ULTRA LONG STROKE PUMPING SYSTEMS: THREE YEAR CASE HISTORY OF AN ALTERNATIVE TO CONVENTIONAL LIFT SYSTEMS

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Abstract

Data collected over a three-year period on individually monitored wells has provided strong evidence to support the rationalization regarding ultra long stroke pumping systems (ULSPS's). A total of thirteen ULSPS's are included in this study. Electrical costs per barrel and failure frequency will be compared to electrical submersible pump systems and conventional beam pumping systems.

Additionally, another evolutionary product, in the form of a modified NEMA C motor, was installed on two of the test wells with the goal of further reducing KWh cost per barrel (one of the highest controllable expenses in artificial lift). Early field data on these motors will also be reported.

Introduction

A previous paper presented data on these ULSPS's[1]. This paper further addresses the operational considerations in choosing the ULSPS and the economic outcome of the decision. The wells selected for testing the use of an ultra long stroke pumping system are located in the East Vacuum Grayburg San Andres Unit (EVGSAU), in the eastern side of the Vacuum Field, approximately fifteen miles northwest of Hobbs, New Mexico. The Vacuum Field was discovered in 1929 by Socony Vacuum Oil Company's Bridges State Well No. 1. Primary development of the field began ten years later and was completed by 1941 with the drilling of 330 producing wells. EVGSAU was unitized in December 1978. The initial waterflood was developed on an 80-acre inverted nine-spot pattern and commenced in early 1979. Oil production reached its peak of 15,500 BOPD in 1983. Tertiary CO_2 injection commenced at EVGSAU in September 1985.[2]

EVGSAU produces from both the Grayburg and San Andres intervals at an average depth of 4400 feet. Reservoir temperature is 101 degrees F and the average reservoir pressure is 2000 psig. Oil gravity is 38 degrees API with an original solution GOR of 465 SCF/STB. Average net pay interval is 71 feet. Corrosion is considered moderate to heavy due to high concentrations of H_2S and CO_2. Of the 209 wells currently in operation, 140 are equipped with beam units, 49 produce with submersible pumps, 13 utilize an ULSPS, 2 have plunger lifts and five are naturally flowing.

Description of Previous Lift Systems

Under primary recovery, beam pumping units were sufficient for keeping the wells pumped-off and producing efficiently. However, as the waterflood response began, many wells were switched to electrical submersible pumps (ESP) to take advantage of higher production potential and to lift increased water volumes.

A previous (1987) study of EVGSAU indicated that wells with producing capacities of less than 500 BFPD were more economically lifted with conventional beam pumping units.[3] Since more than one-third of the Unit wells were capable of producing in excess of 500 BFPD, an extensive submersible pump program was initiated in 1982. All submersible pumps were equipped with non-ferretic steel bodies with monel bolts for corrosion protection from the highly corrosive H_2S/CO_2 environment. A majority of the pumps were equipped with variable speed drives which enabled them to operate efficiently at various frequencies. All downhole submersible pumps are equipped with rotary gas separators to increase pump efficiency. These separators allow the pumps to be efficient up to a gas/oil ratio of approximately 500 cf/bbl.

Increased lease operating expenses resulted from the installation of ESP. As CO2 breakthrough occurred, the resulting increase in GLR caused significant gas interference and/or gas locking problems with the ESP's. Also, an increase in calcium sulfate scaling problems occurred along with gas breakthrough. As a result lower cost pumping systems were desired.

Rod pumping systems have performed well, however very few large units (640 or larger) are available at EVGSAU. New units were not purchased when the waterflood was implemented. Thus most are very old and small (320 or smaller) units running at maximum capacity. Because of the desire to lower overall lifting costs and to utilize new technology, other lift methods were investigated. Gas lift was attempted on two wells, however, this method put a greater load on the gas recompression facility. Even the unconventional option of using a progressive cavity pump in a CO_2 environment was attempted. This system failed miserably as CO_2 swelled the stator elements and iron sulfide caused sticking problems.

The New System: ULSPS

With the recent development and refinement of ultra long stroke pumping systems, a field trial was initiated at EVGSAU in May, 1993. These systems are available with surface stroke lengths of 288" and 306" versus 168" and 192" for a 912 unit. Stroke length is obtained without the increased gearbox size required by beam pumping units. This is accomplished by transmitting rotary motion from a 228 or 320 M in-lb gearbox to a 36" chain sprocket, resulting in an 18" torque arm. The continuous rotational movement of the sprocket drives an enclosed chain tied directly to a mechanical reversing mechanism. The reversing mechanism has a totally enclosed, built-in counterweight box. Articulating pumping motion is created by connecting a shock-absorbing load belt between the combination reversing mechanism counterweight box and the polish rod. Figure 1 illustrates one of the available models.

Large conventional beam units could have been purchased, but because of the above configuration, the ULSPS, in theory, were chosen to optimize operations for three reasons. These are: 1) less rod cycles occur because of the slow, long stroke, thus yielding longer rod and pump life; 2) predictive models indicated that less electricity would be used; and 3) using 'KD' rods as a limiting factor, predictive models indicated that more production capacity would be obtainable .

An economic comparison was performed to compare the benefits of using a ULSPS versus a submersible pump. The primary focus was to lower the routine repair and maintenance cost associated with the frequent ESP failures. Although, the new ULSPS had higher initial investment cost, it was believed that these costs could be more than offset by elimination of the expensive ESP failure workovers. Electrical savings, if experienced, were not accounted for in the initial economics. Table 1 shows the economics used to justify the initial ULSPS installations.

Results of Field Installations

Over a three year period, thirteen wells at EVGSAU have employed the application of ULSPSs. The failure frequency on the ULSPSs averaged .56 failures per well per year, matching that of the average beam lift well in the field. Newly drilled wells accounted for the bulk of the ULSPS failures. Trash was directly responsible for five failures. It is assumed that other "worn pumps" were also caused by similar debris. Six (46%) of the thirteen ULSPS wells experienced no failures during the test period. In comparison, the overall failure rate of all submersible pumps was .71 failures per well per year, however, the failure rate for certain problem wells which experience cycling and scale problems can be over 2.0. This data is contained in Tables 2 and 3. These "problem wells" were the primary target of the initial installations.

Monthly electrical costs data for the ULSPSs were compared with those for 50, 60 and 75-120 horsepower (HP) submersible pumps. Graphical representations of the electrical cost comparisons are shown in Figures 2 through 4.

Despite extremely low gearbox loading, 27% to 67%, the ULSPSs were still more cost effective on a monthly basis in the 300-700 BFPD range than the equivalent 50 and 60 HP ESP applications. Monthly electrical costs for ULSPSs range from $500 to $850/month, as compared to $1200 to $1800/month for 50 HP ESPs, and $800 to $2200/month for 60 HP ESPs. Although higher savings opportunities exist, ULSPSs, to date, have not been utilized for replacing 75-120 HP ESPs. To lift the high fluid volumes of larger ESP's requires the use of high strenght rods. Because of the corrosive CO_2/H_2S environment, vendors have not recommended their use at EVGSAU. Alternatively, to lift high fluid volumes would require large casing sizes and/or bottlenecking the pumps, neither of which were desired during the initial test phase. However, based on the good ULSPS performance, the use of ULSPSs is being planned for the higher volume wells at this time. The actual electrical cost reduction associated with replacing an ESP with an ULSPS for one EVGSAU well is shown in Figure 5. Other wells experienced the same trend.

Average input KWhr/BBL/1000 ft of net lift on the thirteen ULSPS wells (average production of 469 BFPD) was .24, while both the 50 HP ESPs (average production of 495 BFPD) and the 60 HP ESPs (average production of 544 BFPD) had .50 KWhr/BBL/1000 ft of net lift for their average. Hence, electrical costs were reduced by approximately 50% through the use of ULSPSs. This is illustrated in Figure 6.

Based on the above data, the original economics have been rerun using electrical cost savings. Low and high case sensitivities of $300/mo. and $1000/mo. of electrical savings were run. Referring to Table 4, the current economics show the return rate to be 35%-120% higher than the original justification. This evaluation is still conservative because both systems are assigned the same failure rate of 0.5 failures/year. As previously shown, actual failure rate of the ESP's is 0.71 or approximately 27% higher than the 0.56 rate of the ULSPS.

Testing of Modified NEMA C motor

More recently, in an attempt to further optimize the ULSPSs, two of the thirteen wells were selected to test specially modified NEMA C motors. Before implementing the installations, both of the selected wells were analyzed by the Nabla Corporation to determine overall system efficiency on the existing NEMA D motors to ensure the accuracy of the test. Once the data was obtained on the NEMA D motors, the same wells were equipped with modified NEMA C motors.

After allowing the wells to re-stabilize, identical tests were run to compare the two motors. In one of the two tests, the well conditions changed so rapidly that a conclusive test could not be run. However, it appeared that the modified NEMA C motor yielded a 4%-5% increase in overall system efficiency over the NEMA D motor. Further testing is planned in an effort to quantify benefits of the modified NEMA C motor.

Conclusions

1. ULSPS can economically replace submersible pumps, especially in a CO2 flood where gas interference and scaling problems are more pronounced.
2. The failure frequency on the ULSPSs matched that of the average beam pumping unit, while it is slightly less than that of the average ESP by .15 failures per well per year.
3. ULSPS failures in the pilot test wells could be either directly or indirectly linked to debris occurring in new wells. The five older wells experienced no failures during the test period.
4. Electrical costs for ULSPSs averaged $680/month, while those for 50 HP ESPs averaged $1469/month and those for 60 HP ESPs averaged $1667/month. Electrical costs for ULSPSs could not be compared with those of the 75-120 HP ESPs due to rod limitations in CO_2 /H_2S environments.
5. Input KWhr/BBL/1000 foot of net lift was reduced by approximately 50% with the application of ULSPS technology
6. Data from the EVGSAU thirteen well pilot test has provided strong evidence to support the rationalization regarding the use of long, slow stroke units in high volume lift applications.

Nomenclature

BFPD	=	*barrels total fluid per day*
Kwh	=	*kilowatt-hour*
HP	=	*horsepower*
BBL	=	*barrel*
M in-lb	=	*Thousand inch-pounds*
NEMA	=	*National Electrical Manufacturer's Association*

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References

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2. Harpole, K.J. and Hallenbeck, L.D.: "East Vacuum Grayburg San Andres Unit CO_2 Flood Ten Year Performance Review; Evolution of a Reservoir Management Strategy and Results of WAG Optimization", paper SPE 36710 presented at the 1996 Annual SPE Technical Conference and Exhibition, Denver, Colorado, Oct. 3-6.
3. Brownlee, M.H. and Sugg, L.A.: "East Vacuum Grayburg San Andres Unit CO2 Injection Project: Development and Results to Date", paper SPE 16721 presented at the 1987 Annual Technical Conference and Exhibition, Dallas, Sept. 27-30.

Table 1
Pre-Installation Economic Justification

Economics to replace a cycling sub pump with a ULSPS

AARR:	24.5%
NPV:	$27,500
Payout:	4.0 yrs
PI:	1.8

Premises:
- $35,000 higher initial investment, w/ $15,000 higher salvage value
- 20 year project life
- 2 year run life for both systems (0.5 failure rate)
- Failure / workover cost for sub pump $22,000/failure event
- Failure / workover cost for ULSPS $2,000/failure event
- No electrical savings

Table 2
ULSPS Well Data

Well Name	Type	Lift Specs SPMSL-Pump	%Gear Box Loading	Polish Rod HP	Pump Eff	Depth ft	System Eff	KWH Per Day	BBL/ DAY	KWh/BBL/month per net ft lift	Failures	Failures/ Year
2648-004	800-300-288	4.3-288-2.25	49%	20.6	46%	4679	39%	619	364	0.36	0	0.00
2739-003	800-300-288	4-288-2.25	-	-	-	4100	-	606	484	0.31	1	0.83
3333-003	800-300-288	3.5-288-2.25	61%	15.6	48%	4500	33%	405	333	0.27	1	1.00
2648-126	800-300-288	4-288-2.25	62%	28.9	94%	4644	39%	474	396	0.26	0	0.00
3440-005	800-300-288	4.31-288-2.25	64%	31.4	76%	4694	41%	598	519	0.25	4	1.08
3202-015	900-360-288	4.4-291-2.25	40%	23.2	60%	4586	45%	527	452	0.25	0	0.00
3308-002	800-300-288	3.5-288-2.25	50%	19.2	68%	4550	49%	416	391	0.23	1	0.56
3308-007	900-360-288	3.7-291-2.25	37%	21.7	94%	4330	52%	475	485	0.23	3	1.58
3440-007	900-360-288	3.92-291-2.25	45%	26.8	49%	4617	33%	504	425	0.26	0	0.00
3236-012	800-300-288	3.74-288 2.25	47%	19.4	102%	4550	92%	455	568	0.18	0	0.00
2631-022	900-360-288	3.72-291-2.75	27%	13.9	56%	3960	45%	533	665	0.20	2	1.18
3456-013	800-300-288	3.83-288-2.25	43%	17.5	91%	4161	59%	403	594	0.16	0	0.00
3308-006	800-300-288	3.62-288-1.75	42%	12.6	92%	4684	43%	459	415	0.24	3	1.00
										Average Failures/Year		0.56

Table 3
ESP Well Data
Submersible Pump Well Data

	CURRENT EQUIPMENT												
	MOTOR	MOTOR		PUMP			CABLE		CONTROL	CURRENT	PREVIOUS	FAIL-	FAILURES/
WELL	SERIES	HP	V / A	SERIES	TYPE	STAGES	TYPE	LENGTH	SWB/VSD	INSTALL	INSTALL	URES	YEAR
2230-001	450	60	1270/30	400	FC650	148	4 RD	4700	VSD	3/18/96	1/20/94	4	0.89
2622-002	450	120	2080/37	400	M34	245	4 RD	4300	VSD	8/6/96	3/24/93	3	0.68
2622-034	450	50	1200/27	400	FC650	171	4 RD	4045	VSD	5/18/96	10/8/93	5	1.43
2631-110	375	76	1110/52	338	DC800	307	4 RD	4400	VSD	3/17/94	2/7/92	2	0.43
2648-001	456	75	1345/35	400	D950	229	4 RD	4600	SB	9/30/94	2/22/94	4	0.98
2648-023	450	60	1025/38	400	FS950	142	4 RD	4500	VSD	6/28/93		1	0.30
2658-001	450	60	1270/30	400	FC650	143	4 RD	4500	VSD	6/6/96	9/28/94	3	0.91
2658-011	450	60	1250/31	400	FC925	237	4 RD	3900	VSD	7/23/96	1/15/96	5	1.47
2717-004	450	90	2100/22	400	FC1200	209	4 RD	4400	VSD	6/23/95	12/15/94	3	0.68
2721-020	450	50	1200/27	400	B11	220	6 RD	3900	VSD	8/6/96	3/6/92	4	0.62
2721-388	450	60	1250/31	400	FC650	184	4 RD	4600	VSD	11/17/95		1	1.11
2738-003	450	40	965/27	400	DN400	205	4 RD	4500	SB	11/27/95	4/5/94	3	0.77
2739-002	450	48	1000/31	400	W18	188	4 RD	4500	VSD	2/27/95	3/15/94	3	0.75
2739-006	450	100	2080/31	400	FC925	214	4 RD	4200	VSD	3/6/96	5/13/91	3	0.56
2739-007	450	48	1000/31	400	FC650	171	4 RD	4500	VSD	4/28/95	8/4/93	3	0.56
2801-010	450	48	1000/31	400	B11	305	4 RD	4100	VSD	10/17/94	12/10/90	4	0.68
2963-002	456	50	1355/23	400	DN610	172	4 RD	4200	VSD	7/9/96	4/10/96	4	1.03
3127-001	375	55	1265/33	338	DC800	333	4 RD	4200	VSD	6/14/96	7/11/91	4	0.53
3127-008	450	60	1250/31	400	FC650	171	4 RD	4500	VSD	6/18/96	3/12/90	4	0.49
3127-009	450	50	1200/27	400	DN800	191	4 RD	3900	VSD	1/24/96	10/22/93	4	0.69
3202-001	450	60	1270/30	400	FC650	148	4 RD	4700	VSD	7/15/96	5/15/92	4	0.60
3202-006	456	63	1120/34	400	DN800	172	6 RD	4200	SB	5/26/95	10/8/90	2	0.33
3229-001	375	50	1260/30	338	AN900	283	6 RD	4000	VSD	11/5/93	10/15/93	2	0.67
3229-004	450	60	1250/31	400	FC650	143	4 RD	4000	VSD	9/10/95	7/11/92	4	0.93
3229-005	450	50	1200/27	400	W18	188	4 RD	4200	VSD	10/17/95	4/24/95	4	0.75
3229-009	450	48	1000/31	400	FC650	163	4 RD	4500	VSD	6/10/92	3/26/85	2	0.17
3229-010	450	60	1155/35	400	FC650	171	4 RD	9000	VSD	9/9/93	4/6/93	3	0.56
3236-004	456	62.5	1350/29	400	DN610	172	4 RD	4700	VSD	1/24/94	2/6/92	3	0.56
3308-003	450	42	980/28	400	FS400	225	6 RD	4500	VSD	5/31/95	9/8/93	3	0.81
3236-009	450	48	1000/31	400	FS400	246	4 RD	4500	VSD	1/31/95	5/21/94	3	0.83
3308-004	450	60	1250/31	400	FC650	184	6 RD	4300	SB	5/10/94	6/3/92	2	0.47
3315-002	450	100	2080/31	400	H27	357	6 RD	4000	VSD	7/30/93	1/25/91	3	0.35
3328-002	450	120	2080/37	400	M34	245	4 RD	4500	VSD	5/18/93	12/20/90	2	0.34
3315-004	375	51	740/51	338	AN900	279	4 FL	4400	VSD	7/7/94	1/6/90	3	0.30
3333-001	450	63	1200/33	400	DN800	172	4 RD	4000	VSD	8/11/94	9/23/87	2	0.22
3315-005	456	50	1355/23	400	DN800	172	6 RD	4600	VSD	10/12/94	5/3/91	3	0.44
3333-004	450	31	910/22	400	D400	204	4 RD	4550	SB	2/18/94	2/4/92	3	0.45
3333-007	450	48	1000/31	400	FS650	143	4 RD	4350	VSD	12/7/95	1/29/91	3	0.52
3345-035	450	50	1200/27	400	FC650	143	4 RD	4000	VSD	4/24/95	7/20/94	3	0.79
3440-001	375	43	685/48	338	DC800	231	4 FL	4200	VSD	1/2/94	3/18/93	3	0.50
3440-002	450	60	1250/31	400	FC925	258	4 RD	4250	VSD	3/28/96	3/15/96	5	2.27
3456-010	450	120	2080/37	400	FC2200	175	4 RD	4800	VSD	8/24/95	9/21/94	4	1.21
3467-121	450	48	1000/31	400	FC650	163	4 RD	4500	VSD	12/28/95	9/23/93	3	0.73
3467-024	450	72	1310/36	400	FC1200	156	6 RD	4200	VSD	1/3/94	7/1/93	3	0.86
										Average Failures/Year			**0.71**

Table 4
Post-Installation

Economics to replace a cycling sub pump with a ULSPS, including Electrical Savings

	LOW CASE: $300/mo.	**HIGH CASE: $1000/mo.**
AARR:	33.1%	54.0%
NPV:	$48,500	$97,500
Payout:	3.4 yrs	2.2 yrs.
PI:	2.4	3.8

Premises:
- $35,000 higher initial investment, w/ $15,000 higher salvage value
- 20 year project life
- 2 year run life for both systems (0.5 failure rate)
- Failure / workover cost for sub pump $22,000/failure event
- Failure / workover cost for ULSPS $2,000/failure event

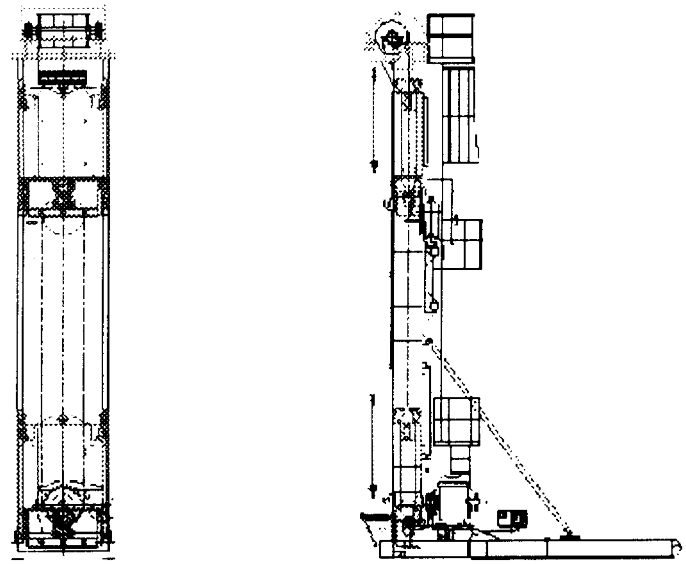

Figure 1 - ULSPS Front View and Side View

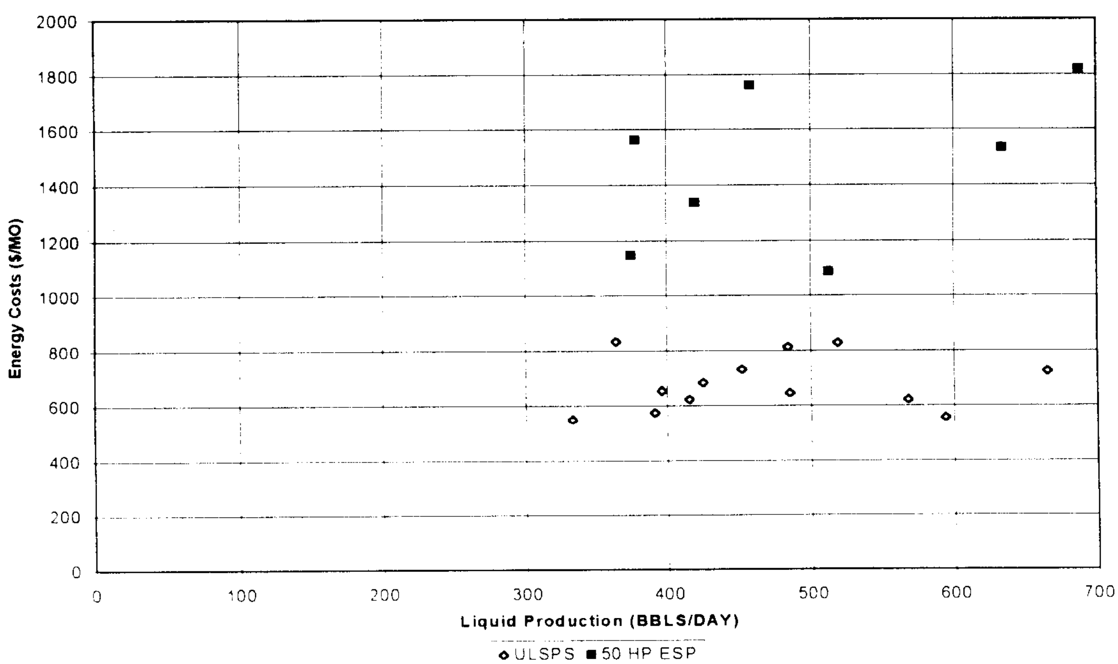

Figure 2 - Electrical Costs - ULSPS vs. 50 HP ESP

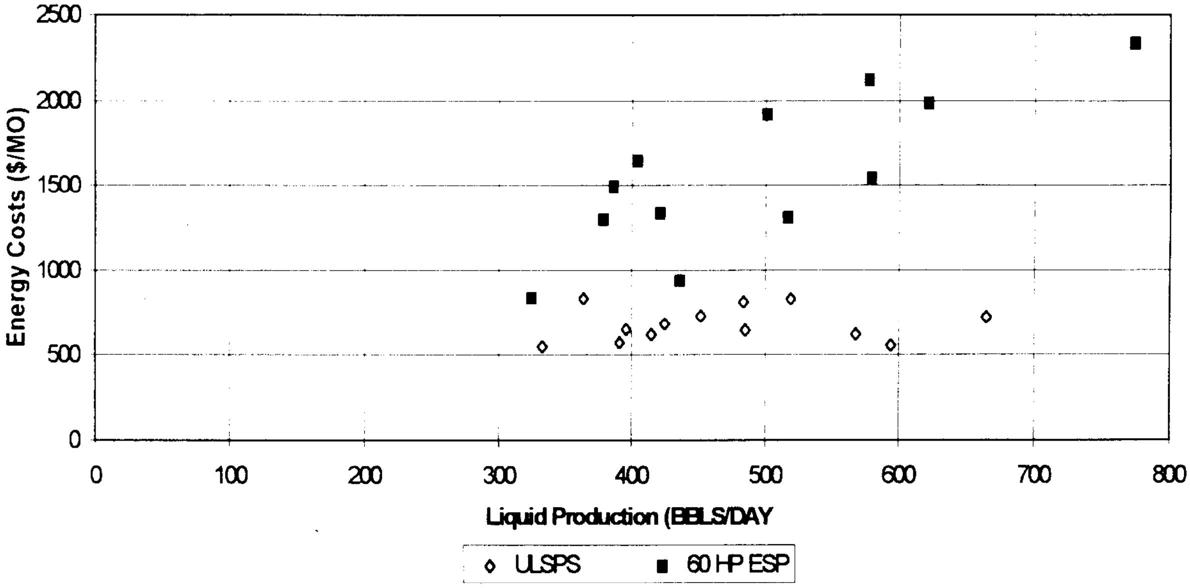

Figure 3 - Electrical Costs - ULSPS vs. 60 HP ESP

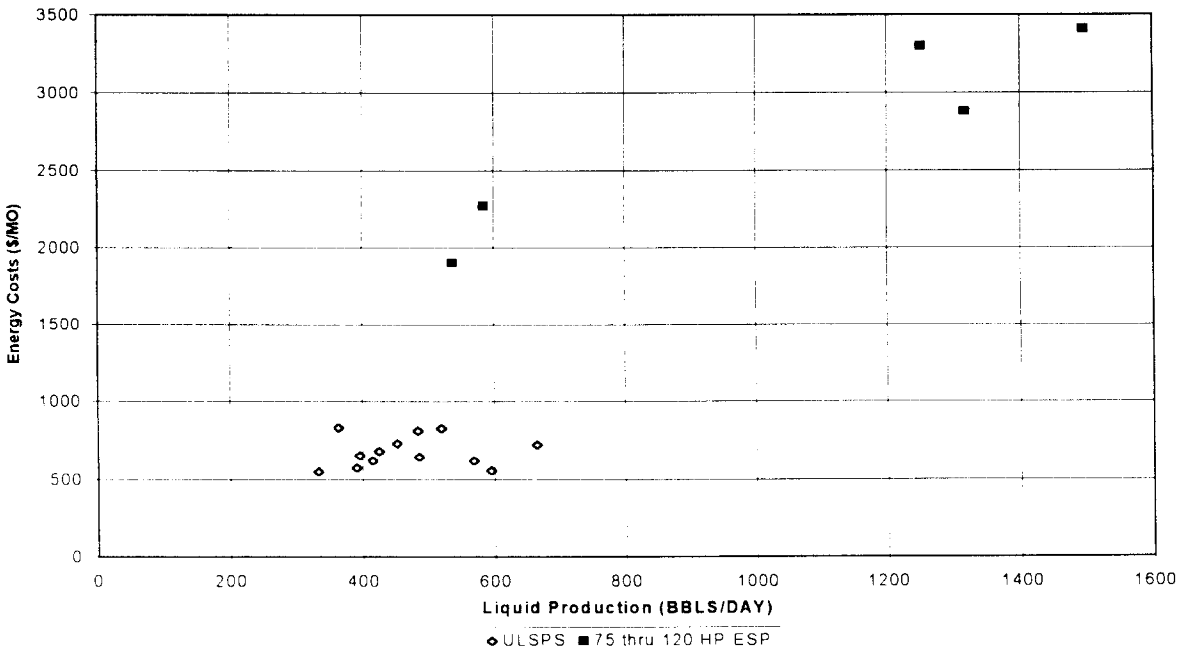

Figure 4 - Electrical Costs - ULSPS vs. 75-120 HP ESP

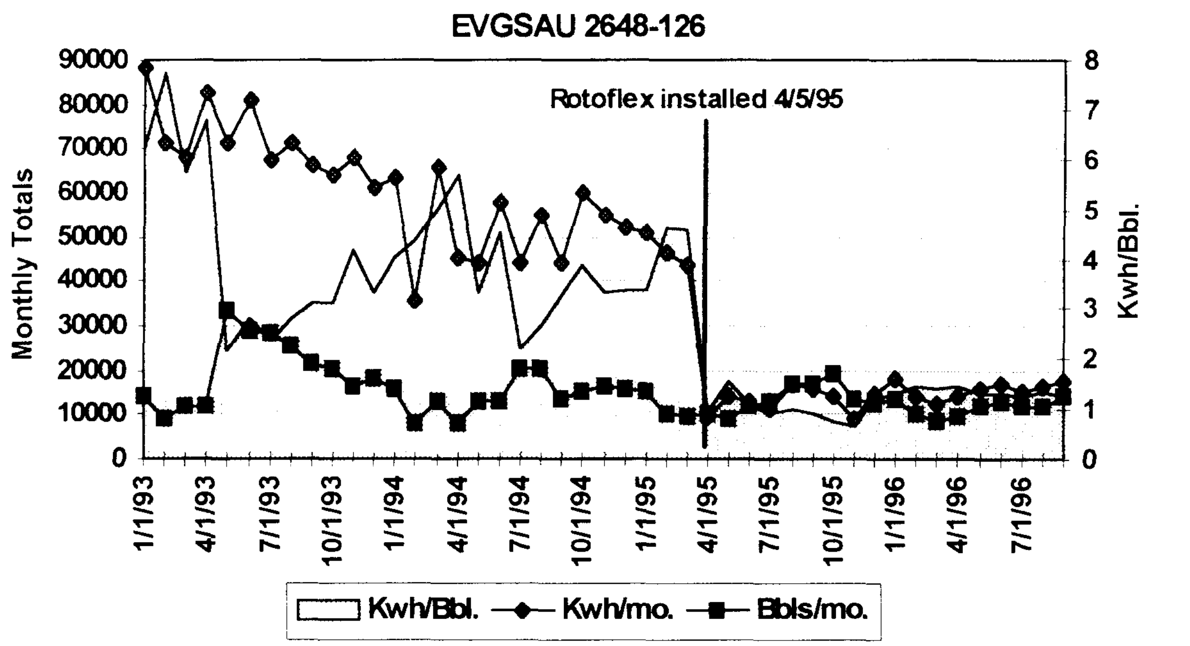

Figure 5 - Electrical Usage History - Pre vs. Post ULSPS Installation

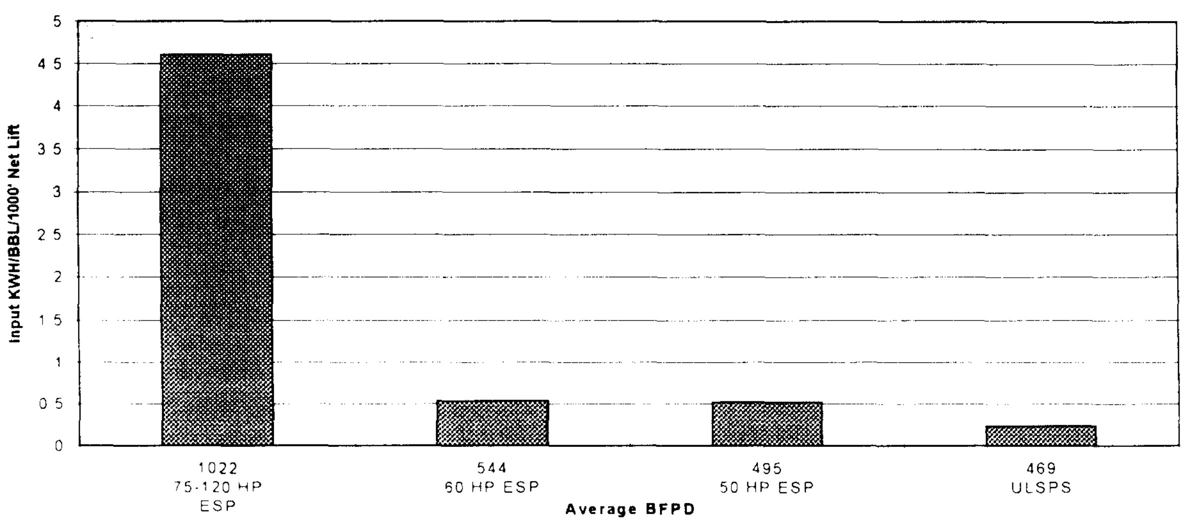

Figure 6 - ULSPS Comparison with ESPs