Production Testing of Oil Well Pumping Motors

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INTRODUCTION

The use of electric motors as prime movers for driving oil well pumping units is well established today. In fact, reliable estimates now indicate that a sizeable majority of new oil wells going on artificial lift are being powered by electric motors. With the tremendous increase in the use of electrified oil well pumping, many operators are examining their horsepower sizing and application formulae more closely than ever in using electric motors to drive beam pumping units.

Field tests, for example, generally have shown that most electrified wells are over-motored and that economy of operation, as well as lower first cost, could be realized with a proper sizing of the motor to the load. Also, there is the question of which type of motor should be selected. There is general interest in the industry today in the evaluation and advantages in the performance of various design types of oil well pumping motors.

Fig. 1 is an illustration of a modern-day electrified oil well pumping installation, showing motor, controller, and power-factor correction capacitor located at the pumping unit.

MOTOR HORSEPOWER DETERMINATION

Because there are so many variables and factors to be considered in the determination of both hydraulic horsepower and friction (subsurface losses) horsepower, it is practically impossible to accurately ascertain horsepower required at the polished rod without actual field measurements after the pumping installation is made.

The subsurface friction horsepower portion is particularly difficult to calculate because of the many variables in sliding friction between fluid and tubing, fluid and polished rod, tubing and rod joints, viscosity of fluid, crookedness of hole, etc. Most oil companies today use either an empirical formula based on experience data to calculate subsurface friction horsepower, or merely a "jeep" factor of some kind is used to operate on the calculated or theoretical hydraulic horsepower to determine the subsurface friction horsepower component.

In the determination of motor nameplate horsepower required to drive a beam pumping unit, the surface efficiency (or losses in the pumping unit) as well as motor losses must be considered. Also, there is the additional thermal heating of the motor due to the peaking overloads and cyclic nature of the load, all of which must be accounted for in correctly sizing the motor.

Motor Horsepower Formulae

Various formulae are used to determine motor nameplate horsepower rating required. By way of illustration, two of such formulae are presented showing method calculation of motor horsepower rating. These are:

1. $$\text{NPHP} = \frac{B \times D}{136{,}000} + \frac{W\,S\,L}{1{,}600{,}000} \times K$$

where, B = maximum barrels pump displacement at 100 per cent volumetric efficiency for 24 hours.

D = producing fluid level in feet.

W = weight of rod string in pounds

L = length of stroke in inches

S = strokes per minute

K = Surface Efficiency and Motor Heating Factor

2. $$\text{Hyd HP} = \frac{\text{Barrels}/24\text{ hours} \times 350\text{ pounds} \times \text{feet lift} \times \text{Specific Gravity}}{1440\text{ Min} \times 33{,}000\text{ foot-pounds}}$$

$$= \frac{\text{Barrels}/24\text{ hours} \times \text{feet lift} \times \text{Specific Gravity}}{135{,}770}$$

For 45 per cent efficiency from plunger to motor,

$$\text{Load HP avg} = \frac{\text{Barrels}/24\text{ hours} \times \text{feet lift} \times \text{Specific Gravity}}{135{,}770 \times .45}$$

$$= \frac{\text{Barrels}/24\text{ hours} \times \text{feet lift} \times \text{Specific Gravity}}{61{,}000}$$

For NEMA Design C, dripproof motor, use cyclic load factor of .75

$$\text{Therefore, Motor HP size} = \frac{\text{Barrels}/24\text{ hours} \times \text{feet lift} \times \text{Specific Gravity}}{45{,}800}$$

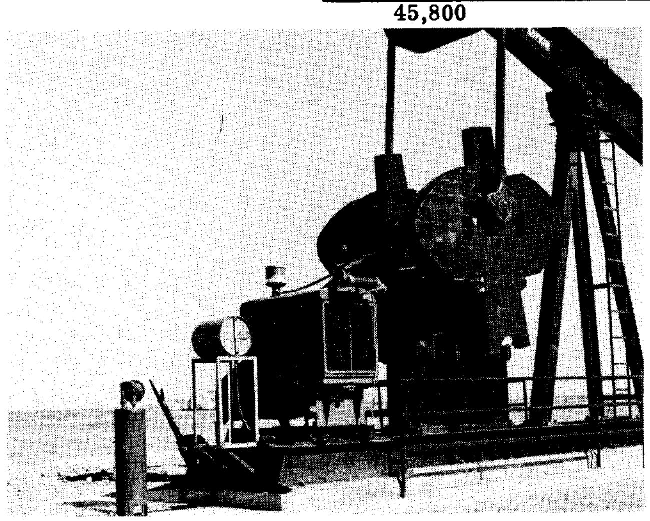

FIG. 1

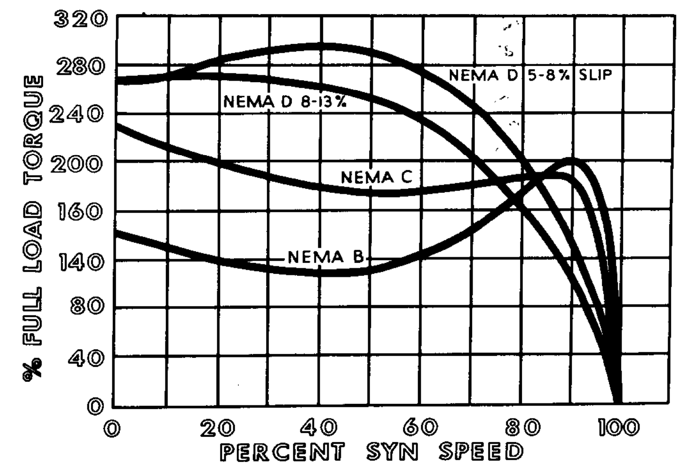

Figure 2. Typical Speed-torque Characteristic Curves for NEMA Design B, NEMA Design C, and NEMA Design D Induction Motors

The first formula is used by an equipment supplier, and the latter is used by a major oil company.

All such motor sizing formula are basically related to the formula:

$$\text{Motor NPHP} - \frac{\text{Hyd HP} \quad \text{Fric HP}}{\text{Surf. Eff.}} \quad \text{CLF}$$

Where CLF is motor Cyclic Load Factor.

This basic formula can be illustrated as:

NPHP MOTOR PMHP PUMPING UNIT PRHP Polished Rod

HYD HP

FRIC HP

where,

NPHP =motor nameplate horsepower rating
PMHP = prime-mover horsepower required
PRHP =polished rod horsepower required

and,

PRHP =Hyd HP Fric HP (subsurface losses)
PMHP = PRHP Surface Efficiency
NPHP =PMHP CLF
CLF =Motor Cyclic Load Derating Factor

Note that motor NPHP is an output rating, and includes motor losses or efficiency.

MOTOR DESIGN TYPES

Various design types of a/c induction motors have been used to successfully produce oil. The most commonly used types, however, are polyphase a/c squirrel-cage induction motors, in outdoor dripproof construction, rated 1200 RPM synchronous speed, either NEMA* Design C, or NEMA* Design D.

The NEMA Design C basically is a high-starting torque (200 to 250 per cent full-load torque), low starting current, normal slip (less than 5 per cent) motor. The NEMA Design D is basically a high-starting torque (275 per cent minimum), low-starting current, high slip (5-8 per cent or 8-13 per cent) motor.

Recent analyses of detailed field tests conducted indicate that, in general, a high-slip NEMA Design D motor has a better cyclic load performance driving rotary counterweighted beam pumping units, as compared to the NEMA Design C motor. These tests show that, in general, the high-slip motor gives the following distinct advantages:

1. Lower current peaks and RMS current, therefore lower KW demand.
2. Lower kilowatt-hours per barrel lifting costs.
3. Lesser thermal loading of motor; therefore, less motor derating or more usable work horsepower per nameplate rating.

Steady-load speed-torque curves for the various NEMA Design motors are shown in Fig. 2.

*National Electrical Manufacturer's Association

MOTOR DERATING FACTOR

It is well to understand that all oil well pumping motors driving beam pumping units have bo be derated from their full-load output rating to account for the additional thermal loading due to the cyclic peaking nature of the pumping load. Cyclic load factor derating factors appear to vary for each design type of motor, depending upon such factors as size and inertia of pumping unit, dead weight lift of load, speed of pumping, viscosity and gas-lift effect of fluid, condition of balance, among other things. Test results indicate that a range of derating factors exists for each type of motor, depending upon the above factors, perhaps in the range of .56 to .70 for NEMA Design C motors, and .68 to .82 for NEMA Design D motors.

MINOR FIELD TESTING PROCEDURES

In order to compare the performance of various types and makes of motors under actual oil well load conditions, and to check the sizing of motors to oil well pumping loads, many operators are now interested in motor field-testing procedures.

Electric instruments and testing devices required for complete field testing of oil well pumping motors are as follows:

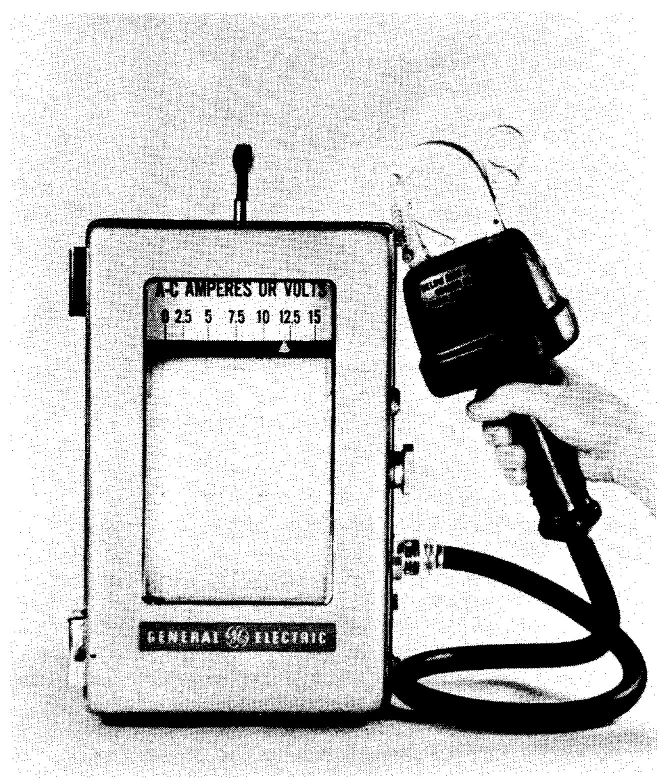

FIG. 3

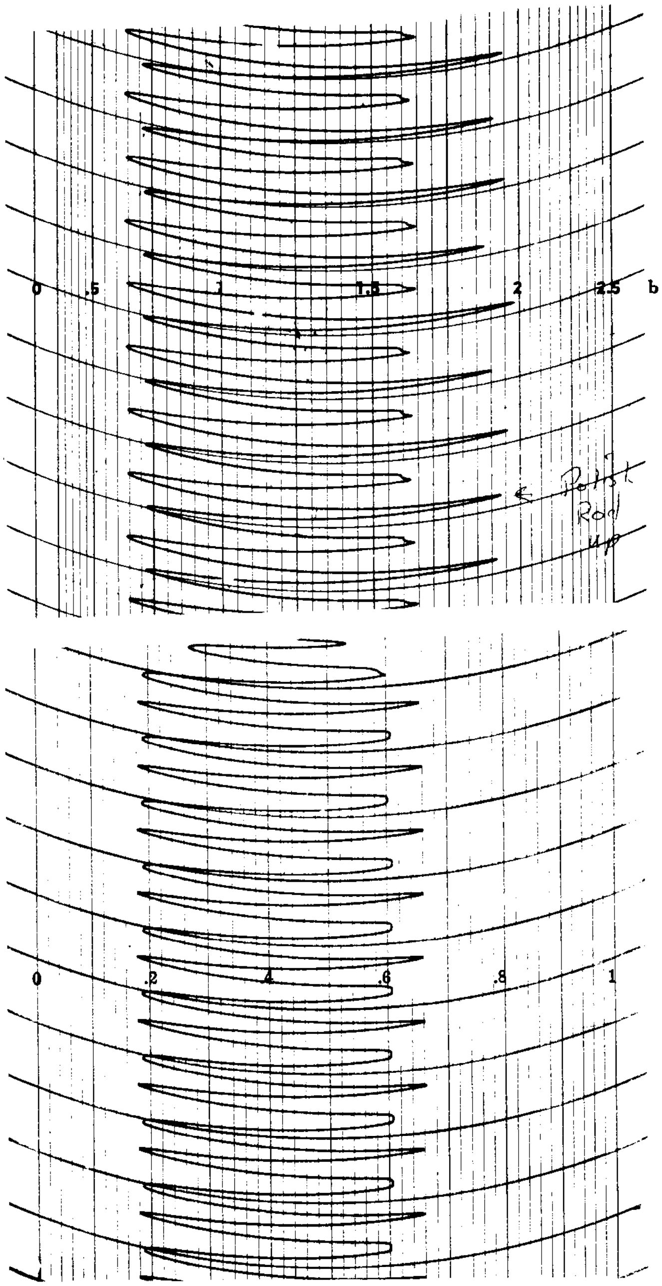

FIG. 4

1. Indicating volt-ammeter, usually clip-on type, to measure current peaks (as described later) and average phase voltages.
2. Thermal-type ammeter, ammeter shunt, and calibration curves to measure RMS line amperes drawn by motor.
3. Polyphase kilowatt-hour meter to measure KW input to motor.
4. Revolution or RPM Counter to measure average motor speed.
5. Accurate stopwatch (not second hand on wristwatch) to count strokes per minute, shaft revolutions of motor, disk revolutions or watthour-meter, production test measurements, etc.

In addition to the above instruments, it may be desirable to have a graphic record of certain electrical input quantities such as line amperes drawn, kilowatt input, and line volts. A recording volt-ammeter is generally used for this purpose with hook-on current transformer attachment for line current measurement as shown in Fig. 3. An instrument with different chart speeds is desirable for close interpretation of measured quantities. Fig. 4 shows examples of strip-chart recordings of kilowatts and line current input to 15 HP oil well pumping motor.

An indicating type of instrument usually cannot be used to obtain accurate readings of such quantities as current, kilowatt, speed, or powerfactor because these values are continuously changing as the load peaks and falls, similar to a sine wave. An indicating voltmeter can be used to obtain accurate phase voltages, particularly if a scale-switching type is used, since line voltage fluctuations are usually not too severe on a typical lease distribution system. Voltage readings on all three phases should be taken and the results averaged to obtain an indication of average line volts. A hook-on indicating volt-ammeter is shown in Fig. 5.

For accurate readings, it is necessary to use a thermal-type ammeter with shunt attachment to measure average RMS line current drawn. Both calibration correction and temperature correction factors should be applied to indicated values to obtain true or accurate readings. A thermal-type ammeter and shunt attachment are shown in Fig. 6.

An integrating type of kilowatthour meter should be used to obtain kilowatt input measurement. This is done by accurately timing a number of disk revolutions (say 20 or 30) by means of a stopwatch, and using the formula:

$$KW_{in} = \frac{N \times 3600 \times K_h}{T\ Z\ 1000}$$

Where,

KW_{in} = Kilowatt input

N = Number of disk revolutions

T = Time in seconds

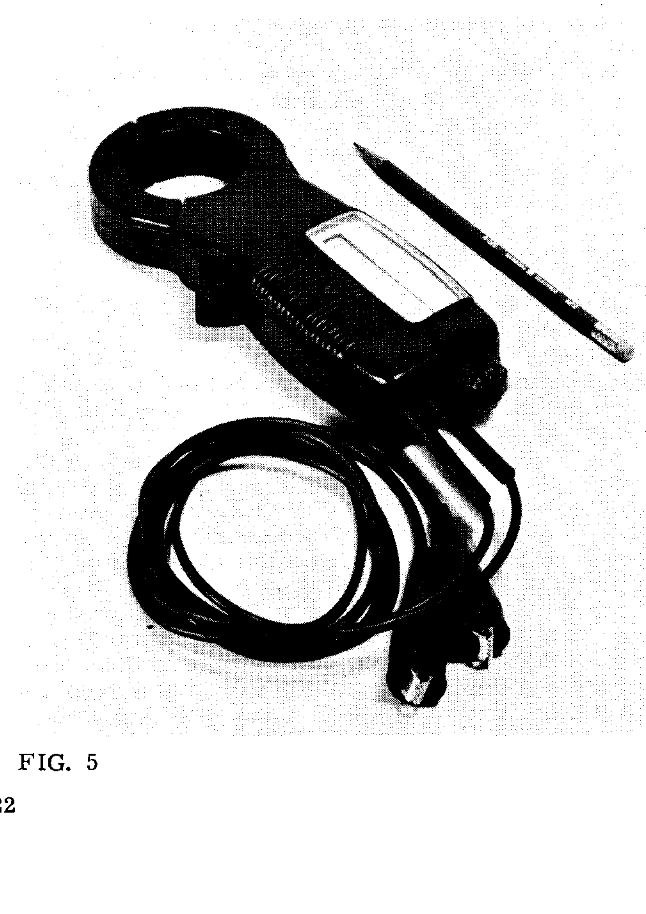

FIG. 5

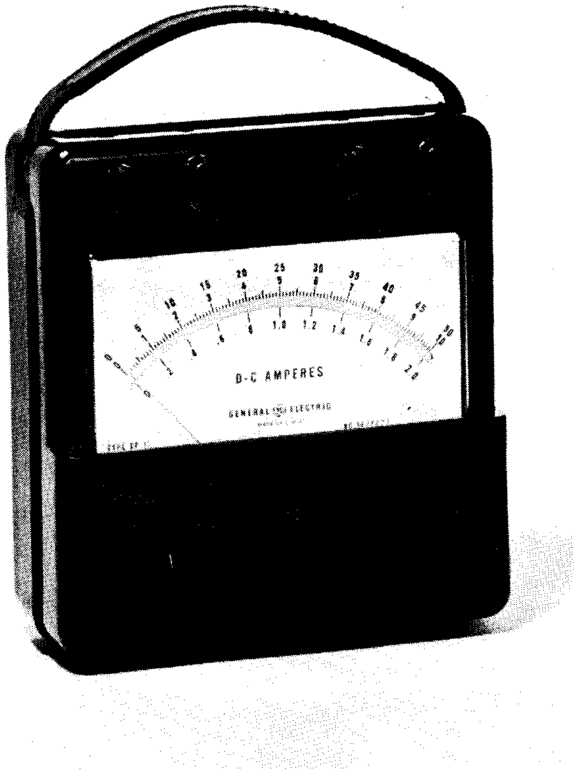

FIG. 6

K_h = Watthour meter constant (found stamped on watthour meter nameplate.)

Demand attachments on watthour meters generally are not precise enough for accurate KW input measurements and should not be used for field testing. A Polyphase a/c kilowatthour meter is shown in Fig. 7.

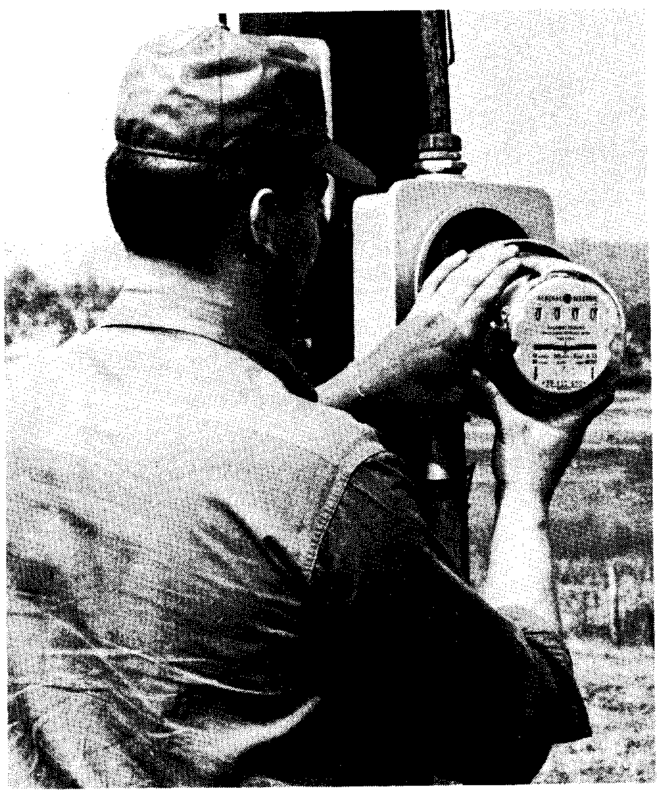

FIG. 7

Having measured RMS line current, average volts, and kilowatt input, average power factor can be calculated from the formula:

$$PF_{avg} = \frac{KW_{in} \times 1000}{\quad}$$

PF_{avg} = Average power factor

KW_{in} = Kilowatt input

V_{avg} = Average line volts

I_{rms} = Measured RMS line amperes

Indicating or recording type instruments are useful in determining peak and low values of quantities being measured. This can be done if a pointer-stop is affixed to the instrument, or by "chasing the pointer" upscale by means of a pencil point, screwdriver edge, or other similar object, to where the needle just barely kicks off the edge or pencil point.

It will be found that the true peak or true valley occurs

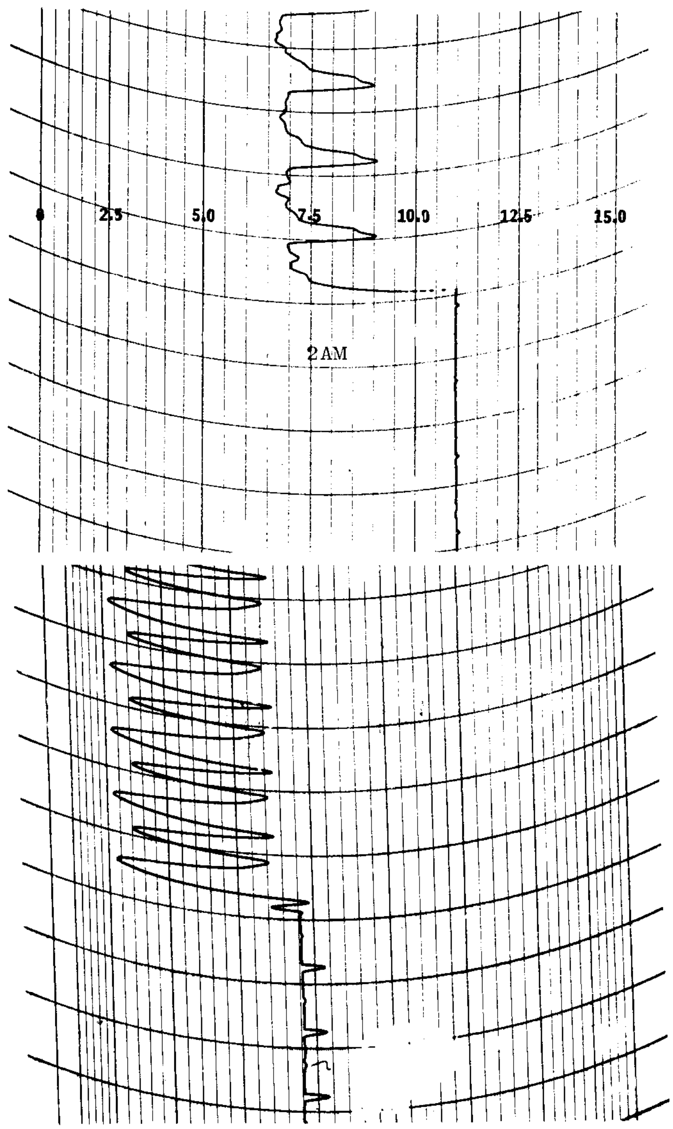

FIG. 8

usually several divisions above or below the indicated or free-swinging point of the instrument needle. This is due to the inertia or damping effect of the instrument movement and works, and should be compensated for in recording true indicated values of current or kilowatt peaks and valleys on upstroke and downstroke. Fig 8 shows examples of indicated peak amperes with pointer freely swinging and when run out to true values.

BALANCING THE UNIT

It is standard practice on many producing oil leases to balance the pumping units by means of a clip-on ammeter. This is done by shifting the counterweights to equalize the current peaks on the upstroke and the downstroke. In order to do a proper job of counter-balancing, it is desirable to use a clip-on ammeter with a pointer stop to accurately check true current peaks as described above. Electrically, from the standpoint of minimum power, a pumping unit theoretically should be balanced using a graphic-type ammeter or wattmeter.

The pumping unit is properly balanced when the area under the curve on the upstroke (lifting rod string) is equal to the area under the curve on the downstroke (lifting counterweight), as shown in Fig. 9. Mechanically, however, it is better to balance on peak torque points in order to minimize shock and wear on the pumping unit, particularly the gear teeth. Therefore, the clip-on indicating ammeter is suited for this purpose. The current peaks (or KW peaks) should be equalized for proper balance as shown in Fig. 10.

COMPLETE FIELD TESTING

In addition to measurements of KW input, RMS current, true current peaks, and calculation of average power factor, motor average speed in RPM can be accurately measured by clocking the motor shaft revolutions (usually in thousands) by means of a stopwatch and revolution counter inserted in the motor shaft opposite the pulley end. This is useful in ascertaining motor average slip (per cent difference from full load synchronous speed) for comparison purposes.

Similarly, average pumping speed in strokes per minute (SPM) can be counted at the polished rod using a stop watch.

Length of stroke (L) can be measured by marking the up and down travel of the polished rod and using a tape rule, or from the dynamometer card.

A polished rod dynamometer can easily be affixed in the field and is very useful in determining average polished rod horsepower (PRHP) and length of stroke (L). If surface efficiency (pumping unit, V-belts and gear losses) or pumping unit efficiency are to be determined, the polished rod dynamometer is a must.

It is extremely important that the producing fluid level (D) be determined and maintained, if the performance of various motors are to be fairly and accurately compared. Since the fluid level does change appreciably in most wells, particularly during shut-in for changing prime-movers, etc., it is important that the producing fluid level be accurately measured. This can be done by "shooting the well" with a Sonolog, and interpreting the recording of sound wave reflections and using a "tubing talley" of the well being tested. Refer to Fig. 11 for Sonolog recording.

To accurately measure production rate, it is necessary to utilize either a portable barrel checker or calibrated tank of known capacity. Gauging at stock tanks pumping over great distances through flow lines is not very accurate, if valid production rates and accurate calculations of lifting costs per barrel of fluid are to be determined for comparison purposes. Obviously, the production should be measured over as long a period of time as feasible, and accurate timing and measurements made, as any errors will be quite significant when projecting the measured production for 24 hours to obtain average barrels per day production rate.

TEST EVALUATION ANALYSES

It is important to note that field tests on oil well pumping motors must be conducted with the utmost accuracy and care, if valid results and interpretations are to be made. It should be emphasized that the motors being tested should be well loaded over the average duty cycle, and that the average load be maintained as nearly constant as possible. Wells that have a tendency to "pump off" or "slug" gas are not to well suited to accurate testing and analyses of motor performance. Generally wells on waterflood or repressuring project, provided near constant load and fluid viscosity are maintained, are the most suited to accurate testing of prime movers.

Oil well motors are generally compared on the following basis:

1. KW input.
2. Kilowatthours per barrel of fluid produced.

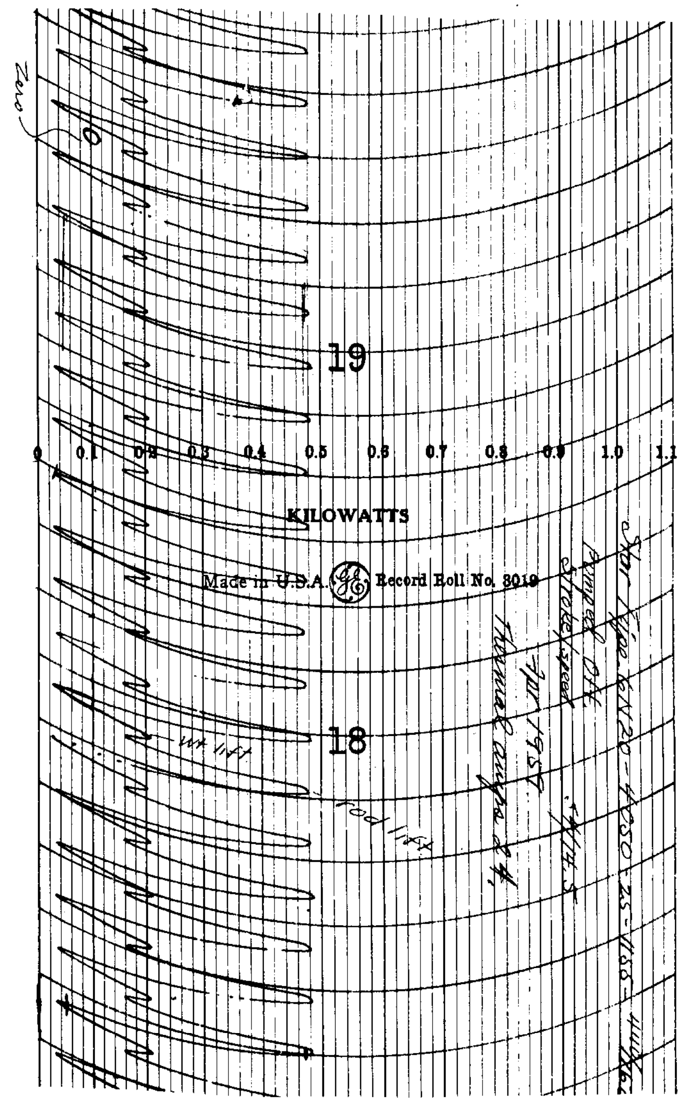

FIG. 9

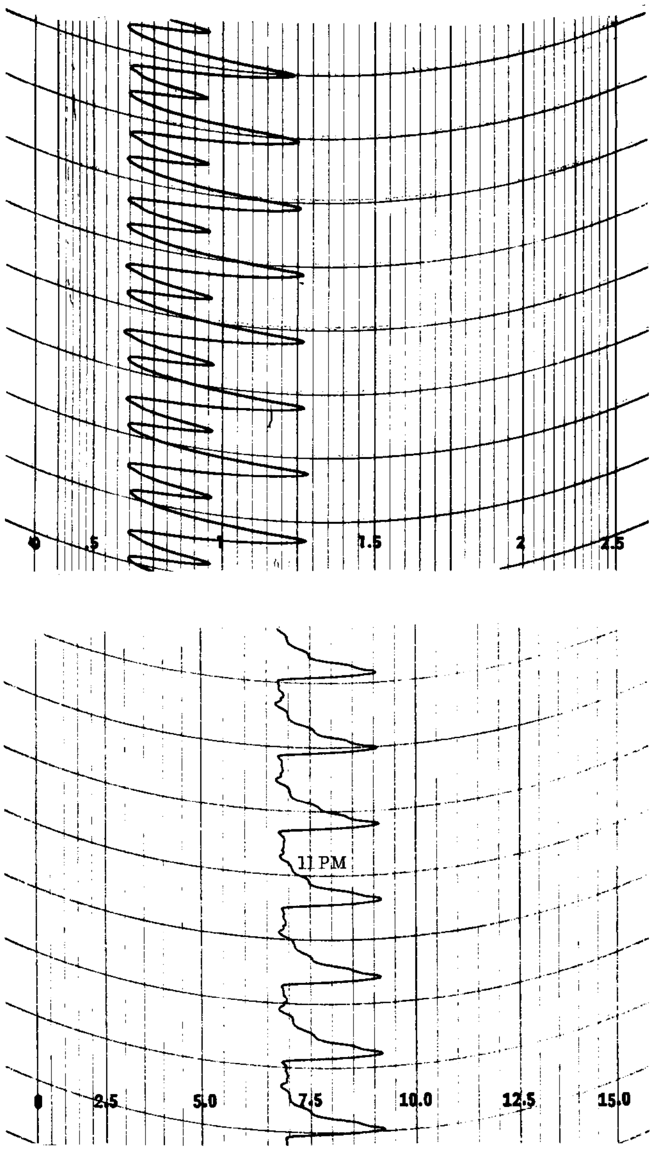

FIG. 10

3. Per cent thermal loading, as a ratio of measured RMS current to nameplate full-load current.
4. Motor derating or cyclic load factor.
5. Calculated power factor.
6. Calculated efficiency.
7. Current peaks drawn compared to rated full-load current.
8. Average RPM or per cent slip compared to nameplate rated full-load speed.

A field Test Data Sheet and Test Summary Sheet, as shown in Fig. 12, can be prepared for data taking and evaluations. Accurate times of test and full motor nameplate data should be recorded as indicated.

Kilowatt Input a motor is a true indication of motor operating expense in regard to power billing. Since most power companies bill largely on a maximum KW demand integrated for a 15 minute period, it is very important to keep KW input or demand to a minimum.

Actual horsepower input can be easily calculated from the formula:

$$HP_{in} = \frac{KW_{in}}{.746} \quad \text{and,}$$

$$HP_{out} = HP_{in} \quad X \quad \text{motor efficiency}$$

DEFINITION OF TERMS

Kilowatthours per barrel of fluid produced is a true measure of motor efficiency in terms of overall lifting costs, since both KW input as well as rate of production in barrels per day are taken into account. This is perhaps the most meaningful measurement to the operator of motor performance, since both motor input power and output rate are indicated.

Percent thermal load is defined as the ratio of the measured RMS current by means of a thermal ammeter to the full-load nameplate current rating of the motor. If measured RMS current exceeds motor full-load nameplate current (times service factor rating of motor), then the motor is thermally overloaded, and probably should be replaced in service. A motor thermally overloaded beyond its nameplate rating will certainly have decreased insulation life and service life, and this practice should be avoided in the oil field.

Cyclic Load Factor is defined as the ratio of the actual horsepower load on the motor to the equivalent thermal horsepower load corresponding to the measured RMS current at that load. As previously discussed, on peaking cyclic load duty, a motor will be thermally loaded to an equivalent horsepower load greater than the actual average mechanical load on the motor shaft. This is due largely to the heating effect on the motor of driving through the peak torques encountered on both the upstroke when the rods and fluid column are lifted, and on the downstroke when the counterweight is lifted.

These peaks torques are generally in the range of 200 to 300 percent average motor torque. Therefore, a motor subjected to this type of load must be derated from its maximum usable horsepower output rating to

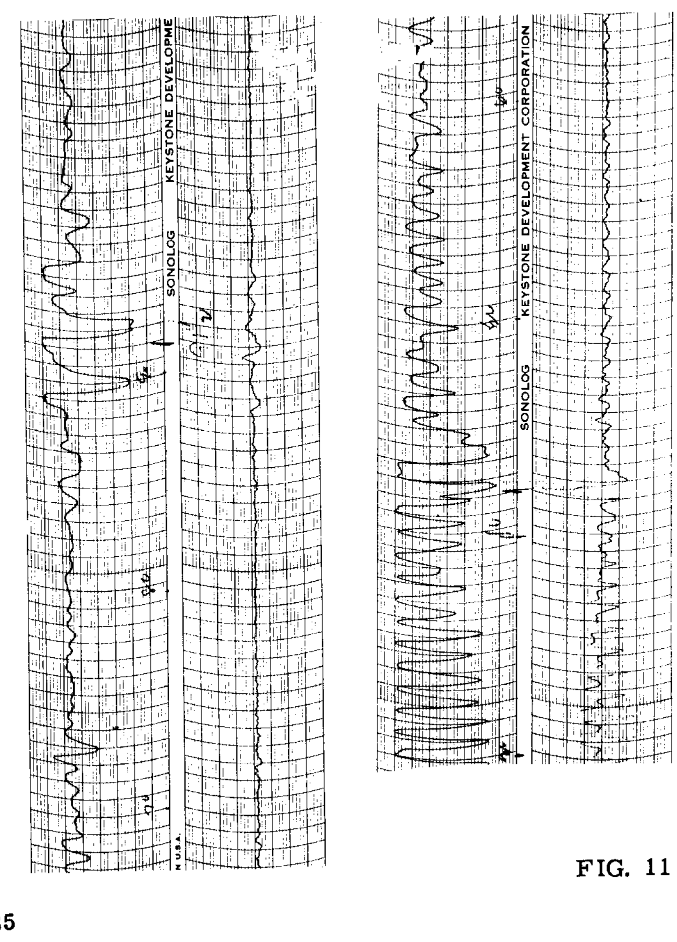

FIG. 11

MOTOR TEST DATA SUMMARY SHEET

Date________________

Well No. and Location: ________________________

Motor Nameplate Data: ________HP, ________FL AMps,

______FL Speed, ______Volts, ______Frame,

______Model #, ______Temp. Rise, ______SF,

______NEMA Code, ______NEMA Design.

Item	Quantity	Symbol	How Derived
1	Test #		
2	Time	T	
3	Strokes per min	SPM	Measured
4	Length of stroke	L	Measured
5	Pump. fluid level	D	Sonolog
6	Barrels per day	B/D	Measured
7	Kilowatt input	KWin	KWH meter
8	Peak Amps-up	Peak Iup	Indicating ammeter
9	Peak Amps-down	Peak Idown	Indicating ammeter
10	RMS current	Irms	Thermal ammeter
11	Corr.RMS Current	Corr.Irms	Ammeter corr. factors
12	Avg.line volts	Eavg.	Voltmeter
13	Avg.motor speed	RPMavg.	Revolution counter
14	Polish rod HP	PRHP	Dynamometer
15			
16			
17			
18	% Thermal load	%TL	Irms/Iflnp
19	% Slip	S	(RPMsych-RPMavg.)/RPMsynch.
20	KWH per Bbl.	KWH/Bbl.	
21	Demand HP	HP in	KWin/.746
22	Horsepower Output	HPout	HPinxEff.motor
23	Thermal HP	HPtherm	Motor curves
24	Motor efficiency	EFF.motor	Motor curves
25	Cyclic load factor	CLF	HPout/HPtherm
26	Avg.Power factor	PFavg.	KWin 3 x E_{avg} x I_{rms}
27	Pumping unit eff.	Eff.pu	PRHP/HPout
28			
29			

Fig. 12. Example of Field Test Data Summary Sheet for testing and evaluating of oil well pumping motors.

allow for the additional thermal load and heating of the duty cycle. Typical motor cyclic load factors on motor derating factors have been previously discussed for the various design classifications of motors. It is well to note again the very decided advantage of the high-slip design motor over the normal or low-slip design motor insofar as derating factor and maximum nameplate usable horsepower are concerned.

The procedure for determining motor cyclic load derating factor is as follows:

1. Determine motor input KW and HP input accurately, as previously discussed.
2. As nearly as possible at the same time read motor RMS line current from the thermal-type ammeter.
3. From the manufacturer's certified curves of motor output performance, determine the HP output corresponding to the measured RMS current, and the motor efficiency (or HP losses) at this current.
4. If motor efficiency instead of HP losses are read from the performance curves, the actual losses can be calculated as follows:

$$\text{Motor efficiency} = \frac{\text{HP out}}{\text{HP input}}$$

$$\text{HP input} = \frac{\text{HP out}}{\text{Motor efficiency}}$$ and,

motor HP losses HP output minus HP input where, HP output HP corresponding to measured RMS current, and motor efficiency efficiency read from motor curves at corresponding RMS current.

4. Subtract motor HP losses determined above (3) from metered motor HP input (1) to obtain motor HP output.
5. Divide motor HP output (4) by thermal HP output (3), therefore;

$$\text{CLF} = \frac{\text{Actual HP output}}{\text{Thermal HP output}}$$

Example: Fig. 13 represents manufacturer's certified curves of motor output performance for NEMA Design D motor rated 15 HP, 1200 RPM.

From actual test data, a HP input by clocking watthour meter disc rotation was observed to be 10.85 HP. At the same time, the motor RMS line current was read to be 16.8 amps.

From the motor curves, at a RMS current of 16.8 amps corresponds to 12.7 output horsepower and .84 motor efficiency. Therefore, the motor losses equal 15.13 HP input (12.7 HP output divided by .84 efficiency) minus 12.7 HP output, or 2.43 HP losses. Therefore, actual HP output equals 10.85 HP input minus 2.43 HP losses, or 8.42 HP output. And cyclic load factor for this particular application is equal to 8.42 HP output divided by 12.7 HP thermal, or .781.

Average power factor can be easily calculated as explained before from the basic formula:

$$\text{Avg. PF} = \frac{KW_{in} \quad X \quad 1000}{3 \quad X \; I_{rms} \; X E_{avg}}$$ where,

KW_{in} = measured KW input to motor

I_{rms} = RMS amps from thermal ammeter

E_{avg} = average line volts from clip-on voltmeter.

Power factor is a measure of motor electrical efficiency, and bears a direct relationship to system I^2R power losses. Because a poor power factor does in fact result in high line currents and KVA capacity demand on the system, power factor improvement is important to the operator from both the power cost standpoint (higher motor line currents result in higher I^2R power losses), and the system capacity point of view (higher KVA rating per HP load).

Fig. 14 is a compilation of typical uncorrected power factors for different oil well pumping motors. Of particular interest is the inherent higher power factors of the NEMA Design D high-slip motors as compared to NEMA C Design motors.

Motor efficiency can be calculated as previously described by deducting motor HP losses from the metered HP input to obtain actual HP output. Therefore, motor efficiency equals HP output divided by HP input. Typical calculated motor efficiencies are low for oil well pumping motors, because of oversizing necessary for cyclic load derating. and because the average motor mechanical load is light compared to the motor full-load nameplate rating.

Current peaks, as determined either from an indicating ammeter or recording ammeter using the pointer stop method as described above, are valuable in ascertaining the "cushioning" effect of different design motors in damping out or attenuating current and power peaks drawn by the motor. The higher the current peaks drawn, the higher will be the RMS current, since the peak current drawn largely determines the difference in RMS currents between two different motors on the samp pumping application.

Although peak currents do not in themselves register on power demand meters since they are instantaneous,

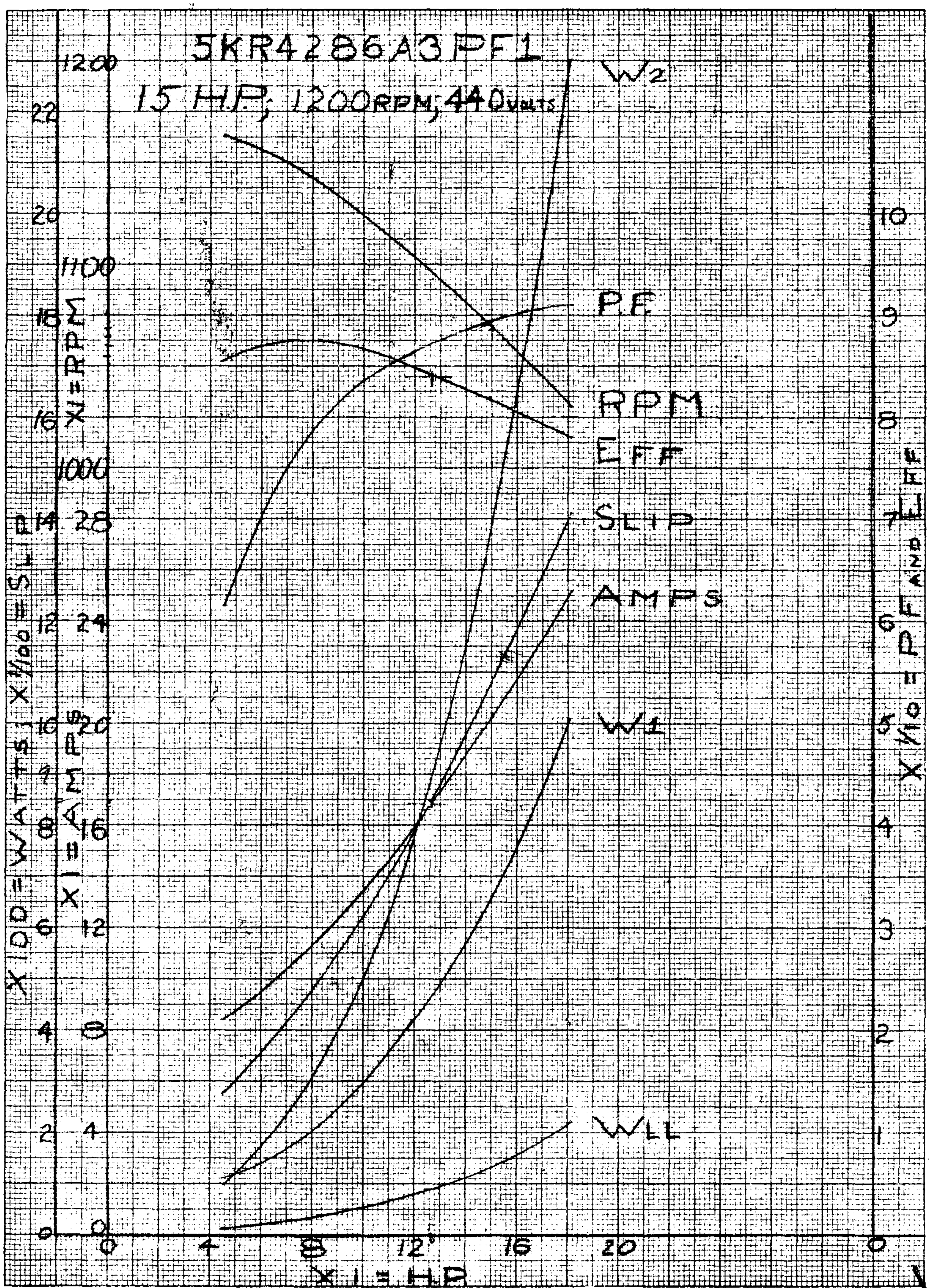
5KR4286A3PF1
15 H.P.; 1200 RPM; 440 VOLTS
W2
P.F.
RPM
EFF
SLIP
AMPS
W1
WLL
X1 = HP
X1 = RPM
X1 = AMPS
X 1/10 = P.F. AND EFF

FIG. 13

Motor HP Rating	Demand HP	NEMA Design	Avg. Slip	Avg. PF
5	4.4	C	1.3%	.49
5	4.8	C	2.0	.49
15	12.5	C	3.6	.52
15	12.8	C	4.3	.50
20	7.7	C	0.75	.48
25	21.8	C	5.0	.55
10	7.8	D	5.1	.68
10	9.4	D	6.4	.63
15	10.9	D	5.4	.63
15	10.9	D	5.8	.65
15	11.2	D	6.2	.65
25	22.1	D	5.2	.67
25	23.5	D	5.2	.72
25	26.8	D	6.8	.68
25	21.3	D	6.5	.61

Fig. 14 Tabulation of calculated uncorrected power factor for various sizes and types of oil well pumping motors.

the effects of higher peak currents will result in increased KW demand, because of the higher resulting RMS current and because of the integration of the larger power consumption during the peaking portions of the cycle. Comparison of peak currents drawn to motor nameplate full-load current will give some indication, for comparison purposes, of the suitability of different types of motors to oil well pumping duty, and to the probable difference in RMS current and power input costs.

Average RPM or per cent slip is indicative of overall motor speed-torque characteristics. A "stiff" or low slip motor (NEMA Design B or C) will have higher current peaks and higher RMS currents for the same cyclic load as compared to high-slip motors (NEMA Design D). Therefore, these motors will have to be derated more than high-slip motors.

It is well to note that average motor speed is not necessarily directly related to average strokes per minute (SPM). As a matter of fact, many field tests have shown that average SPM falls off only slightly using a high-slip motor, because of the inherent speeding up as well as slowing down of this type of motor working under the cyclic load. Also, actual production tests have indicated that in many instances, production rates have actually increased even with a slightly slower pumping speed. This may be explained by the fact that the slowing down action at the time of maximum torque, when changing direction on the upstroke and downstroke, results in more complete filling of the working barrel in the bottom-hole pump, and less rod stretch and, hence, better volumetric efficiency of this pump.

Typical motor speed and production rates between NEMA C and NEMA D motors are compared in Fig. 15.

Of all the above enumerated tests, perhaps the most significant to the operator and the simplest to obtain are: (1) kilowatt input as a measure of power costs, (2) per cent thermal load based on ratio of measured RMS amperes to nameplate full-load amperes as a measure of motor size to load, and (3) Cyclic Load Factor based on ratio of actual horsepower output to equivalent thermal horsepower output as a measure of motor derating for cyclic load duty.

CONCLUSIONS

By a carefully planned and executed approach to proper testing and analyses of oil well pumping motor loads, the operator can not only determine proper sizing of motors for minimum first costs, but can also ascertain which type of motor will result in minimum operating costs. The economics thus affected could well result in the savings of many dollars for increased profits to the operator, as well as a more efficient and reliable prime mover installation.

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2. "Test Comparisons of Design D Motors on Oil Well Pumping Load" by T. L. Scott, Phillips Petroleum Company, AIEE Petroleum Industry Conference, Dallas, Texas, September, 1958.
3. "Types of Electric Motors for Oil Well Pumping" by J. H. Day, Jr., General Electric Company, West Texas Oil Lifting Short Course, Lubbock, Texas, April, 1957.
4. "Sizing Electric Motors for Oil Well Pumping" by F. W. Beach, Cities Service Oil Company, AIEE Petroleum Industry Conference Kansas City, Mo., September, 1956.

TEST DATA TABULATION, 15 HP, 1200 RPM OIL WELL PUMPING MOTOR

NEMA Design	C	D	D	C	D
Average speed of motor-RPM	1148	1135	1126	1153	1130
Percent slip %S	4.3	5.4	6.2	3.6	5.8
Strokes per minute-SPM	20.3	20.0	19.7	20.1	20.1
Length of stroke, L(inch)	50-1/8	50-1/8	50-1/8	50-1/8	50-1/8
Pumping fluid level, D(A)	1566	1566	1566	1566	1566
Barrels per day, B/D	245	247.5	246	249	249
Kilowatt input, KW_{in}	8.78	8.14	8.34	9.34	8.10
Kilowatt-hours per barrel, KWH/bbl.	.915	.788	.814	.900	.781
Peak KW lifting rods	19.6	18.4	15.2	20.0	17.8
Peak KW lifting weights	19.2	14.4	11.6	16.0	14.8
Nameplate full load amps, FLA	20.4	22.3	20.5	21.6	21.6
RMS Amperes, I_{rms}	23.6	20.5	16.7	24.8	16.8
Percent Thermal Load	115%	92%	81.4	115	77.8
Peak Current Lifting Rods	44.0	34.1	29.2	46.0	29.5
Peak Current Lifting weights	36.6	27.3	23.3	35.0	23.3
Average line volts, $E_{avg.}$	430	430	441	421	426
Average power factor, PF	.499	.533	.654	.516	.655
Average motor efficiency, Eff_{motor}	0.88	.866	–	0.85	0.84
Cyclic Load Factor	.546	.642	–	.568	.663

FIG. 15 Field comparisons of NEMA C and NEMA D motors on the same well and pumping load.