That point is zero pounds of load. Fig. 1 is a dynamometer card on which is depicted the six basic loads which are vital to card interpretation. Four of these loads are measured under static conditions while the other two represent dynamic loads. Calculating the theoretical loads and scribing them on the dynamometer card in advance of actual well weighing should be emphasized strongly. These provide valuable indicators of trouble-free operation or trend to pinpoint sources of trouble which should be investigated.

ZERO LOAD. This load is scribed on the card while no weight is being applied.

STANDING VALVE LOAD. This load is a misnomer as the load on the standing valve is not measured. The measured load in this instance is the weight of the rods in fluid. To compare this load with its calculated counterpart, a building block representing the weight of rods in air, W_r, is placed on the zero line in Fig. 2. From that load is subtracted the load indicated by building block $W_r \cdot B$, which represents the buoyancy of the well fluid on the rods. The combination of these blocks gives the weight of the rods in fluid which is called the "Standing Valve Test", and is represented by the formula

$$SV = W_r - W_r \cdot B = W_r [1-B] \quad \ldots\ldots [1]$$

TRAVELING VALVE LOAD. This load is one which can be measured on a dynamometer card and also calculated. To demonstrate this load, building blocks representing W_r, the weight of the rods in air, and W_f, the weight of the well fluid on the net plunger area, are added on Fig. 3, and the result is

$$TV = W_r + W_f \quad \ldots\ldots [2]$$

There has been some disagreement in the past as to whether the net or gross plunger area should be used in calculating fluid loads. The use of either area is correct providing the appropriate weight of rods in air or in fluid is used. Fig. 4 was used to illustrate this point. The following was found to be very helpful in demonstrating that if the fluid weight is effective on the net plunger area, a corresponding weight of rods in air should be used.

Pressure at Pump, P_f

$$P_f = G \cdot D = \frac{\#/in.^2}{ft} \cdot ft = \frac{\#}{in.^2}$$

where: P_f = pressure exerted on traveling valve by fluid in tubing, psi
G = well fluid gradient, psi/ft
D = pump depth, ft

Buoyancy, B

$$B = w \cdot h \cdot A$$

where: w = specific weight of displaced fluid, pounds/unit vol.
h = average height of displaced fluid, unit height
A = average cross-sectional area of displaced fluid, [unit length]^2

Buoyant Force When Rods Extend to Surface, F_b

$$F_b = \text{Pressure} \cdot \text{Area}$$

where: Pressure = w·h

$$F_b = w \cdot h \cdot A$$

$$\therefore F_b = B$$

Upward Force on Rods, F_r [Also equal to F_b]

$$F_r = P_f \cdot A_r = \frac{\#}{in.^2} \cdot in.^2 = \#$$

where: P_f = fluid pressure at pump, psi
A_r = weighted cross-sectional area of rods, in.^{2}

Downward Force on Traveling Valve, F_p

$$F_p = P_f \cdot A_p = \frac{\#}{in.^2} \cdot in.^2 = \#$$

where: P_f = fluid pressure at pump, psi
A_p = gross area of pump plunger, in.^{2}

Net Force At Traveling Valve, F_n

$$F_n = F_p - F_r$$

$$F_n = [P_f \cdot A_p] - [P_f \cdot A_r]$$

$$F_n = P_f[A_p - A_r]$$

[Note: Annulus pressure on pump neglected in this illustration.]

Since the point of reference up to this step has been at pump depth, it is necessary to add only the weight of rods in air to change the reference point to the dynamometer as the buoyant force acting on the rods has already been considered.

MINIMUM LOAD. This load is depicted on Fig. 5 by building blocks W_r, $W_r \cdot B$ and $W_r \cdot c$, where where $W_r \cdot c$ is the load due to the acceleration of the rods.

$$ML = W_r - W_r \cdot B - W_r \cdot c = W_r[1-B-c] \quad . . . [3]$$

PEAK LOAD. Building blocks W_r, W_f and $W_r \cdot c$ are used to find this load which is depicted on Fig. 6. $W_r \cdot c$ in this calculation represents the load due to the acceleration of the rods.

$$PL = W_r + W_f + W_r \cdot c = W_r[1 + c] + W_f \quad . . [4]$$

COUNTER BALANCE EFFECT. This load, shown on Fig. 7, is calculated by one of the following:

$$CB = \frac{PL + ML}{2} \quad . . . . [5]$$

$$CB = \frac{SV + TV}{2} \quad . . . . [6]$$

$$CB = ML + \frac{\text{Load Range}}{2} \quad . . . . [7]$$

$$CB = PL - \frac{\text{Load Range}}{2} \quad . . . . [8]$$

Loads recorded by the dynamometer are the resultant of forces acting on the polished rod at the times the loads are measured. These loads in themselves are valuable data, but corresponding pump positions and actions must be visualized by the interpreter to maximize the unitization of the data. Fig. 8 represents schematic diagrams of the standing and traveling valves during the "standing valve test" and "traveling valve test". These drawings proved to be invaluable in associating pump action with loads measured on the dynamometer card. It is essential for the interpreter to have a firm background on this aspect before any confidence can be placed in card interpretation.

Another effective visual aid is shown on Fig. 9.[2] This further defines the relationship between the loads reflected by the dynamometer card and the respective pump action.

One of the most effective visual aids was a wooden model of a pumping unit three feet high as shown by Fig. 10. The relative crank weight angles and polished rod positions can be demonstrated very clearly on this model. This unit was also used to demonstrate the components of torque factors.[3] To simplify the calculations and make them easier to understand, an extended pitman was constructed, and the participants actually measured the perpendicular distances required in determining the torque factors for the various crank weight angles rather than using trigonometry. This determination is illustrated by Fig. 11.

After understanding the make-up of torque factors, a set of torque factors supplied by the manufacturer of a pumping unit can be used with a better understanding of the principles involved.

Fluid levels should be taken, whenever possible, at the time each dynamometer card is taken. This additional information compliments and substantiates that obtained by the use of dynamometer. These instruments, when used in conjunction with each other, sometimes gives apparent conflicting data. However, when well conditions are investigated and understood, the validity of the data is established, and both sets of data become usable.

Fig. 12 is a form used to compare calculated loads vs actual loads. Any significant differences between measured and calculated loads become apparent on the form. A typical dynamometer card is reproduced or drawn on the form, and sufficient additional cards are drawn on supplementary sheets to give a complete story of the various loads recorded during the dynamometer survey. When used in conjunction with the cards, the calculated and measured loads tend to point out pumping problems to be investigated. Using these data, the test engineer can make appropriate and practical recommendations for corrective action.

This form is completed by the test engineer and given to the foreman requesting his services. Since he has been trained in basic dynamometer card interpretation, the foreman can evaluate the test engineer's recommendation.

RESULTS OF TRAINING

This investment in training has definitely proven profitable to Continental Oil Co. It has made test engineers more aware of the proper method of operating dynamometer and fluid level equipment and more knowledgeable in analyzing and solving pumping problems.

One of the most important benefits realized is the spirit of teamwork that now exists between foremen and test engineers. Formerly the foremen did not fully utilize the services of test engineers as they were unaware of the extent of assistance that could be expected. The foremen are now familiar with test engineering equipment. The course instilled a high degree of confidence in the data obtained by the use of dynamometer and fluid level instruments, and the foremen are now taking the initiative in requesting the services of test engineers. This has resulted in increased producing efficiency and additional revenue. A few typical examples are presented as follows:

L. Paulus No. 5, Fig. 13

This is an example of increasing oil production by lengthening the stroke. A fluid level showed a pump submergence of 1,251 ft. The stroke length was increased from 29 to 54 in., and the strokes per minute were reduced from 21 to 14. At the same time the pump size was changed from 2-1/2 to 2-1/4 in. As a result, the total fluid production was increased from 182 to 354 B/D. Oil production increased from 4 to 19 B/D. This is an example of cooperation between W. H. Taylor, Test Engineer, and B. J. Segers, Production Foreman.

J. M. Shannon "A" No. 28, Fig. 14

This is an example of increasing oil production by reducing the pump size and lowering the pump. A dynamometer card reflected a fluid pound. Due to the well hook-up, a fluid level could not be obtained at that time. The pump size was reduced from 3-3/4 to 3-1/4 in. and was lowered from 2,000 to 3,500 ft without overloading the unit. At the same time, the well hook-up was changed to permit fluid levels to be obtained. As a result, the oil production was increased from 40 to 99 B/D. This is a reflection of the cooperation between L. S. Puckett, Test Engineer, and O. Q. Alford, Production Foreman.

J. M. Shannon "D" No. 6, Fig. 15

This is an example of overcoming a subsurface pump compression ratio problem. A dynamometer card taken on Aug. 11, 1962 showed a "gas lock" condition. While the "traveling valve" test was being made, the gas lock was broken. The second card taken on Aug. 11, which is superposed on the first card, reflects this condition. The conventional 2-1/4 in. pump was removed, and a 2 in. two-stage pump was run. The fluid level instrument showed 1,340 ft of pump submergence on Aug. 11. Considering all the data, it was decided the pump should be lowered from 4,500 to 6,000 ft at the same time it was changed. The volumetric efficiency was increased from 11 to 92 per cent, and the oil production was increased from 14 to 59 B/D without overloading the unit. This is an example of the cooperation between L. S. Puckett, Test Engineer, O. Q. Alford, Production Foreman, and W. M. Groesbeck, Production Engineer.

SEMU Pennsylvanian No. 61, Fig. 16

This is an example of preventing excessive pulling jobs. Frequent rod box breaks had been experienced. A dynamometer card substantiated that pumping conditions were normal and there were no excessive loads. The sucker rod manufacturer was contacted, and subsequent test revealed the trouble was in the rod boxes. They were replaced, and rod box failures have been eliminated. This is an example of close cooperation between W. D. Howard, Test Engineer, and B. H. McGinnis, Production Foreman.

W. C. Williams No. 1, Fig. 17

This is an example of preventing unnecessary pulling jobs. The production from this well had declined to one barrel of oil per day. The head roustabout had been unsuccessful in increasing the production. The first dynamometer card and the associated fluid level revealed the well was producing all the fluid entering the annulus. Subsequent cards and fluid levels showed the well to be completely pumping off. Thirty barrels of water were dumped down the casing, and a dynamometer card reflected normal pump action. This is depicted very clearly on the bottom card on Fig. 17 which has the preceding card superposed. Since the pump was performing satisfactorily, it was concluded that a pulling job was unnecessary. The district engineer was furnished the results of the survey to allow him to evaluate remedial work possibilities. This is an example of the cooperation between C. D. Fleming, Test Engineer, and J. L. Smith, Head Roustabout.

CONCLUSIONS

The results of this educational program are extremely encouraging. The level of comprehension of this technical subject by personnel without technical training is of such magnitude that management has a very fertile field for increasing unit productivity at a nominal investment in training costs, providing such training is presented in an understandable manner.

ACKNOWLEDGMENTS

Appreciation is expressed to the management of Continental Oil Co. for permission to use data from which this paper was prepared and for permission to publish this paper. Acknowledgment is also made to the several employees of Continental Oil Co., particularly to F. W. Gipson, and to L. W. Fagg of Johnson-Fagg Engineering Co., Inc., for their valuable advice and assistance.

NOMENCLATURE

B = Buoyancy factor = $\frac{\text{wt. of 1 cu ft of fresh water}}{\text{wt. of 1 cu ft of steel}}$ x S.G.

c = Acceleration factor = $\frac{LN^2}{70,500}$

CB = Counter balance effect, lbs
F_p = Force on pitman, lbs
L = Length of polished rod stroke, in.
ML = Minimum Load, lbs
N = Number of strokes per minute
O = Zero load scribed on dynamometer card
PL = Peak load, lbs
R = Reference line on dynamometer card
SV = "Standing Valve" load = Weight of rods in fluid, lb
T = Torque, in.-lb
TV = Traveling Valve Load, lb
W_f = Weight of fluid on the net plunger area, lb
W_n = Net well load, lb
W_r = Weight of rods in air, lb

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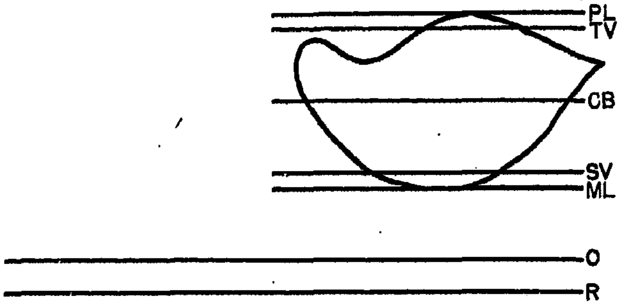
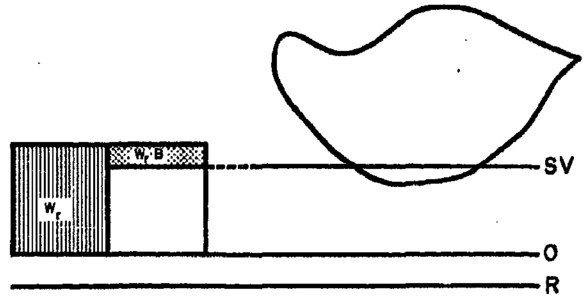


O = Zero pounds of load

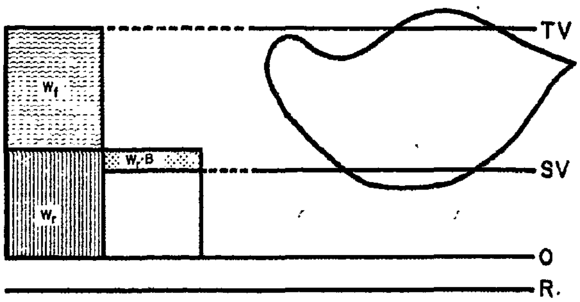
Figure 1



O = Zero pounds of load

$$SV = W_r - W_r \cdot B = W_r(1-B) \qquad (1)$$

Figure 2

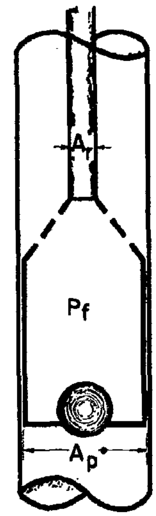


O = Zero pounds of load

$$SV = W_r - W_r \cdot B = W_r(1-B)$$

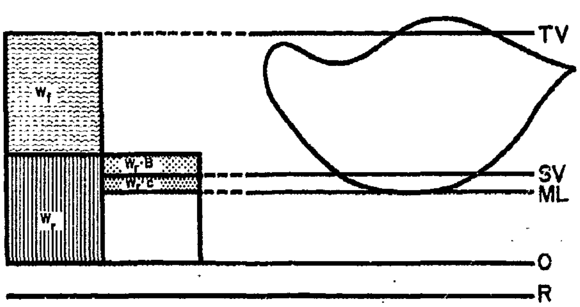
$$TV = W_r + W_f \qquad (2)$$

Figure 3



Schematic Diagram of Traveling Valve

Figure 4



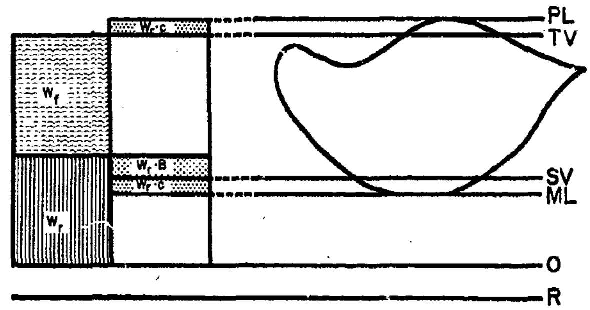
O=Zero pounds of load

$$SV = W_r - W_r \cdot B = W_r(1-B)$$

$$TV = W_r + W_f$$

$$ML = W_r - W_r \cdot B - W_r \cdot c = W_r(1-B-c) \qquad (3)$$

Figure 5



O = Zero pounds of load

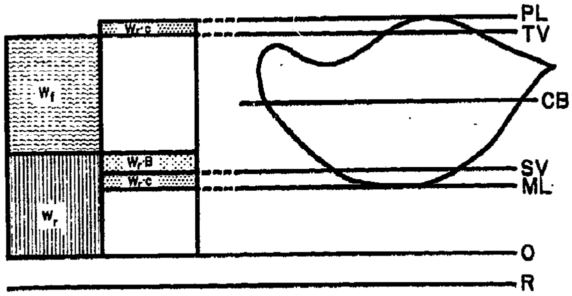
$$SV = W_r - W_r \cdot B = W_r(1-B)$$

$$TV = W_r + W_f$$

$$ML = W_r - W_r \cdot B - W_r \cdot c = W_r(1-B-c)$$

$$PL = W_r + W_f + W_r \cdot c = W_r(1+c) + W_f \qquad (4)$$

Figure 6



O = Zero pounds of load

$$SV = W_r - W_r \cdot B = W_r(1-B)$$
$$TV = W_r + W_f$$
$$ML = W_r - W_r \cdot B - W_r \cdot c = W_r(1-B-c)$$
$$PL = W_r + W_f + W_r \cdot c = W_r(1+c) + W_f$$
$$CB = \frac{PL + ML}{2} \qquad (5)$$

Figure 7

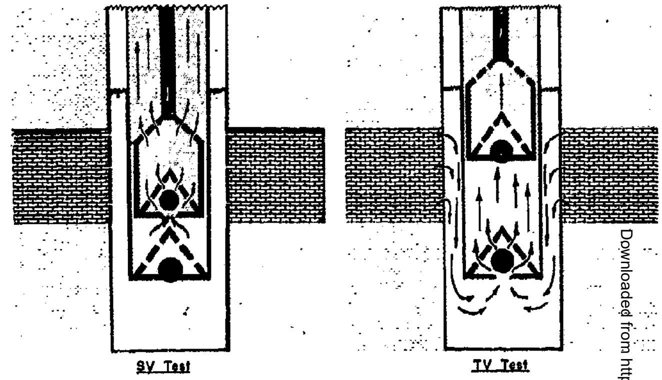


Figure 8

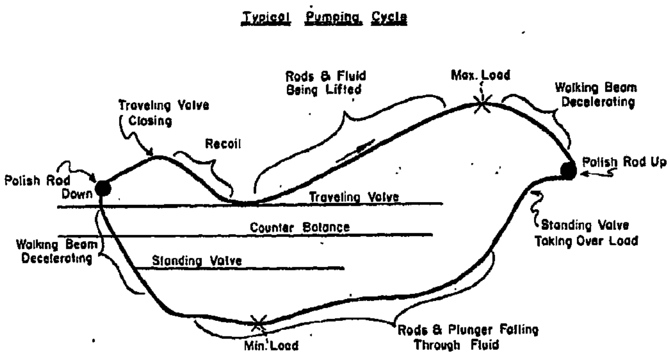


Figure 9

(After Russell, World Oil)[2]

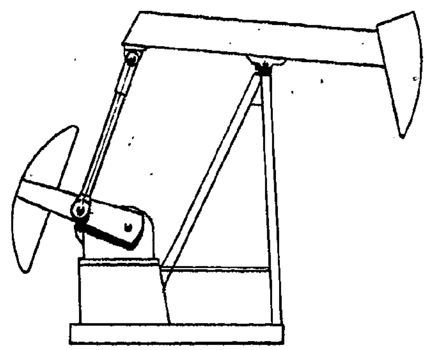
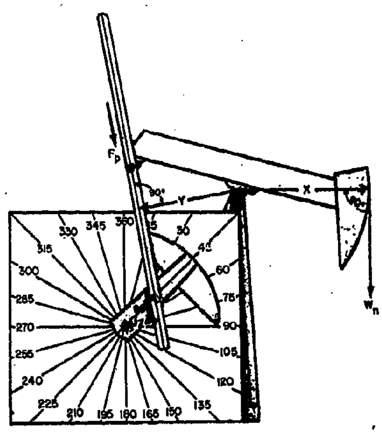


Figure 10



$$W_n \cdot X = F_p \cdot Y$$
$$F_p = \frac{W_n \cdot X}{Y}$$
$$T = F_p \cdot Z$$
$$T = \left(\frac{W_n \cdot X}{Y}\right) Z$$
$$T = W_n \frac{X \cdot Z}{Y}$$

Figure 11

<u>DYNAMOMETER AND/OR FLUID LEVEL SOUNDER TEST REPORT</u>

Well____________________ Pool____________________ Date________________

WELL DATA

Pump Size________Type________________Set @____________SPM______SL________
Pumping Unit: Make____________________Size______________Type____________
Prime Mover: Size__________ ________Type__________________Tbg. Size________
Sheave Sizes: Pumping Unit__________________Prime Mover____________________
Rod Size: 1" No. Rods________x 25 =__________x 2.88 =__________#
7/8" No. Rods________x 25 =__________x 2.20 =__________#
3/4" No. Rods________x 25 =__________x 1.64 =__________#
5/8" No. Rods________x 25 =__________x 1.15 =__________#
Calculated Total Weight of Rods in Air (W_r) =__________#

PRODUCTION DATA

Pumping is: Continuous____Intermittent____(check one)
If intermittent, well is pumped___hours on and___hours off.
Daily Allowable:_____BOPD, Top Possible Allowable:_____BOPD
Actual Production: Oil_____B/D, Water_____B/D, Total Fluid_____B/D___% wtr.
Fluid Level_____,T.P._____,C.P._____,Sp. Gr.: Fluid_____Gas_____,GOR_____
Pump Capacity (Net Plunger Travel @ 100% Vol. Eff.)_______BPPD.
Calculated Volumetric Efficiency_____%. Tubing anchored: Yes___No___

DYNAMOMETER ANALYSIS

	Calculated Loads	Measured Loads
Rod Weight in Fluid (S.V. Weight)		
Fluid Wt. on Net Plung. Area of Pump (W_f)		
W_r + W_f (T.V. Weight)		
Peak Load		
Minimum Load		
Load Range in Pounds		
Load Range in % of Max. Load		
Rod Stress		
Counter Balance Effect		
Peak Torque		

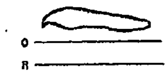
Dynamometer Constants: 1" =__________Pounds: 1" =__________In. of Pol. Rod Stroke

Recommendations:

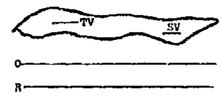
Distribution: Prepared by:

Figure 12

Continental Oil Company
L. Paulus No. 5
East Arnim Field
Fayette County, Texas



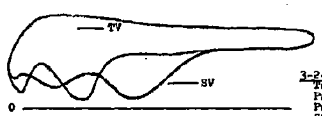
<u>10-23-63</u>
Total Depth 2,146'
Rod Size 5/8"
Pump Size 2-1/2"
Pump Depth 2,016'
Stroke Length 29"
SPM 21
BOPD 4
BWPD 178
Pump Capacity, Bbls. 250
(Net Plunger Travel
@ 100% Vol. Eff.)
Calc. Vol. Eff. 73%
Fluid Level 765'
Peak Load 4,624#
Rod Stress 15,062 psi



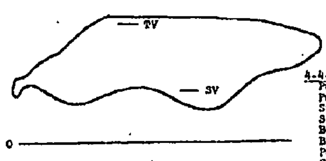
<u>12-22-63</u>
Rod Size 3/4"
Pump Size 2-1/4"
Pump Depth 1,783'
Stroke Length 54"
SPM 14
BOPD 19
BWPD 335
Pump Capacity, Bbls. 396
Calc. Vol. Eff. 89%
Fluid Level 1,660'
Peak Load 5,148#
Rod Stress 11,647 psi

Figure 13

Continental Oil Company
J. M. Shannon "A" No. 28
Elkhorn Ellenburger Field
Crockett County, Texas



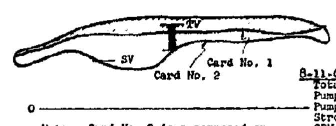
<u>3-2-62</u>
Total Depth 7,350'
Pump Size 3-3/4"
Pump Depth 2,000'
Stroke Length 120"
SPM 10
BOPD 40
BWPD 381
Pump Capacity, Bbls. 1,760
(Net Plunger Travel
@ 100% Vol. Eff.)
Calc. Vol. Eff. 24%
Fluid Level NA
Peak Load 17,052#
Rod Stress 21,722 psi



<u>4-4-62</u>
Pump Size 3-1/4"
Pump Depth 3,500'
Stroke Length 120"
SPM 8
BOPD 94
BWPD 528
Pump Capacity, Bbls. 876
Calc. Vol. Eff. 72%
Fluid Level 3,472'
Peak Load 22,272#
Rod Stress 28,372 psi

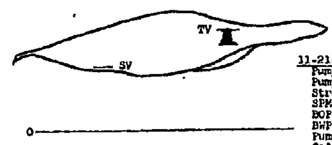
Figure 14

Continental Oil Company
J. M. Shannon "D" No. 6
Elkhorn Ellenburger Field
Crockett County, Texas



Note: Card No. 2 is superposed on Card No. 1.

<u>8-11-62</u>
Total Depth 7,238'
Pump Size 2-1/4"
Pump Depth 4,500'
Stroke Length 120"
SPM 10
BOPD 14
BWPD 46
Pump Capacity, Bbls. 548
(Net Plunger Travel
@ 100% Vol. Eff.)
Calc. Vol. Eff. 11%
Fluid Level 3,160'
Peak Load 16,240#
Rod Stress 20,688 psi



<u>11-21-62</u>
Pump Size 2"
Pump Depth 6,000'
Stroke Length 120"
SPM 7
BOPD 59
BWPD 176
Pump Capacity, Bbls. 256
Calc. Vol. Eff. 92%
Fluid Level 5,770'
Peak Load 21,112#
Rod Stress 26,894 psi

Figure 15

Continental Oil Company
SEMU Pennsylvanian No. 61
Cass Pool
Lea County, New Mexico

<u>Well Data</u>
Total Depth 10,434'
Size Tubing 4" EUE
Size Rods 1"
Size Pump 3-3/4"
Pump Depth 2,500'

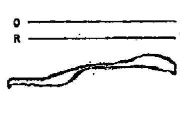
<u>Card Data</u>
Date 10-31-63
Stroke Length 96"
SPM 8
BOPD 2
BWPD 998
Pump Capacity, Bbls. 1,029
(Net Plunger Travel
@ 100% Vol. Eff.)
Calc. Vol. Eff. 97%
Fluid Level 1,270'
Peak Load 13,485#
Rod Stress 17,178 psi

Figure 16

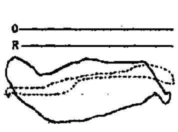
Continental Oil Company
W. C. Williams No. 1
Hundley Conglomerate Field
Montague County, Texas

<u>Well Data</u>
Total Depth 6,451'
Pump Size 1-1/4"
Pump Depth 6,400'

<u>6-26-63 9:45 A.M.</u>
Stroke Length 44"
SPM 16
Fluid Level 6,350'
BOPD 1
BWPD 0



<u>6-26-63 11:00 A.M.</u>
Stroke Length 44"
SPM 12
Fluid Level 6,340'
Well was pumped off.



<u>6-26-63 12:40 P.M.</u>
Stroke Length 44"
SPM 16

Note: This card was taken after 30 bbls. of water were dumped in casing. Dotted card is 11:00 A.M. card superposed.

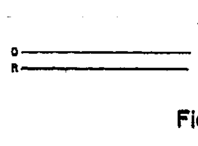


Figure 17