EFFICIENT BEAM PUMPING GIVES RESULTS

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INTRODUCTION

Efficient Sucker Rod Beam Pumping has been a problem for years. Excessive rod and pump failures have caused lifting costs to skyrocket.

This paper discusses an extensive program that was undertaken in 1978 and 1979 to maximize efficiency in the Beam Pumping System in the MCA Unit, Maljamar, New Mexico. Approximately 220 pumping wells were checked for proper design and corrections to each well were made to improve the pumping system. Each unit was checked for sucker rod design, pump design, pumping unit speed, stroke length, torque, and electrical equipment.

Results of the project are as follows:

1) During the last year the cost of sucker rods and sucker rod pumps went down, i.e.

   1978 vs. 1977 cost = +$22,073
   1979 vs. 1978 cost = +$49,591
   1980 vs. 1979 cost = -$45,115

2) The cost for rigs to do pump changes and fish broken rods has decreased. The costs are as follows:

   1978 = $221,233
   1979 = $190,762 = 14% decrease vs. 1978
   1980 = $196,950 = 11% decrease vs. 1978

   Note that the costs for 1979 and 1980 are down even with a significant increase in inflation during these years.

3) Average pump life in "days of pump run time" has increased from a fluctuating 340 days to 450 days per pump. This is a 32% increase in pump life. See Fig. 1.

4) Pump repair cost has decreased from a high $15,000/month to a cost of $8,000/month. A decrease of 47%. See Fig. 2.

5) There are other significant factors that were affected by properly designing our equipment, and they will be dealt with in individual sections of this paper. See discussion.

DISCUSSION

The MCA Unit is made up of approximately 220 producing wells. Fluid production is from the Maljamar Grayburg-San Andres formation at 4,000 feet. Field production is approximately 5,000 BOPD and 18,000 BWPD. Production per well ranges from just a few barrels per day to several hundred barrels per day.

Pumping equipment ranges from 57D pumping units to 912D units. Sucker rods are 1", 7/8", 3/4" and a few 5/8" Grade "C" rods. Most rod strings are tapered. The sucker rod pumps range from 1-1/4" diameter stationary barrel pumps to 2-1/4" tubing pumps. Pump types are RWBC. Tubing strings are not anchored.

General problems in producing from this field are that the wells are open hole completions. Calcium carbonate and calcium sulfate scale exists and there is a severe corrosion problem. Corrosion is high because of H_2S gas in concentrations of approximately 2,000 PPM.

The MCA Unit usually had anywhere from 2 to 4 pulling units working at changing pumps and fishing rod parts. Upon inspection of random wells in the field it was found that much of the pumping equipment was over sized. Fluid pound and gas locking problems existed, and these led to other problems. Effective time clocking was nearly impossible because of inaccurate well tests and because of a shortage of personnel and time to monitor 220 wells.

Because of these problems a plan was formulated to try and overcome some of them. The plan covered the following areas:

1) Well test systems - repeatability and accuracy.

2) Guidelines from the following reference articles were used for pumping unit design, sucker rod design, proper pump design and counterbalance effect:

   API RP 11L, "API Recommended Practice for Design Calculations for Sucker Rod pumping Systems (Conventional Units)". 3rd Edition, Feb. 1977.

   API RP 11AR, "API Recommended Practice for Care and Use of Subsurface Pumps". 1st Edition, 1968

   API Spec 11AX, "API Specification for Subsurface Sucker Rod Pumps and Fittings". 7th Edition, June 1979.

   API Spec 11B, "API Specification for Sucker Rods". 18th Edition, March 1979.

   API RP 11BR, "API Recommended Practice for Care and Handling of Sucker Rods".

3) Electrical systems on each well were checked to confirm horsepower requirements. Fuse sizes were determined.

4) Follow-up checks were planned on each unit to ensure that the proper steps had truly been taken.

WELL TEST SYSTEMS

Each well in this system is tested automatically. Test times were formulated according to production and purge requirements. The production test headers were the C. E. Natco type "Invalco" valves, and each system and each valve was checked for leakage. All leakage problems were corrected.

Test treaters ranged from 4' X 20' vertical vessels to 6' X 20' vertical vessels. A one barrel prover was brought into the field and each treater was "proven" to dump one barrel. Permanent marks were stenciled into each treater near the sight glass to show how much vertical space made up one barrel. NOTE! It was found that approximately 12" in a 4' metering treater and 4" in a 6' metering treater was one barrel. We had errors in nearly all dump cycles on the test treaters. Each treater was checked for proper dump cycle once each month from then on, and corrections back to the permanent marks were made immediately. We then proceeded to test each well and find normal production.

Also included in well testing were the physical acts of shooting fluid levels on each well to ensure "pump down" conditions and also the use of dynamometer analysis to guarantee good pump action. These two tools are a critical part of efficient well pumping.

A well was determined to have a "stable well test" when the fluid level was within 500 feet of the pump (500 feet of pump submergence) and well tests nearly repeated each other 2 or 3 times. The number "500 feet" was arrived at by the use of IPR curves. It was determined that with 500 feet or less submergence the production was not significantly affected. See Figs. 8 and 8A (IPR Curve and Calculations).

After all of these factors were taken into account and all corrections were made our test systems have been operating at 90+% accuracy. See Fig. 3.

DESIGN

Each well was then studied from a design standpoint. A computer was used to run API RPIIL calculations that gave us "optimum" pumping design criteria. This optimum design was then implemented, and stroke lengths were changed and strokes per minute (SPM) were adjusted as needed. When the stroke lengths and SPM of a given unit were changed, then the pumping unit was also counterbalanced, and the pump was properly "spaced out". A well is properly spaced out when the traveling valve and the standing valve are as close together as mechanically desirable. Usually ±3 inches.

Counterbalancing was done with an ammeter. Upstroke and downstroke ampere readings were taken before and after balancing took place. A design goal of 10% accuracy in counterbalance was set. This could not be reached in several instances, but each unit was balanced as close as equipment on hand would allow. Five hundred feet or less pump submergence was required before balancing a unit. Each pump was "spaced out" to ±3 inches to ensure good pump compression. This of course had to be coincided with pump construction to be sure that the valve rod was cut to the proper length.

This maneuver helped eliminate gas lock problems. As each well was spaced out we had to guarantee that it would be re-spaced if future work was done. Each time a well is pulled and put back on production a fluid level is shot, and when pump submergence is 500 feet or less the well is re-spaced. Fig. 4 recaps this total design set-up.

Sucker rod percentages were recorded for any given tapered string, and allowable vs. actual rod stresses were checked. If the rods were over stressed then steps were made to correct the problem. This was not a very significant problem in the MCA Unit. If actual rod tapers differed significantly from design then notes were put in that well's file to make corrections when the well was pulled. Unless a well was severely out of tune with design criteria it was not pulled until another problem existed.

Proper sinker bar designs were made for each well and again were initiated whenever the well was pulled.

ELECTRICAL SYSTEMS

It is a fairly common practice to fuse pumping equipment to its maximum rating and not to its actual usage. Because of this, motors burn up, belts burn off when equipment fails (Example: shallow rod parts), and generally most equipment is damaged when units continue to run during catastrophic failures (Example: wrist pin breakage).

Plans were made to check all electrical systems on pumping units for proper horsepower requirements, fuse sizes, and in the cases of extremely high slip electric motors torque "mode" would be checked. The design work for proper horsepower requirements and for torque "mode" in extremely high slip motors was done in conjunction with the other design data mentioned above. The fuse size was to be physically determined by the use of an ammeter when the unit had been counterbalanced. (Remember, units weren't balanced until all other work was done and the pump submergence was 500 feet or less). Fuses were then changed. See Fig. 4.

It is believed that we had less electrical problems after the change than before. We also found that in many instances a "pumper" could tell if there was something wrong with a well by the physical effects at the surface, i.e. blown fuses, improper balance, and sometimes the unit wouldn't turn over at all.

It was also determined that the SPM of a unit could be changed by 1 to 3 SPM by changing "modes" only on a given unit. There was no definite pattern that could be set but it generally depended on whether the motor was fully loaded or not. See Fig. 4. MCA No. 321 is an example. SPM differential was 1.47(by changing from high mode to low mode in this case.

SPECIAL TESTS

Two wells were tested during this program for special effects that might be accomplished. These two effects were gear box torque differences created by changing only torque modes on a given unit, and the other effect checked was electrical usage per day when some of the changes mentioned above were done to a unit. The wells were picked at random.

In test case No. 1 (see Fig. 4 - well No. 069 for well data) gear box torque changed from a high of 346,723 inch pounds in the high mode to 317,634 inch pounds in the low mode. This is a reduction of about 8%. The minimum gear box torque changed from a -105,271 inch pounds to a -48,439 inch pounds.

This is a positive change of 54%. This was caused by the extremely high slippage in the motor design. See Figs. 5 and 6. Fig. 9 shows actual dynamometer cards for this test case. Figs. 10 and 11 show actual torque analysis loads.

In the second test electrical usage was measured in kwh/day and was calculated in conjunction with the use of a thermal ammeter. The unit was checked first in high mode, then high mode but slowed down, and last in low mode slowed down. The unit picked had an extremely high slip size 3 motor on it. Results were as follows:

Normal speed - High Mode - 254.15 kwh/day running 13 hrs/day
Slowed down - High Mode - 450.43 kwh/day running 24 hrs/day
Slowed down - Low Mode - 168.91 kwh/day running 24 hrs/day

See Fig. 7 for exact calculations and data. From high mode normal to low mode slow there is a 34% reduction in kwh/day even though the first test ran 13 hours per day and after the change it ran 24 hours per day.

CONCLUSION

Corrections in each well were physically made and then each well was checked again for stroke length, SPM, gear box torque, counterbalance, pump size, rod taper, and pump capacity. Electrical systems were monitored and adjustments made where necessary. Overall, the system has been working very well for the past year. Volumetric efficiency is ±70% in most of these wells.

Sucker rod pump life measured in "days run time" have increased. Pump repair costs have decreased by 47%. Rig time spent on pump changes and fishing jobs has decreased which gives more time for constructive jobs such as remedial work.

Efficient "beam pumping" can be accomplished on a well by well basis or in a large scale field application. The time, effort, and capital spent on this type of program can be recouped, and profit can be made.

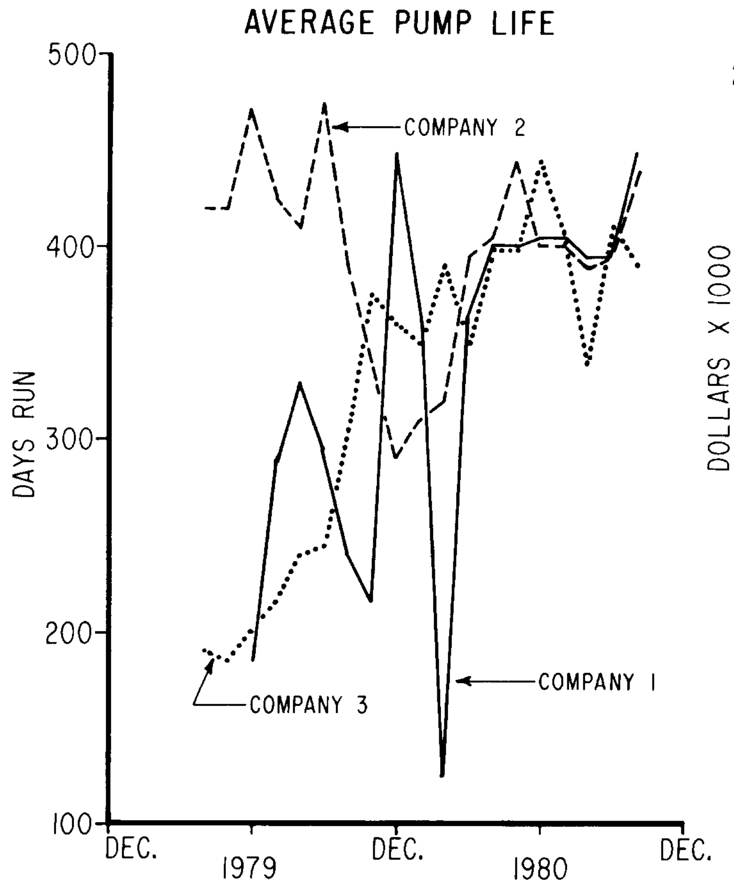


FIGURE 1

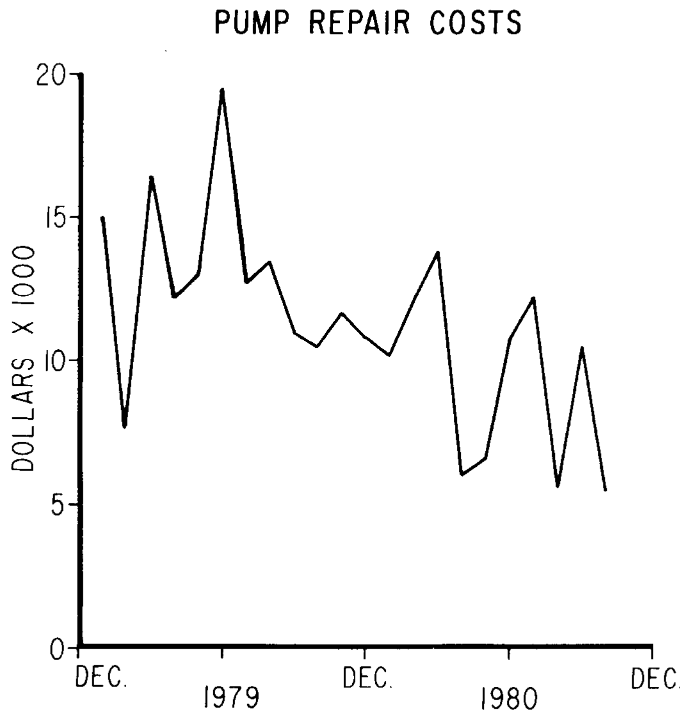


FIGURE 2

WELL TEST SYSTEMS

	Recorded Tests	Reference Tests	LACT Lse Prod	Tst System Validity	Tst System Lse Wtr Prod
MCA 1A Test Header	425	459		53%	1385
MCA 1B Test Header	199	300		40%	1785
MCA 1C Test Header	221	368		23%	1644
Battery TOTAL	845	1127	871	-2%	4814
MCA 2A Test Header	580	524		50%	977
MCA 2B Test Header	174	206		67%	726
MCA 2C Test Header	477	689		22%	3358
Battery TOTAL	1231	1419	1293	-4%	5061
MCA 3A Test Header	682	764		32%	1360
MCA 3B Test Header	366	426		59%	3332
MCA 3C Test Header	1030	1047		39%	2535
Battery TOTAL	2078	2237	1823	13%	7227
MCA 4A Test Header	415	488		52%	687
MCA 4B Test Header	156	174		48%	500
MCA 4C Test Header	323	341		34%	109
Battery TOTAL	894	1003	920	-2%	1296
TOTALS	5048	5786	4907	+5%	18,398

FIGURE 3

RECAP OF CHANGES TO WELLS

Well Name	Stroke Length Before	Stroke Length After	SPM Before	SPM After	Motor Size	Mode Before	Mode(b) After	CB Amps Before Up/Down	CB Amps After Up/Down	Actual Fuse Size (Amps)	Run Time	Spacing
MCA No. 069	100	100	12.90	11.70	E-3	High	Low	20/18	20/18	20	24 hrs	2"
MCA No. 071	120	120	12.17	11.76	E-4	High	Low	38/36	38/36	50	24 hrs	17"
MCA No. 077	36	36	10.66	10.66	7.5 HP	-	-	8/9	8/9	12	45%	3"
MCA No. 083	34	86	7.14	7.14	E-3	Low	Low	20/18	20/18	25	17 hrs	12"
MCA No. 120	120	120	7.43	10.91(c)	E-3	High	Med	40/44	40/44	45	24 hrs	3"
MCA No. 122	85	85	10.93	7.58	E-3	Low	Low	20/18	20/18	30	24 hrs	9"
MCA No. 136	102	85	13.04	7.32(c)	E-3	Low	Low	21/10	21/10	25	17 hrs	27"
MCA No. 149	86	86	10.76	12.24	E-3	High	Low	13/17	13/17(a)	25	45%	6"
MCA No. 196	64	64	9.23	12.82(c)	E-2	Med	Low	16/15	16/15	20	22 hrs	0"
MCA No. 231	86	86	16.22	11.41(c)	E-3	Low	Low	40/23	31/33	35	24 hrs	4"
MCA No. 260	86	124	15.46	9.07(c)	100 HP	-	-	80/79	80/79	125	24 hrs	14"
MCA No. 262	168	168	11.21	8.00(c)	100 HP	-	-	125/150	135/140	150	83%	2"
MCA No. 321	100	100	8.50	7.03	E-3	High	Low	10/21	22/20	30	17 hrs	12"
MCA No. 322	74	74	14.89	8.72(c)	E-2	High	Low	9/16	19/16	25	18 hrs	11"
MCA No. 323	86	61	11.67	6.52(c)	E-3	High	Low	6/20	7/18(a)	25	54%	4"
MCA No. 336	100	85	9.02	5.96(c)	E-3	High	Low	19/13	19/13(a)	25	20 hrs	8"
MCA No. 346	86	86	11.76	6.14(c)	E-3	Med	Low	16/20	16/20(a)	25	19 hrs	15"
MCA No. 347	100	85	7.14	7.14	E-3	Med	Low	22/20	22/20	30	18 hrs	8"
MCA No. 352	64	44	11.70	11.70	E-2	Low	Low	27/12	15/17	20	14 hrs	12"

SPECIFICATIONS

Extremely High Slip Motor Rating	Fuse Size
1	20
2	40
3	60
4	100
5	150
6	300

NEMA D Motor Rating	Fuse Size
7.5 HP	15
100 HP	150

FIGURE 4—(a) These wells could not be counterbalanced any closer with the equipment on hand. (b) Some of these motors were still too large even when put in low mode. (c) On these wells sheave sizes were also changed to either reduce or increase the SPM of the unit.

FIGURE 4

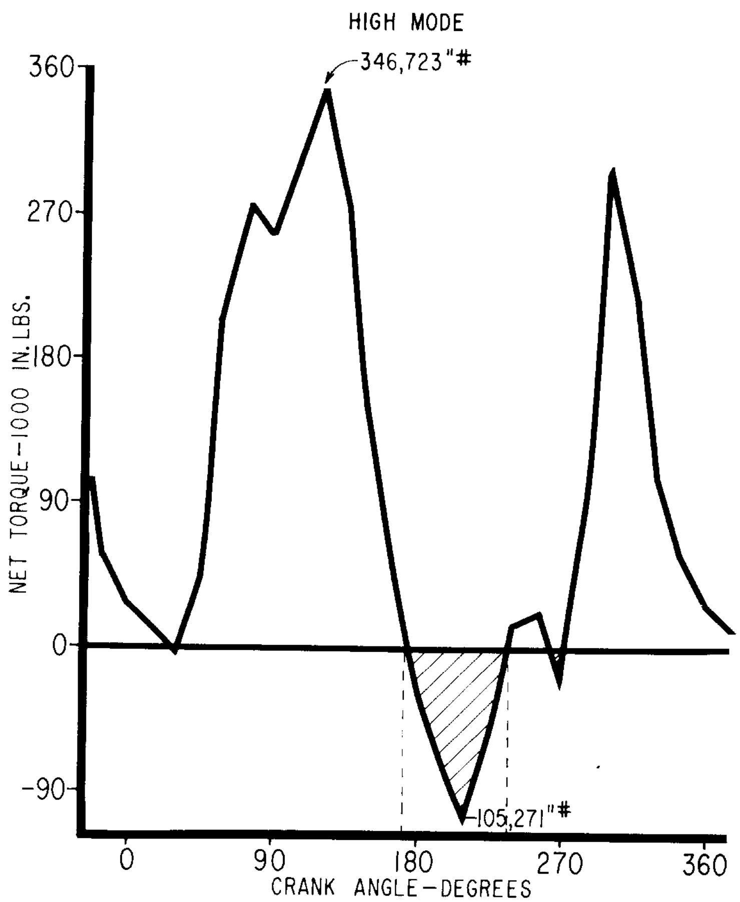


FIGURE 5

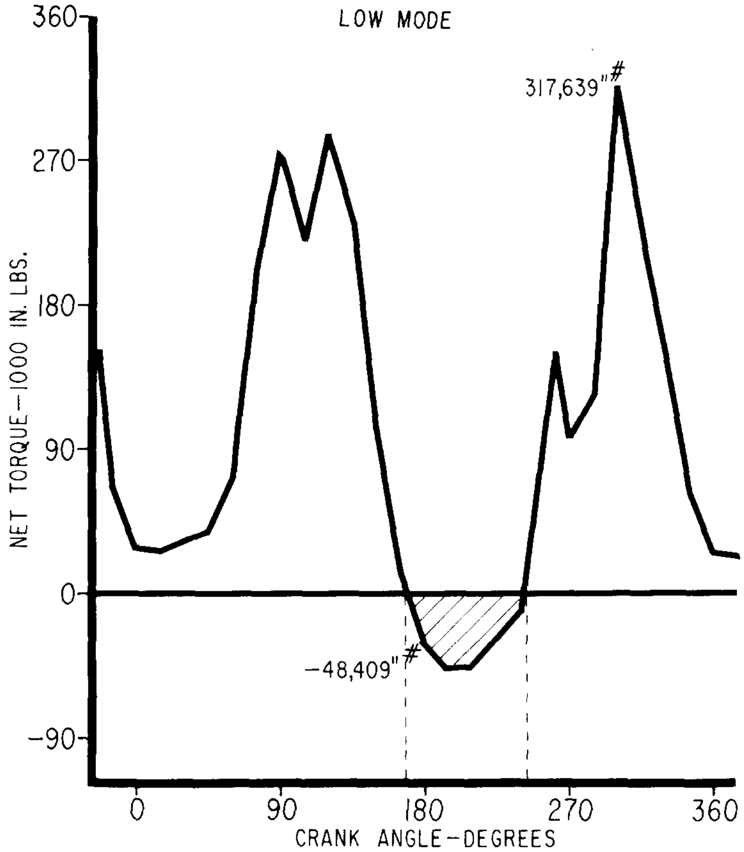


FIGURE 6

ELECTRICAL USAGE - BEFORE AND AFTER CHANGES

Before unit was slowed down in High Mode

SPM = 12.9

$w = V \times A \times 3^{0.5}$
$w = 460 \times 25 \times 1.7$
$w = 19550$

kwh/day = 19550 X 13/1000
kwh/day = 254.15 @ 13/hr day

After unit was slowed down in High Mode

* SPM = 7.4

$w = V \times A \times 3^{0.5}$
$w = 460 \times 24 \times 1.7$
$w = 18768$

kwh/day = 450.43 @ 24 hr/day

After unit slowed down in Low Mode

**SPM = 6.6

$w = V \times A \times 3^{0.5}$
$w = 460 \times 9 \times 1.7$
$w = 7038$

kwh/day = 168.91 @ 24 hr/day

Where:
w = Watts
V = Volts
A = Thermal Amperes

NOTE: *The unit was first slowed down by changing the prime mover sheave (changed from 12.9 to 7.45 SPM.)

**The reduction from 7.4 to 6.6 SPM was due to the change in mode only.

FIGURE 7

CALCULATIONS FOR IPR CURVE

GIVEN:

Present Production - oil - 12 BPD, water 468 BPD
Casing Pressure - 60 psi
SIBHP - 2500 psi
Fluid Gradient - .33 psi/ft
Center of Perforations - 3850 feet
Seating Nipple Depth - 3654 feet

P_1 = Five hundred feet of submergence above the pump but this is 696 feet above the center perf. THEREFORE: 696 X .33 = 230 psi

P_1 = 230 psi + 60 psi = 290 psi

then $\frac{290}{2500}$ = .12, this then results in a number of .97 on the IPR curve.

P_2 = Zero feet submergence above the pump but this is 196 feet above the center perf. THEREFORE: 196 X .33 = 65 psi.

P_2 = 65 psi + 60 psi = 125 psi,

then $\frac{125}{2500}$ = .05, this then results in a number of .99 on the IPR curve.

Now to figure total production:

$$\frac{(480\ \text{BFPD})\ (.99)}{.97} = \frac{475.2}{.97} = 490\ \text{BFPD}$$

At an oil cut of 2.5% this results in an oil production increase of .25 BPD and a water production increase of 9.75 BPD.

FIGURE 8-A

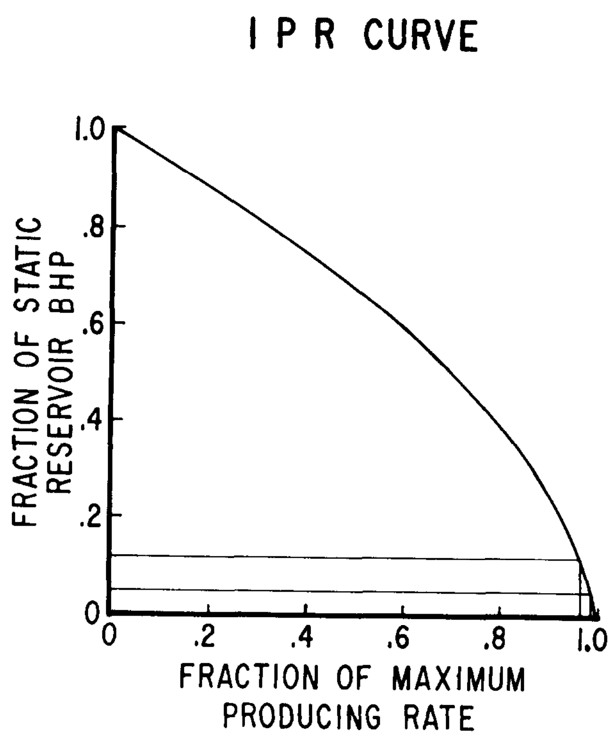
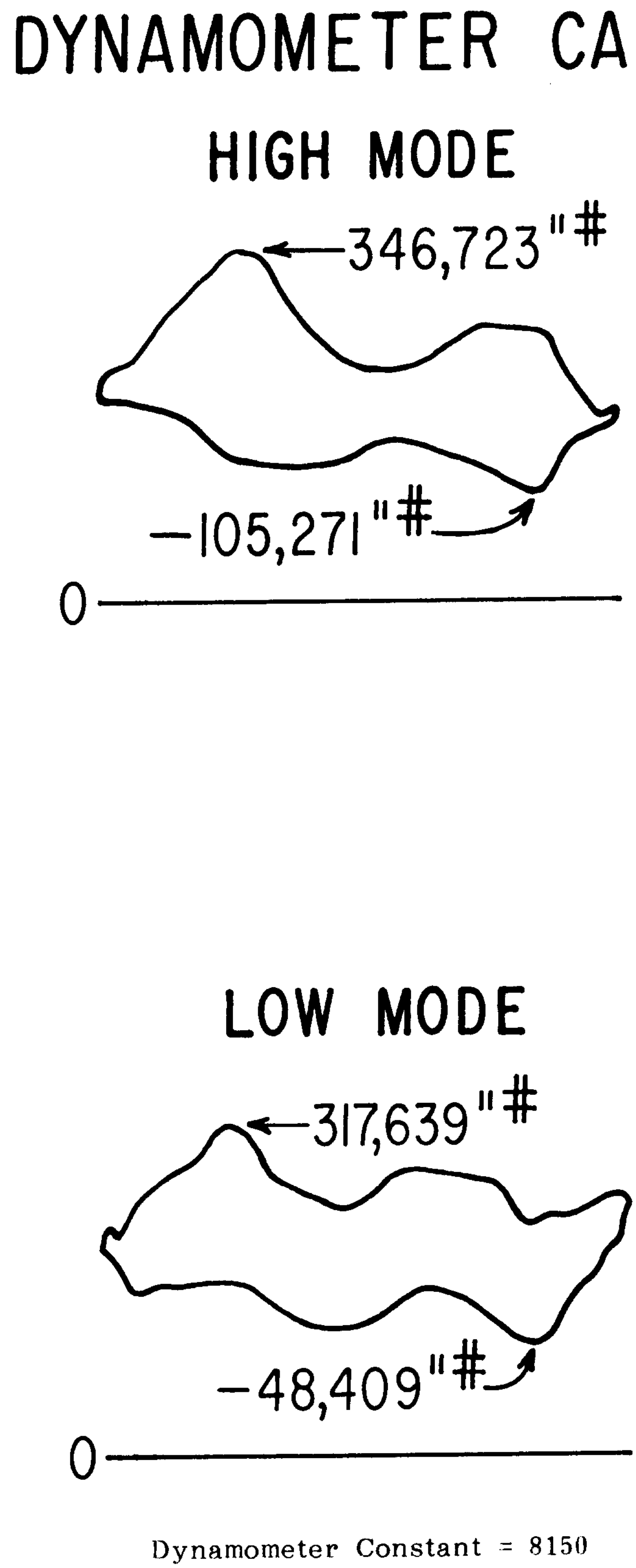


FIGURE 8



Dynamometer Constant = 8150

FIGURE 9

PUMPING UNIT TORQUE PROGRAM - HIGH MODE LEASE -- MCA

LEASE --MCA WELL NUMBER -- 69
UNIT MANUFACTURER AND DESIGNATION -- LUF C456 256 100 CARD 2 HIGH
STROKE LENGTH = 100.0 IN. STROKES PER MINUTE = 12.9
ASSUMED STRUCTURAL EFFICIENCY = 0.83
PUMPING UNIT -- CONVENTIONAL, ROTATION IS COUNTERCLOCKWISE

DYNAMOMETER CONSTANT = 8150. LBS./IN.
CARD CALC. STROKE LENGTH = 0.00 IN. * 0.00 IN./IN. = 100.0 IN.
TORQUE FACTOR CORRECTION = CALC. S.L./MFG. S.L. = 1.000
STRUCTURAL UNBALANCE = 500. LBS.

(1) CRANK ANGLE	(2) DY. CARD VALUES	(3) WELL LOAD	(4) NET WELL LOAD	(5) COR. TORQUE FACTOR	(6) WELL LOAD TORQUE	(7) LEVER COR. FAC.	(8) C. BALANCE TORQUE	(9) THEORETICAL NET TORQUE	(10) NET TORQUE
0.0	1.15	9372.	8872.	2.540	22536.	0.000	0.	22536.	27151.
15.0	1.09	8883.	8383.	-15.368	-128837.	0.258	136078.	7241.	8724.
30.0	1.08	8802.	8302.	-32.187	-267216.	.500	262884.	-4332.	-3595.
45.0	0.98	7987.	7487.	-44.715	-334781.	0.707	371774.	36993.	44569.
60.0	0.75	6112.	5612.	-50.973	-286086.	0.866	455328.	169242.	203906.
75.0	0.73	5949.	5449.	-51.271	-279401.	0.965	507852.	228451.	275243.
90.0	0.87	7090.	6590.	-47.482	-312930.	1.000	525768.	212837.	256431.
105.0	0.80	6520.	6020.	-41.598	-250419.	0.965	507852.	257432.	310160.
120.0	0.65	5297.	4797.	-34.924	-167547.	0.866	455328.	287780.	346723.
135.0	0.71	5786.	5286.	-28.005	148048.	0.707	371773.	223725.	269548.
150.0	0.90	7335.	6835.	-20.839	-142434.	0.499	262883.	120449.	145119.
165.0	0.95	7742.	7242.	-13.089	-94797.	0.258	136078.	41281.	49736.
180.0	1.02	8313.	7812.	-4.260	-33283.	-0.000	-0.	-33283.	-27625.
195.0	1.05	8557.	8057.	6.027	48562.	-0.258	-136079.	-87516.	-72638.
210.0	1.01	8231.	7731.	17.597	136051.	-0.500	-262884.	-126833.	-105271.
225.0	1.29	10513.	10013.	29.350	293896.	-0.707	-371774.	-77878.	-64638.
240.0	1.50	12225.	11725.	39.580	464075.	-0.866	-455328.	8746.	10538.
255.0	1.43	11654.	11154.	46.898	523123.	-0.965	-507852.	15270.	18398.
270.0	1.28	10432.	9932.	50.740	503949.	-1.000	-525768.	-21818.	-18109.
285.0	1.45	11817.	11317.	51.112	578460.	-0.965	-507852.	70607.	85068.
300.0	1.85	15077.	14577.	48.137	701717.	-0.866	-455328.	246388.	296854.
315.0	1.75	14262.	13762.	41.827	575644.	-0.707	-371773.	203870.	245627.
330.0	1.42	11573.	11073.	32.071	355122.	-0.499	-262883.	92238.	111131.
345.0	1.25	10187.	9687.	18.832	182435.	-0.258	-136078.	46356.	55851.

PEAK LOAD = 15077. LBS. AT 300.0 DEGREES
MINIMUM LOAD = 5297. LBS. AT 120.0 DEGREES
P.R.H.P. = 0.0
COUNTERBALANCE EFFECT AT POLISHED ROD, MEASURED AT 90 DEGREE CRANK ANGLE = 11573. LBS.
MAX. COUNTERBALANCE TORQUE = (11573. - 500.) * 47.482/1.000 = 525768. IN. -LBS.
OPTIMUM MAX. COUNTERBALANCE TORQUE TO PROPERLY BALANCE UNIT = 501870. IN. -LBS.
OPTIMUM MAX. COUNTERBALANCE EFFECT TO PROPERLY BALANCE UNIT = 11069. LBS.

WARNING WHEN UNIT IS PROPERLY BALANCED, NEG. TORQUE EXISTS IN THE HIGH SPEED PROTION OF THE STROKE AT ANGLES - 30. 225.

FIGURE 10

PUMPING UNIT TORQUE PROGRAM - LOW MODE LEASE -- MCA

LEASE --MCA WELL NUMBER -- 69
UNIT MANUFACTURER AND DESIGNATION -- LUF C456 256 100 CARD 1 LOW STROKE LENGTH = 100.0 IN.STROKES PER MINUTE = 11.7 ASSUMED STRUCTURAL EFFICIENCY = 0.83
DYNAMOMETER CONSTANT = 8150. LBS./IN.
PUMPING UNIT -- CONVENTIONAL, ROTATION IS COUNTERCLOCKWISE

CARD CALC. STROKE LENGTH = 0.00 IN. * 0.00 IN./IN. = 100.0 IN.
TORQUE FACTOR CORRECTION = CALC. S.L./MFG. S.L. = 1.000
STRUCTURAL UNBALANCE = 500. LBS.

(1) CRANK ANGLE	(2) DY. CARD VALUES	(3) WELL LOAD	(4) NET WELL LOAD	(5) COR. TORQUE FACTOR	(6) WELL LOAD TORQUE	(7) LEVER COR. FAC.	(8) C. BALANCE TORQUE	(9) THEORETICAL NET TORQUE	(10) NET TORQUE
0.0	1.13	9209.	8709.	2.540	22122.	0.000	0.	22122.	26653.
15.0	0.90	7335.	6835.	-15.368	-105040.	0.258	125061.	20021.	24121.
30.0	0.88	7172.	6672.	-32.187	-214751.	0.500	241600.	26848.	32347.
45.0	0.91	7416.	6916.	-44.715	-309271.	0.707	341674.	32403.	39039.
60.0	0.92	7498.	6998.	-50.973	-356709.	0.866	418463.	61754.	74403.
75.0	0.72	5868.	5368.	-51.271	-275222.	0.965	466735.	191513.	230738.
90.0	0.72	5868.	5368.	-47.482	-254883.	1.000	483200.	228317.	275080.
105.0	0.90	7335.	6835.	-41.598	-284322.	0.965	466735.	182413.	219775.
120.0	0.70	5705.	5205.	-34.924	-181779.	0.866	418463.	236684.	285161.
135.0	0.72	5868.	5368.	-28.005	-150330.	0.707	341674.	191343.	230534.
150.0	0.98	7987.	7487.	-20.839	-156021.	0.499	241599.	85578.	103106.
165.0	1.15	9372.	8872.	-13.089	-116132.	0.258	125061.	8928.	10757.
180.0	1.25	10187.	9687.	-4.260	-41268.	-0.000	-0.	-41269.	-34253.
195.0	1.42	11573.	11073.	6.027	66736.	-0.258	-125061.	-58324.	-48409.
210.0	1.36	11084.	10584.	17.597	186246.	-0.500	-241600.	-55353.	-45943.
225.0	1.32	10758.	10258.	29.350	301072.	-0.707	-341674.	-40602.	-33699.
240.0	1.32	10758.	10258.	39.580	406011.	-0.866	-418463.	-12452.	-10335.
255.0	1.52	12388.	11888.	46.898	557523.	-0.965	-466735.	90787.	109382.
270.0	1.42	11573.	11073.	50.740	561844.	-1.000	-483200.	78643.	94751.
285.0	1.43	11654.	11154.	51.112	570128.	-0.965	-466735.	103393.	124570.
300.0	1.80	14670.	14170.	48.137	682101.	-0.866	-418463.	263637.	317635.
315.0	1.60	13040.	12540.	41.827	524510.	-0.707	-341673.	182836.	220285.
330.0	1.47	11980.	11480.	32.071	368191.	-0.499	241599.	126591.	152520.
345.0	1.22	9943.	9443.	18.832	177830.	-0.258	-125060.	52769.	63577.

PEAK LOAD = 14670. LBS. AT 300.0 DEGREES
MINIMUM LOAD = 5705. LBS. AT 120.0 DEGREES
P.R.H.P. = 0.0
COUNTERBALANCE EFFECT AT POLISHED ROD, MEASURED AT 90 DEGREE CRANK ANGLE = 10676. LBS.
MAX. COUNTERBALANCE TORQUE = (10676. - 500.) * 47.482/1.000 = 483200. IN. -LBS.
OPTIMUM MAX. COUNTERBALANCE TORQUE TO PROPERLY BALANCE UNIT = 498761. IN. -LBS.
OPTIMUM MAX. COUNTERBALANCE EFFECT TO PROPERLY BALANCE UNIT = 11004. LBS.

WARNING WHEN UNIT IS PROPERLY BALANCED, NEG. TORQUE EXISTS IN THE HIGH SPEED PROTION OF THE STROKE AT ANGLES - 225. 240.

FIGURE 11