OPERATING AND PERFORMANCE EXPERIENCE WITH A COMPUTER-CONTROLLED LONG STROKE ROD PUMPING SYSTEM

HOWARD C. TAIT
NATIONAL PRODUCTION SYSTEMS
NATIONAL SUPPLY COMPANY-ARMCO INC.

ABSTRACT

Dramatic change in the economic climate of the petroleum industry over the past year places a demanding challenge on oil producers to achieve positive cost effectiveness in their producing operations. Overall lifting costs for artificially lifted wells will be a significant factor in meeting this challenge.

A new long stroke sucker rod pumping system has been developed which offers benefits to deal with these cost factors. Performance results to date confirm reduced energy consumption and improved pumping performance.

INTRODUCTION

During the past ten years oil producers woldwide have come through a period of unprecidented escalation of revenues received for their produced oil. This led to our greatest boom ever during 1981, and dramatically changed the economics of finding and producing oil.

In the producing segment of the industry, this boom resulted in an all out effort to get wells on production. Not only new completions, but a high rate of marginal and abandoned wells were brought on. With higher crude prices, the costs of these producing operations were not nearly as burdensome as under the tight price control of the past. The incentive to put the well on artificial lift to increase its producing rate became very high.

Following the traditional pattern, more of these wells were equipped with sucker rod pumping systems than any other lift method. Industry statistics report more than 33,000 wells were outfitted with rod pumping equipment in 1981, a fifty percent increase over 1980. This brought the total of U.S. wells on this lift method to the 500,000 level.

1982 brought dramatic change in the economic climate which had been established. Leveling and some downturn of crude prices brought on great uncertainty as to future price behavior. By January 1983 very strong possibility existed for rapid deflation in crude revenues available to support producing operations.

This places a new challenge on oil producers to achieve a high level of cost effectiveness in all of their producing operations. Artificially lifted wells must be operated at peak performance to accomplish this in the face of probable continued increases in operating costs. Energy costs alone show high potential for further escalation beyond the already high levels.

Assistance in meeting this requirement may come from a development program undertaken by a production systems manufacturer more than three years ago.This project had as its broad objective the development of a lift system design capable of improved overall performance of the pumping operation.

Achievement of this objective would translate into reduced operating costs for pumping the well, measured in terms of cost per barrel of fluid lifted. Acknowledging the broad acceptance and proven benefits of the rod pumping method of lift, the project was directed to restudy this method as a complete system, seeking improvement in all components of the system. Application techniques were also required to assure proper selection of components to assure maximum cost effectiveness from the installation.

The product of this development program is identified as the National LIFTRONIC Pumping System. Installations are now in operation on producing oilwells, and are proving to offer measurable reduction in overall lifting costs. In addition, production results indicate possible improvement in well performance as a result of the improved stroking motion of this pumping system. A typical installation of this new system is shown in Figure 1.

SYSTEM DESIGN CONCEPTS

In defining this development project, three major areas were identified for design consideration. First, a means of improving downhole pumping efficiency. Second, a mechanical design which would assure maximum operating efficiency of the system. And third, an operating control system capable of maintaining optimum performance throughout the stroking cycles of the system.

Pumping Efficiency

A long stroke pumping action, operating at a low cycle rate, was identified as most beneficial for improved downhole efficiency. A minimum stroke length of thirty feet, operating in the three stroke per minute range, was selected for the design. This stroking motion contributes to improved volumetric efficiency in the pump through higher compression ratio and fewer valve actions. The low cycle rate reduces wear rate and dynamic loading on all downhole components.

Mechanical Design

To further contribute to high operating efficiency, the mechanical design called for simplicity, with the most direct drive mechanism possible to transmit stroking power to the rod string. Uniform counterbalance effect throughout the stroke was also desirable for efficient operation. The resulting design met these criteria and provided an extremly compact machine which offered additional installation advantages.

Operating Control

The concept for the operating control was to constantly monitor operating parameters which influence overall performance, with the ability to be responsive to changing conditions to maintain optimum performance. A microprocessor based electronic control system was selected to provide this capability.

EQUIPMENT DESCRIPTION AND OPERATION

Figure 2 schematically illustrates the installation arrangement of surface and subsurface equipment for the LIFTRONIC system. Major components include the pumping unit, an operating control, and the subsurface well equipment.

This equipment and its operation has been decribed in published literature, however a review here is appropriate for discussion of its potential application and operating benefits.

Pumping Unit

The pumping unit for this system is a fully enclosed machine containing two contoured drums (cams) mounted on a common shaft, two load carrying chains (well and counterweight), and two chain idlers. A double reduction planetary gear reducer is externally mounted on the housing. A fail-safe brake mounts on the gear reducer. Power is transmitted from an electric motor to the gear reducer through a belt drive.

The use of high strength chains to carry the well and counterweight loads accounts for the extremely compact design of the pumping unit. To achieve a low profile installation, the counterweights are suspended in a fifty foot deep cased hole adjacent to the well. The complete pumping unit mounts directly on the well and counterweight holes.

In operation, the load carrying chains are wrapped and unwrapped on the contoured cams to effect the stroking motion. During the upstroke, with the cam rotating in a clockwise direction (Figure 2), the wellside chain wraps upon itself to smoothly increase the working diameter on the cam, reaching maximum dimension at the top stroke reversal.

Meanwhile, as the wellside chain wraps itself to maximum working diameter, the counterweight chain unwraps to lower the counterweights, until no chain remains wrapped on the cam at the top reversal.

At the optimum point in the stroke reversal, as determined by the microprocessor in the operating control, motor power is shut off. This permits cam rotation to respond to the applied loads of the system. The imbalance of these loads resulting from differences in the working radii (moment arms), brings about the stroke reversal. Again under control of the microprocessor, motor power is reapplied to complete the downstroke.

Figure 3 shows the unit with the cover removed to illustrate the difference in working radii of the chains at the top reversal. A similar but reverse imbalance of loads occurs at the bottom stroke reversal.

Operating Control

The Liftronic operating control is a modular solid-state electronic panel mounted in a weather-tight enclosure. It provides all manual and automatic control of the operation of the Liftronic pumping unit. The modular construction of this control panel facilitates servicing by module replacement, as opposed to electronic ciruit troubleshooting.

A computer module, operating in conjunction with the other control modules within the panel, provides "intelligence" to the control system to perform the following functions:

1. Control motor power during stroke reversals.
2. Monitor operating parameters and automatically shutdown the unit if a potentially hazardous condition develops.
3. Automatically restart the unit if the condition clears.

4. Shutdown the unit in event of a "pump-off" condition, and restart following an adjustable "off-time".
5. Feed output data to an XY plotter for dynamometer card print-out.

Motor Control

As the pumping unit nears the end of either the upstroke or downstroke, the control senses stroke position plus other operating parameters, and shuts off motor power through solid state circuitry to begin the stroke reversal. While power is off, motor polarity is reversed through contactors within the control panel. When the motor reaches the syncronous speed range in the reversed direction, power is reapplied through a low voltage control. This sequence assures smooth reversals and minimizes current and torque spikes when power is applied.

Shut-down/Restart

Automatic shut-down ocurrs when the control senses any of several programmed operating problems. These include: excessive motor temperature, overload or overspeed; exceeded limits of polished rod travel; loss of pressure at the fail-safe brake; power supply problems; or computer module malfunction sensed during constant interrogation of this device. These safety controls protect the equipment against damage as a result of such well problems as sucker rod parts or a stuck pump, as well as mechanical problems within the pumping unit.

When automatic shut-down does occur, the computer identifies the cause to determine if a restart can safely be attempted. If not, the brake is set and a warning beacon on the control panel is lighted. If safe restart is indicated, a programmed procedure is initiated to restart the unit. If this is not accomplished after several attempts, the brake is set and the beacon lighted.

A digital display on the control panel indicates the operating mode of the unit during the stroking cycle. In the event of shut-down, this display shows an "error code" to identify the cause of shut-down. The operator may identify the time, cause and operating conditions at the shut-down through a download procedure which displays operating data stored in the computer memory.

Pump-off Control

The integral pump-off control system senses operating parameters during the critical portion of the top reversal and beginning of the downstroke to identify indication of a pumped-off or fluid pound condition at the downhole pump. When this indication is repeated on successive strokes, the unit is shut down. It remains off for an adjustable "off-time" period, as set by the operator, and is then automatically restarted by the control.

When a pump-off shutdown occurs, the digital display shows the time remaining of the programmed "off-time" in minutes and seconds.

Dynamometer

Plug-in terminals on the control panel accept connecting jacks from an XY plotter for local print-out of an operating dynamometer card. With "position" plotted on the X axis, three values can selectively be plotted on the Y axis; polished rod load as measured by a load cell integrally mounted in the pumping unit, motor speed in RPM, and motor current in AMPS. A future option will also permit transmission of these data to a remote read-out point.

Well Equipment

To accommodate the low-profile installation of the pumping unit, a replacement for the conventional stuffing box is required. The "wellhead seal assembly" developed for this application is installed on the wellhead and extends approximately forty feet into the well (Figure 2). The tubing string is suspended on the outer jacket of this assembly. The sucker rod string is attached to the polished rod in the assembly.

A dual seal arrangement is provided in the assembly to assure reliable containment of well fluids within the flow stream. A stationary seal at the lower end of the assembly packs-off against the traveling polished rod. A piston provides transition from the well-side chain to the polished rod and, as well, carries resilient seals which travel within a polished tube. Both seals are spring-loaded and self-adjusting for sealing reliability. Automatic purging of any leakage above the stationary seal is accomplished by the stroking piston to contain leakage within the flow stream. Fluid flow from the tubing moves up the annular area between the polished tube and outer jacket to the flow line connection.

Conventional steel or fiberglass sucker rods may be used. API insert or tubing type pumps are adaptable to the long stroke application, or special configurations or accessories may be used to achieve maximum pump performance.

APPLICATION

The application range for the current LIFTRONIC model generally fits well conditions requiring an API 228 or API 320 beam pumping unit, however broader pumping conditions may be suitable for this size system. Operating installations have replaced beam units from API 160 to API 456 sizes. A prototype unit of a larger model, about double the capacity of the original, is now producing a well previously equipped with an electric submersible pumping system.

A computer application design program has been developed for the system in conjunction with the NABLA Corporation. In addition to providing application design, this also permits analysis of predicted performance of the new system as compared to other methods of lift.

Table 1 identifies basic specifications for the current model. Table 2 tabulates nominal pump displacements and depth limits for various pump bores at a range of pumping speeds.

Planned development of this new lift system includes one smaller size, and two higher capacity sizes. The objective will be to cover the broadest possible range of pumping conditions, from moderate to high volume lifting requirements, and depths to the limits of sucker rod capacity.

The operating characteristics of this new lift system offer performance and operating cost benefits for virtually all well conditions within its capacity which are suitable for lift by the sucker rod pumping method. These range from wells which present no specific pumping problems, to those troubled by gas interference, heavy crude, or a variety of special requirements associated with enhanced recovery operations.

In all of these applications, a key benefit of this new system is the potentially significant saving in energy consumed in the lifting operation, translating directly to reduced operating costs. This energy reduction has been measured as high as 25% for the new system compared to the beam pumping system it replaced. Savings of 15% appear to be a realistic expectation. Added to this is the anticipated improvement in pumping performance and longer service life from the well equipment.

The most obvious application benefit of this lift system relates to the extremely compact configuration of the surface equipment. This makes rod pumping a suitable selection for locations on which this lift method has been excluded due to the physical size of the beam unit. Figure 4 illustrates this size comparison. On urban sites, the LIFTRONIC installation could be made more aesthetically acceptable simply by enclosing the equipment within a six foot high screening fence. The fully enclosed pumping unit, having no exposed moving parts adds to its attractiveness for these locations.

Multiple well locations having restricted surface space would also benefit from the compact pumping unit design. The entire unit has maximum overall dimensions of 3 feet wide by 7.5 feet long. The 4000 pound pumping unit weight adds to the size benefit for offshore platform application.

Locations having defined height limitations may also be served by this lift system. Installed overall height of the pumping unit is under 8 feet, making it suitable for application under most overhead irrigation systems.

OPERATING RESULTS

Following prototype testing on a well during 1980, the current model was first installed on a Los Angeles Basin well in April 1981. This continues in operation, serving as a valuable engineering development installation. During this period, the well's production has been brought from 100% water to 15 BPD net oil with 460 BPD gross fluid.

Other operating installations of the LIFTRONIC system are producing wells ranging from steam cycled heavy crude in Alberta, Canada, unheated heavy crude in the San Joaquin Valley, California, and light crude, high water cut production in the Los Angeles Basin.

Performance Comparison

Comparison of performance of two installations in California on which conventional beam pumping systems were replaced by the LIFTRONIC System are shown in Tables 3 and 4. Data gathered from both operating systems permits performance comparison in terms of power consumption per barrel of fluid lifted (KWH/BBL). This is further converted to power cost per barrel at local power rates. In addition, production results may be used to compare pumping performance.

Well A (Table 3) is producing from a light gravity crude zone at 4200 feet. Net oil production was increased from zero with the ten foot stroke beam unit to an average of 15 BPD operating with the thirty foot stroke LIFTRONIC. Power consumption has been reduced by 25.9% per barrel of gross fluid lifted. Power cost represents 7.5% of produced oil revenue at 32 dollars per barrel.

The uniform shape of the LIFTRONIC dynamometer card, as compared to that produced by the beam system, verifies the optimized efficiency of the

LIFTRONIC pumping unit design. This is the net result of the desirable stroking motion established by the new pumping unit.

Well B (Table 4) is producing 14°API heavy crude from a zone at 2400 feet. During operation under the LIFTRONIC system, net oil production has been doubled over the previous rate with only a six percent increase in average gross production. Power consumption has been reduced by 20.7% per gross fluid barrel lifted. This power saving, combined with increased net oil production has reduced power cost as a percent of oil revenue ($20 per barrel) from 17% to 7%.

The LIFTRONIC dynamometer card from this well illustrates a pumped-off condition.

CONCLUSIONS

1. Experience to date with operating installations of the LIFTRONIC Pumping System has demonstrated that performance characteristics of the system are meeting the original design objectives of the development project.

2. Measurable reductions in power consumption have been recorded. Production records indicate improved downhole pumping performance in steam enhanced production, unheated heavy crude and light oil production. Installations in environmentally sensitive areas are being considered.

3. Additional operating experience is required to further verify these results and to more fully evaluate long-term reliability and service life of the equipment in the system.

4. The performance and installation benefits of the LIFTRONIC system appear to warrant further evaluation by California operators.

REFERENCES

1. Moore, S. D.: "Well Servicing Expenditures Top The $4-Billion Mark," PETROLEUM ENGINEERING INTERNATIONAL, (July, 1982) 29-36.

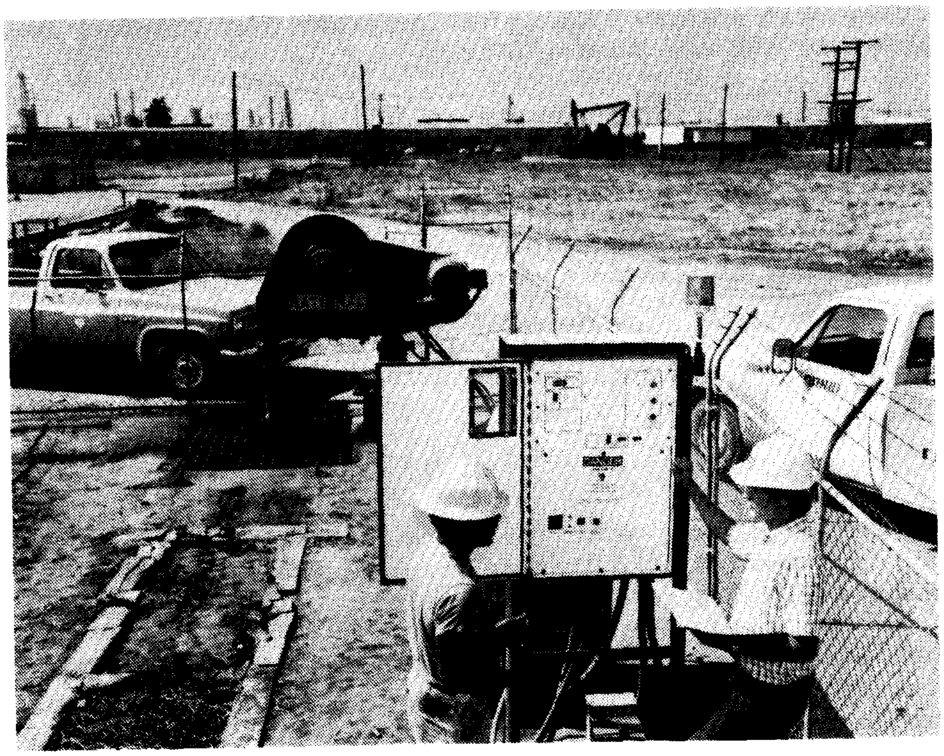


FIGURE 1 — TYPICAL LIFTRONIC INSTALLATION

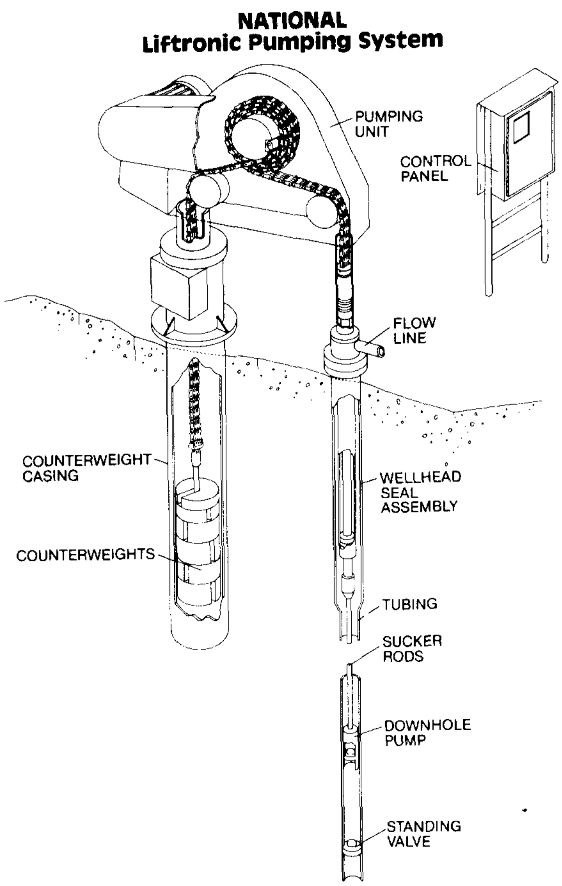


FIGURE 2 — INSTALLATION ARRANGEMENT

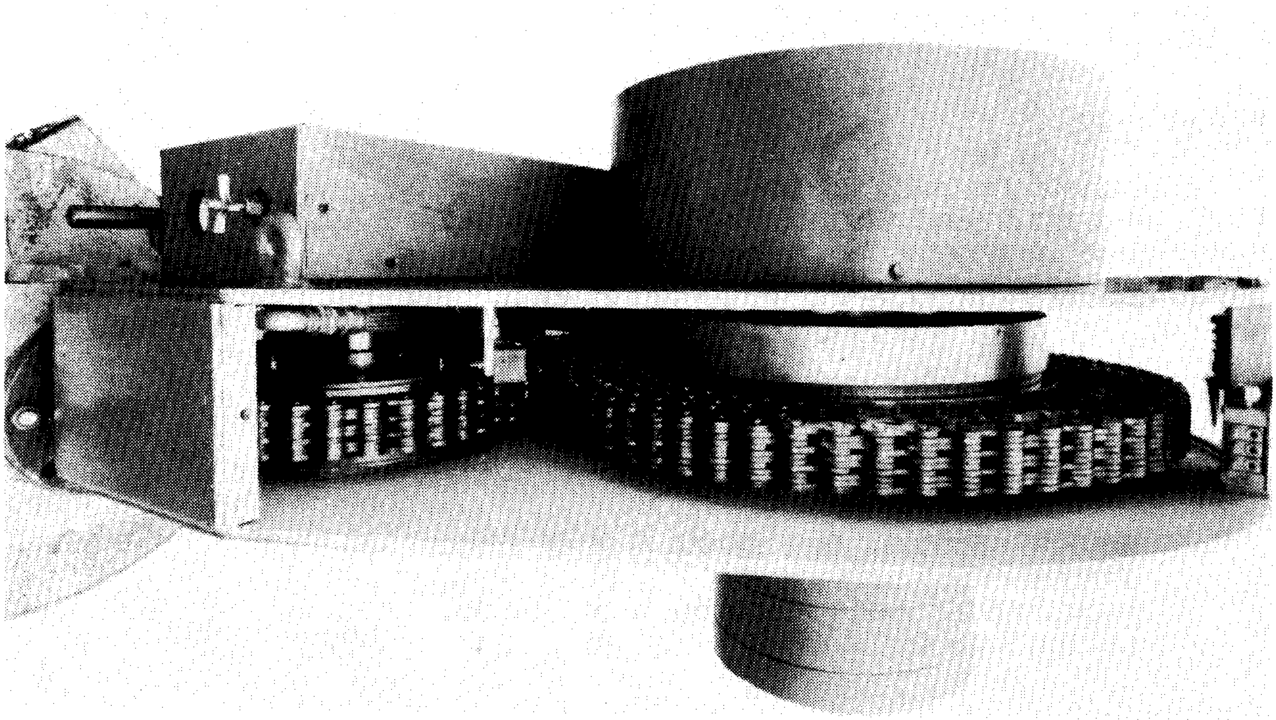


FIGURE 3 PUMPING UNIT WITH COVER REMOVED

FIGURE 4 LIFTRONIC AND API 456 BEAM UNIT

TABLE 1
LIFTRONIC SPECIFICATIONS MODEL A12-360

PUMPING UNIT

MAXIMUM POLISHED ROD LOAD	LB	12000
NOMINAL STROKE LENGTH	IN	360
PUMPING SPEED RANGE	SPM	1.5 - 3.5
GEAR REDUCER	-	DOUBLE REDUCTION PLANETARY
MOTOR	-	NEMA B HIGH EFFECIENCY, 460VAC, THREE PHASE
OVERALL HEIGHT INSTALLED	IN	86
WEIGHT	LB	3800

COUNTERWEIGHT ASSEMBLY

MAXIMUM COUNTERBALANCE EFFECT	LB	9000
COUNTERWEIGHT CASING DEPTH	FT	50
COUNTERWEIGHT CASING DIAMETER	IN	24
SPACING FROM WELLHEAD	FT	4

SEAL ASSEMBLY

OVERALL LENGTH	FT	40
OUTSIDE DIAMETER	IN	4.625
POLISHED ROD DIAMETER	IN	1.5
PACKING	-	KEVLAR SELF ADJUSTING
MAXIMUM TEMPERATURE		
STANDARD	°F	250
OPTIONAL	°F	650
MAXIMUM PRESSURE	PSI	700

TABLE 2
NOMINAL PUMP DISPLACEMENT AND DEPTH LIMIT

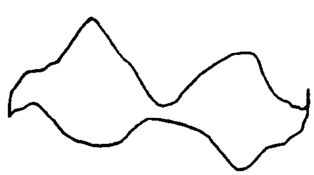
PUMP BORE (IN)	PUMPING SPEED (SPM)					DEPTH (FT.)
	1.5	2.0	2.5	3.0	3.5	
	(DISPLACEMENT - BPD)					
1.25	98	130	163	196	228	6000
1.50	140	186	233	280	326	5350
1.75	193	257	321	386	450	4750
2.00	251	334	418	502	585	4200
2.25	318	424	530	636	742	3750
2.50	393	524	655	786	917	3300
2.75	475	633	792	950	1108	2950
3.25	665	886	1108	1330	1550	2700
3.75	885	1180	1475	1770	2065	1750

* AT 100% DISPLACEMENT EFFICIENCY.
NOTE: API 66 ROD STRING 1.25" THRU 2.75" PUMP BORE.
API 76 ROD STRING 3.25" THRU 3.75" PUMP BORE.

TABLE 3
PERFORMANCE COMPARSION WELL A

	BEAM UNIT	LIFTRONIC
	C-456D-265-120	A12-360
CONDITIONS		
PUMP DEPTH	4265'	4218'
PUMP BORE	1-3/4"	2"
ROD STRING	API 76	API 76
STROKE LENGTH	120"	360"
PUMPING SPEED	11 SPM	2.9 SPM
MOTOR SIZE	25 HP	25 HP
PERFORMANCE		
AVG PRODUCTION	358 BPD	427 BPD
AVG OIL PRODUCTION	-0-	15 BPD
AVG POWER CONSUMPTION	1.31 KWH/BBL	.97 KWH/BBL
POWER COST PER BARREL	.114$/BBL	.084$/BBL

DYNAMOMETER CARD



BEAM
UNIT

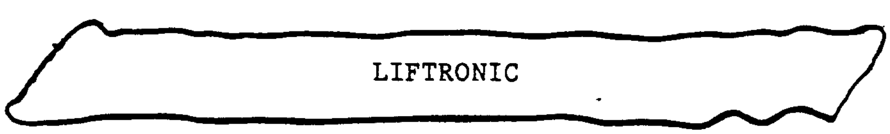
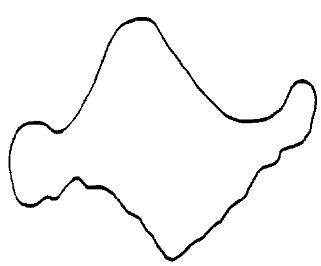


TABLE 4
PERFORMANCE COMPARSION WELL B

	BEAM UNIT	LIFTRONIC
	C-228-213-120	A12-360
CONDITIONS		
PUMP DEPTH	2230'	2358'
PUMP BORE	2-1/4"	2-3/4"
ROD STRING	API 66	API 66
STROKE LENGTH	120"	360"
PUMPING SPEED	13.5 SPM	3.1 SPM
MOTOR SIZE	40 HP	25 HP
PERFORMANCE		
AVG PRODUCTION	790 BPD	840 BPD
AVG OIL PRODUCTION	9 BPD	19 BPD
AVG POWER CONSUMPTION	.454 KWH/BBL	.360 KWH/BBL
POWER COST PER BARREL	.040$/BBL	.031$/BBL

DYNAMOMETER CARD



BEAM UNIT