ACHIEVING LOW PRODUCING BOTTOM HOLE PRESSURES IN DEEP WELLS USING HYDRAULIC RECIPROCATING PUMPS

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The Citronelle oil field, underlying the town of Citronelle, Alabama, is located on a topographic high approximately 350 feet above sea level (Figure 1). The existence of this surface anomaly encouraged oil and gas exploration in the Citronelle area. Oil was discovered in 1955 with the drilling of the Donovan Well #1 on a vacant car lot. The discovery well flowed about 500 barrels of oil per day with an initial bottom hole pressure of 5000 psi. As discovery of the field continued, over 450 wells were drilled on 40-acre tracts covering about 17,600 acres. Cumulative production through 1997 was approximately 161 MMBO and 125 MMBW from the Citronelle field which is about half of the total oil produced in the State of Alabama. Oil production is currently averaging about 3300 barrels of oil per day with 10,000 barrels of associated saltwater production. Figure 2 reflects the historical oil production and water injection in the Citronelle oil field.

GEOLOGY

Production is from a lower Cretaceous sandstone reservoir that is the equivalent to the lower Glen Rose of Louisiana and Mississippi. The Citronelle reservoir, commonly referred to as the Rodessa formation, has a gross thickness of 850 feet located between 10650 feet to 11500 feet. The anticlinal structure is highly stratified with interbedded shale and sandstone's overlying a large, deep-seated salt intrusion. The structure has a northwest to southeast trend with approximately 250 to 300 feet of closure (Figure 3). The reservoir is divided into an upper and lower productive zone by intervening saltwater sand more than 100 feet thick. Over 300 separate oil-bearing lens have been identified and categorized into 42 different sand layers. The productive layers are composed of meandering channel sands of varying size, shape, and thickness. These sand layers are illustrated on an east-west oriented stratigraphic cross section of the Rodessa formation (Figure 4). The sand characteristics indicate that deposition occurred in a shallow marine environment typical of delta plains.

The hydrocarbon accumulation in this reservoir was believed to have developed east of Citronelle but migrated westward to its present site during a number of geological events. Migration through the various fault planes could help to explain the undersaturated reservoir conditions in the Citronelle area. There was no free gas present in the reservoir. Most gulf coast equivalents to this section are typically prolific in both oil and gas production. Original production resulted from the expansion of reservoir fluids with minimal water drive from the salt-water sands. As a result, primary oil production was low, 14.8 percent of original oil in place, as expected from depletion type reservoir.

SECONDARY RECOVERY

In the late 1950s and early 1960s, several geological and engineering studies were performed to evaluate the feasibility of secondary recovery. The studies concluded that water injection could restore the reservoir energy and lead to the recovery of over 100 million barrels of oil, which prompted unitization of the field. A disagreement between major operators resulted in the field being unitized into three separate units: the Citronelle Operators Unit with 341 (40 acre) tracts, Sun's Southeast Citronelle Unit with 38 tracts, and Ancora's East Citronelle Unit with 31 tracts. The Citronelle Operators Unit currently composed of over 800 working interest owners and an employed staff hired by the Unit Manager operates 2000 royalty interest owners. The other two smaller units, East and Southeast Units, are currently being operated by an independent oil company. During the late 1970s, the Citronelle field was expanded in the northwest direction by the drilling of 30 additional wells. These wells were unitized in 1979 to form the Northwest Citronelle Unit. Figure 3 shows the boundaries of these four separate units.

Secondary recovery was initiated in 1962 using the Donovan discovery well. The waterflood pilot was very successful which instigated the expansion of waterflooding throughout the field. To date, about 105 wells have injected over 300 million barrels of water into the numerous sand layers of the Rodessa formation. The sand layers have a high degree of heterogeneity with porosity ranging from 10 to 16 percent and permeability from 0.5 to 75 millidarcies. Permeability variations between sand layers result in higher perm sands watering out prematurely. Fluid flow efficiency is also greatly affected by the crossflow between sand layers. A study of the individual sand isopachous maps was made to determine the most efficient flood pattern for this reservoir. It was determined that the use of any type of geometrical waterflood pattern was not possible because of the nature and characteristics of the sand layers. The type of pattern utilized for this reservoir can be described as a random type of pattern at the surface that is specific for each sand layer. Typically, water is injected into the thicker, more permeable sand sections to flood the oil toward the pinched out edges. However, those sands (24,36,38,40, & 42) with a defined oil/water contact, it is more efficient to locate the injectors near the contact and displace the oil up dip to the top of the sand. Freshwater injection wells and producers are continually shut in and reactivated based on the progression of the flood fronts in those particular sands that are penetrated by the wellbore. A typical wellbore in the field penetrates 8 to 12 productive sand layers with 5 or 6 utilized for production or water injection at one time. The Citronelle field is under a continual study to determine the position of the flood fronts, volumetric displacements, water-oil ratios, and waterflooding efficiencies.

HYDRAULIC PUMPING

While many of the wells came in flowing at rates of 500 barrels of oil per day, reservoir pressures declined rapidly and it soon became apparent that the wells would need to be artificially lifted early in their life. Attempts at artificial lift in the field were challenging due to the depth of the wells and fluctuating production rates. Sucker rod lift and gas lift was initially attempted but deemed to be insufficient. Hydraulic pumping was determined to be the most viable method of artificial lift because of the depth and low inflow capability of the Rodessa formation. It was found that this type of lift would provide the versatility needed to produce the wells over a wide production range. By April 1962, all producing wells in the Citronelle field were being lifted artificially. The Citronelle field uses an open power fluid system at each of the 26 tank battery sites (fig A). The tank batteries are strategically located throughout the field to produce the maximum number of wells. Each producing well utilizes a downhole double-acting hydraulic pump to transfer the produced fluids to the tank battery sites (fig B). The "free" type hydraulic allowed the pump to removed hydraulically. This is accomplished by reverse circulating (down the casing and up the tubing) the pump to the surface for repair (fig. C). A common wellhead hook-up using a four-way valve is installed on each well (fig. D). 2 7/8" tubing takes 6 barrel per thousand feet to displace. In an operation where you are circulating at a rate of a barrel a minute, it would take 66 minutes to pump out the pump from 11,000 feet.

The Citronelle Operators Unit, referred to herein as the Unit, currently has 329 wells. There are 130 active wells producing into 21 tank batteries, 48 active water injection wells, 4 active saltwater disposal wells and 2 active freshwater supply wells. The other wells are either shut in or temporarily abandoned. Oil production varies from a high of 350 BOPD and 1600 BWPD into the largest tank battery to a low of 30 BOPD and 75 BWPD into one of the smaller tank batteries. The largest tank battery at the Unit utilizes two National J-250 triplex pumps (fig. E) and one Kobe 3-E (fig. F) triplex pump to supply the power oil requirements for 12 active producing wells. The total output of the triplexes is 7800 barrels of power oil per day at an operating pressure of 3250 psi. Downhole hydraulic pump sizes range from a 2 ½" X 1 5/8" X 1 ¼" using 720 BPOPD @ 2900 psi to a 2 ½" X 1 7/16" X 1 ¼" using 450 BPOPD @ 1700 psi at this tank battery. The smallest tank battery contains 3 active wells and utilizes one Kobe 3-E triplex pump for the power oil requirements. Bottomhole pressure data from the wells has revealed that the downhole hydraulic pumps are doing an exceptional job at pressure drawdown.

OPERATING COSTS

Hydraulic pumping is a high cost artificial lifting technique. Today, as costs of supplies and services have increased, a producer must pay close attention to operating costs and try in every way to optimize production. The operating costs have averaged $7.50 per barrel of oil during 1998. The two cost categories of most concern are electrical power consumption and hydraulic pump repair (see Figure 5). The following describes how these lifting costs can be optimized to make hydraulic pumping economic even at today's low crude prices ($13.00/BO).

ELECTRICAL POWER. During 1998, electrical power costs have averaged approximately $145,000 per month, accounting for 21 percent of the total operating costs at the Unit. Electrical power consumption is high because of the large number of plunger pumps and the associated electrical motors required for hydraulic pumping systems. About 100 plunger pumps are used to pump high-pressure power oil down the tubing to activate the downhole hydraulic pumps. The most common downhole pump size is a 2 ½" X 1 7/16" X 1" and is usually pumped at 44 strokes per minute requiring a power oil rate of 370 BOPD at an operating pressure of 1800 psi. The pump end displacement is 2.56 barrels per day per strokes per minute, which equates to a displacement of about 110 barrels of fluid per day.

To optimize the electrical power usage in a hydraulic pumping system, the fluid requirements and operating pressures of the downhole pumps need to be coordinated with the pumping capacity of the surface plunger pumps to prevent the bypassing of significant amounts of power oil. More power oil equates to higher electrical power costs. The Unit utilizes 11 different size 2 ½" hydraulic pumps and 6 different size 2" hydraulic pumps. Most of the wells were completed with 2 7/8" 8rd tubing, 2 ½ " bottomhole assemblies (fig, G), and single grip retrievable packers. It is pertinent to note that the 2" pumps can be run in 2 7/8" tubing by utilizing a 2 ½" adapter on top of the pump to seal inside of the bottomhole assembly. These smaller pumps take less fluid and pressure to operate and generally run longer and less expensive to repair than the 2 ½" pumps. At the Unit, 17 different pump sizes are available providing a wide range of flexibility when sizing pumps and the corresponding operating pressures for wells in the same tank battery. The Unit has used jet pumps in the past to produce high volume wells (more than 500 barrels per day). However, the operating costs of jet pumps were considerably higher due to the additional power oil requirements and higher operating pressures. At present, no jet pumps are being used throughout the field.

Due to the recent drop in crude oil prices, the Unit has shut in 7 wells and changed the hydraulic pump sizes in 12 wells to reduce the power oil requirements and operating pressures at the tank batteries. As a result, the Unit has been able to shut down 10 triplex pumps resulting in savings of $17,400 per month. The downsizing has adversely affected oil production by approximately 66 barrels of oil per day (Figure 6).

After optimizing the pump sizes at each tank battery, some wells still require a pump with a high pump end displacement to engine end displacement (P/E Fig. H) ratio to operate efficiently, which equates to a high operating pressure. Instead of operating the tank battery at a high operating pressure for one or two wells, the Unit has split the power oil header into two separate headers; a low-pressure side and a high-pressure side. The Unit recently split the power oil header at tank battery D-6-12. One of the 7 wells producing into this tank battery required a hydraulic pump with a high P/E ratio and an operating pressure of 2700 psi. Attempts to resize the pump to lower the operating pressure have resulted in poor pump efficiency. Consequently, the header pressure at this tank battery had to be maintained at a high level in order to pump this one well. It should be pointed out that the header pressure at a tank battery should be maintained 300 psi above the highest pumping pressure in order to adequately provide power oil to a group of wells. The hydraulic pumps operating in the other 6 wells required pressures of only 1950 psi or less. A Kobe 3-E triplex pump and a National J-150 triplex pump were supplying the power oil requirements at this tank battery. To reduce power consumption, the header was split into a 2250 psi side and a 3000 psi side. The Kobe 3-E triplex was hooked up into the high-pressure header to pump one well and the National J-150 triplex was hooked up into the low-pressure header to pump the six wells. A choke valve was installed between the high-pressure header and low-pressure header to by-pass any extra power oil not used on the high-pressure side to the low-pressure side. By splitting the header, the operating pressure of the National J-150 triplex was reduced from 3000 psi to 2250 psi. As a result the electrical demand/consumption has decreased by about 20 percent for a savings of $650.00 a month. The facility modification costing about $1000.00 has paid out in less than 2 months. The maintenance costs on the National J-150 triplex should also be significantly reduced because of the lower operating pressure and corresponding less wear and tear on the equipment. Splitting the power oil headers at other tank batteries continues to be investigated.

HYDRAULIC PUMP REPAIR. Pump repair costs have averaged $105,000 per month in 1998 and account for 16 percent of the total operating expenses at the Unit. Shown on Figure 7 are yearly averages for the number of producing wells, the number of pump repairs, average monthly repair cost, and the average number of days run per pump from 1991 through the end of 1998. In an attempt to improve the pump performance, the engine end and pump end efficiencies are calculated to determine the specific problem of that well or tank battery. The following table reflects the possible causes for low or high pump end and engine end efficiencies. The normal operating ranges have been customized for the field to take into account the pump setting depth, low gas oil ratios, and pumping bottomhole pressures.

Engine End Efficiency

- Normal Operating range 65%-95%
- Above 95%-Indicates faulty power oil meter
- Below 65%-Indicates the presence of a leak and/or poor power oil quality

Pump End Efficiency

- Normal operating range 25%-75%
- Above 75%-Well is not being pumped off
- Below 25%-Pump size too large, excessive pump speed, produced oil contains solids, low bottomhole pressure and/or corrosive produced fluids (scale deposition)

Operating Pressure

- If pressure is below the pump-off pressure by more than 100 psi, need to speed pump up or change to larger pump size

Methods to increase pumping efficiency and extend the life of downhole pumps are addressed herein.

POOR POWER OIL QUALITY. A considerable amount of time and money has been spent establishing quality control guidelines for the power oil. Minimizing the amount of solids in the power oil is probably the most important factor in controlling repair costs. Power oil quality should be in the range of 15-20 parts per million total solids and 12 pounds of salt per 1000 barrels. Particle size should be no larger than 15 micron. The crude oil in the Citronelle field has an average API gravity of 43 degrees at standard conditions. Higher gravity crudes can tolerate even less total solids. Concentrations of solids have been found as high as 500 parts per million in the Citronelle power oil systems. X-ray diffraction identified the bulk of the solids as iron, quartz, and chloride compounds. Casing leaks are becoming more and more prevalent in the field because of the age of the production casings. The unconsolidated formations adjacent the leak intervals allow fine sand (quartz) to be produced along with the reservoir fluids. The sand adversely affects the performance of the plunger pumps and downhole hydraulic pumps by eroding or plugging the engine valve assemblies and valve plates. The chloride solids are probably entering the power oil system from the produced fluids. Whereas, the iron solids are believed to be the results of rust and scale buildup on the insides of the production vessels. Methods currently being used to improve power oil quality include cleaning the vessels (heater treaters and power oil tanks) on a routine basis and utilizing an effective chemical-treating program. A two-foot fresh water bath is maintained in the bottom of the power oil tanks along with a level spreader for power oil washing. The chloride content of the power oil water is maintained below 10,000 parts per million. Additionally, fresh water is continuously injected at rates of 50-100 barrels of water per day into the piping of the power oil header. This helps to increase the amount of freshwater and crude oil mixing and lowers the chloride content of the oil. Surfactants/demulsifiers are also being added to the power oil water to remove the oil coating covering the solid particles.

In order to remove solids from the produced oil by gravity separation, the power oil tanks should be designed for an upward velocity of less than two feet per hour. Colder climate regions should design for even lower upward velocities. Figure 8 shows the relationship between the settling time in the power oil tanks and the average days run per pump. There is an obvious correlation between the tank batteries with high upward velocities (greater than 4 ft/hr) in the power oil tanks and those tank batteries experiencing high solid concentrations. All of the 21 tank batteries except for four are utilizing a 1500 barrel power oil tank or two 1500 barrel power oil tanks connected in series. Magnetic filter units are being used at each tank battery for removal of the iron solids. Cartridge filter units using 15-5 micron filter elements are also being used to filter the fluid returns of newly activated wells.

Frequent monitoring the quantity of solids and water content in the power oil systems is essential in order to improve the hydraulic pump performance and optimize the chemical-treating program. The chemical company's representatives monitor on a weekly basis the amount of chlorides and basic sediment & water in the power oil and the chlorides in the power oil water. Early detection of possible problems is paramount in controlling the pump repair costs.

PREMATURE PUMP FAILURES. Other methods to increase pump performance include promoting competition between pump supply companies. The Unit prepares a detailed monthly computer printout summarizing the performance by pump supplier. The Unit's pump repair summary compares the 2" and 2 ½" pumps by supplier based on average cost per pump, days ran per pump, cost per pump per day, cost per barrel of produced fluid, and cost per barrel of produced oil (Figure 9). Efforts are currently underway to negotiate a pricing schedule for pump repairs based on pump performance. This type of arrangement would promote quality control by pump supply companies.

LOW FLUID LEVELS IN WELLBORES. Downhole hydraulic pumps should be sized to maintain adequate fluid levels in the wellbores to prevent excessive wear and tear. In order to properly evaluate the efficiencies of the pump, it was necessary to determine the pump intake pressure under a variety of producing conditions. Amerada recording instruments was run below the pump setting depth to record static and pumping bottomhole pressures at various pumping speeds. Static pressures have been measured at about 3500 psi and pumping bottomhole pressures have been measured below 200 psi (Figure 10). Wells are considered pumped off at bottomhole pumping pressures less than 300 psi. The downhole pump should be set as close to the top perforated interval as possible for maximum production. The Rodessa formation in the Unit's area is in fluid balance, so additional water injection should have a fairly quick response. Balancing injection and withdrawals on an area by area basis and sand by sand basis helps to insure adequate bottomhole pressures in the producing wells. An active stimulation program consisting of dilute HCL acid is also underway to remove calcium carbonate precipitation in the near wellbore area. Following the acid jobs, scale inhibitor treatments are used to prevent future scale buildup.

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2. Raves, E. (1976) Citronelle Oil Field, Mobile County, Alabama. American Association of Petroleum Geologist Memoir 24, 259-275

3. Wilson, M.D. and Warne, J.R. (1964) Sand Continuity Study, Citronelle Field, Mobile County, Alabama, Citronelle Operations Report

4. Citronelle Operators Unit, Various monthly reports regarding cost, hydraulic pump repair, power cost, etc.

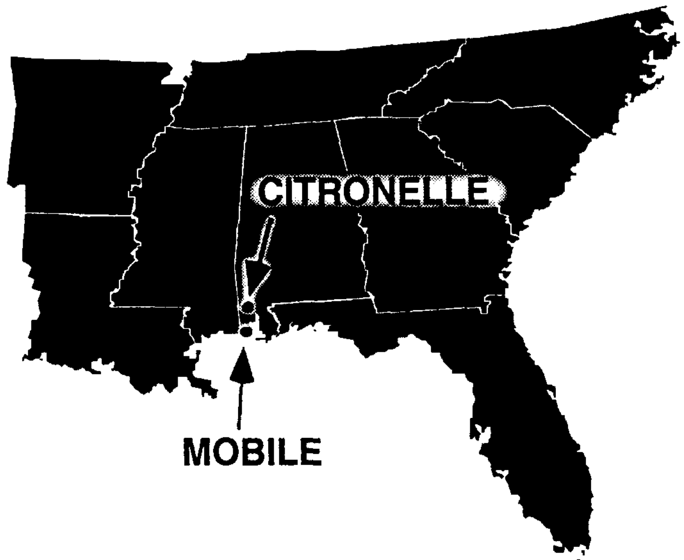


Figure 1 - Citronelle Field Location

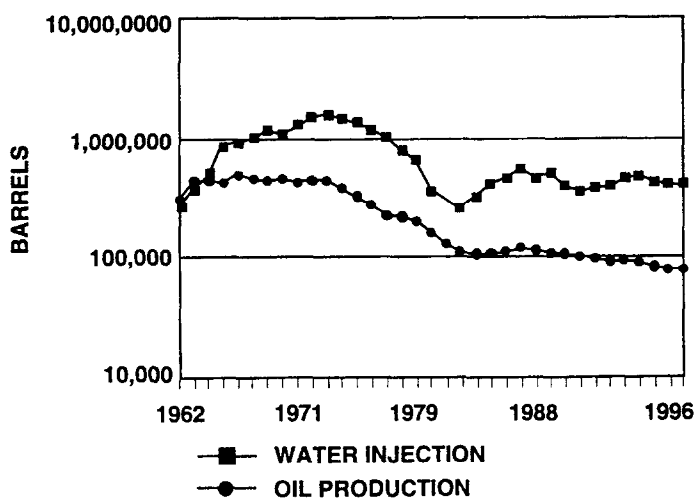


Figure 2 - Citronelle Field Project
Historical Oil Production and Water Injection

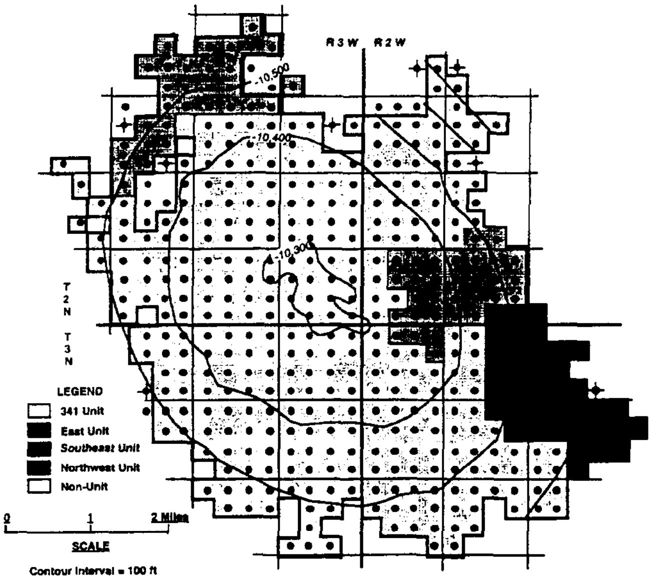


Figure 3 - Citronelle Field
(Ferry Lake Structure)

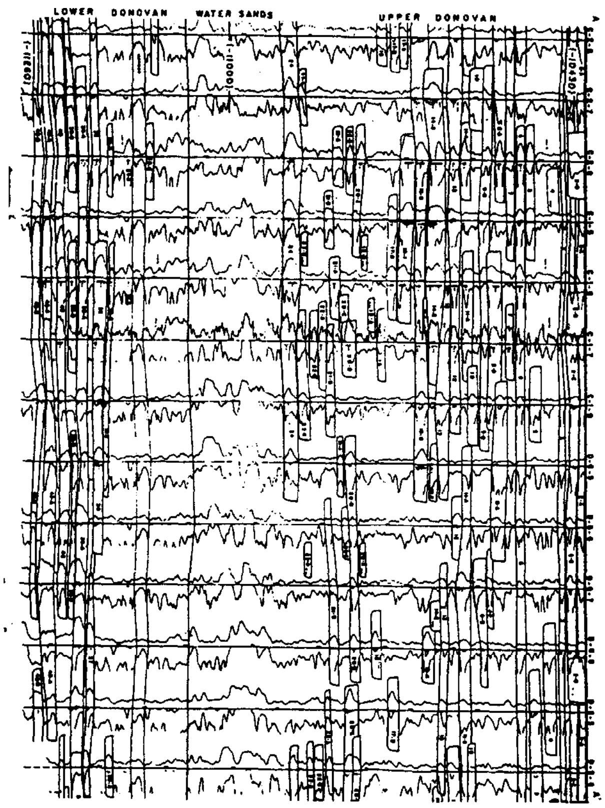


Figure 4

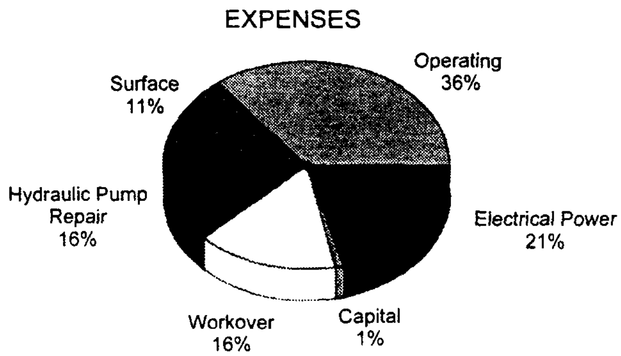


Figure 5 - Operating Expenses by Category
January 1998 through October 1998

TANK BATTERY	WELLS	TRIPLEX PUMP	PUMP REPAIR + POWER SAVINGS	PRODUCTION LOSS
A-23-12	A-23-6 RPS	SI J150 Start Kobe	\$1600	6 BOPD
A-28-16	A-34-4 RPS A-34-5 RPS	SI Kobe	\$2300	4 BOPD
A-26-7	A-27-1 SI A-26-6 RPS A-26-4 RPS	SI Kobe	\$1600	10 BOPD
A-35-7	A-35-7 RPS	SI Kobe	\$ 900	2 BOPD
C-3-8	C-3-1 SI C-3-8 #2 SI	SI KOBE	\$2300	12 BOPD
C-11-4	C-10-7 SI C-11-5 SI	SI J150 START Kobe	\$2300	9 BOPD
D-18-4	D-18-4 RPS D-18-2 RPS	SI Kobe	\$1600	7 BOPD
C-13-7	C-13-1 SI	SI J150 Start Kobe	\$1600	8 BOPD
C-14-2	C-14-8 SI C-14-3 RPS C-11-10 RPS	SI J150 Start Kobe	\$1600	4 BOPD
D-17-5	D-17-12 RPS D-17-5 RPS	SI J150 Start Kobe	\$1600	5 BOPD
TOTALS			\$17.400/mth	66 BOPD

RPS - Reduced Pump Size

Figure 6 - Operation Modifications Due to Low Oil Prices
Citronelle Operators Unit - March 1998

	ACTIVE PRODUCERS	NO. OF PUMP REPAIRS	AVG. MONTHLY REPAIR COST	DAYS RUN PER PUMP
1991	152	1388	$141,830/mth.	40
1992	145	1359	$127,430	39
1993	143	1123	$111,750	44
1994	129	918	$89,670	51
1995	130	1071	$98,580	43
1996	133	1125	$110,200	42
1997	136	1339	$108,250	37
1998 (10 mos.)	134	1092	$92,780	37

Figure 7 - Downhole Pump Performance
Citronelle Operator's Unit

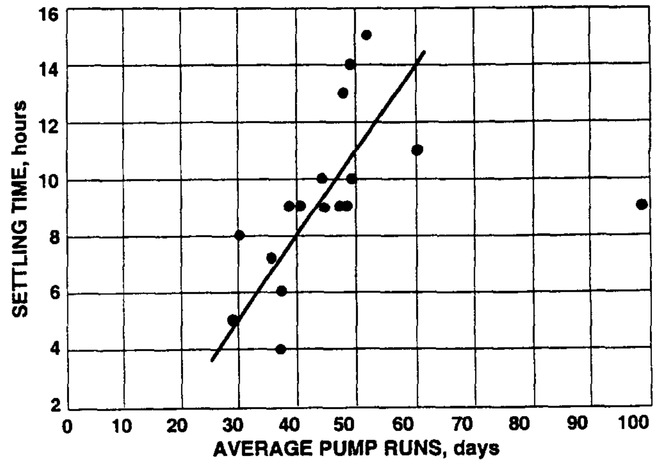


Figure 8 - Hydraulic Pumping
Settling Time vs. Pump Runs

PUMP REPAIR SUMMARY
YEAR OF 1997

DATE RUN 2/03/98
TIME RUN 10:03:35

PROGRAM PUR457
PAGE NUMBER 1

BATTERY	COMPANY	SIZE	PUMPS REPAIRED	NT PULLS	DAYS RAN	TOTAL REPAIR COST	AVG COST PER PUMP	DAYS RAN /PUMP	$/PUMP /DAY	$/BBL FLUID	$/BBL OIL
A-23-12	USSCO	2 1/2"	2	19	153	3,276.80	1,638.40	76.5	21.42	.278	.821
A-23-12	USSCO	2"	3	14	122	2,972.46	990.89	40.7	24.35	.577	1.991
A-24-13	KOBE	2 1/2"	14	18	268	15,407.35	1,100.53	19.1	57.62	.363	2.112
A-24-13	OWHYD	2 1/2"	15	7	663	16,970.33	1,131.36	44.2	25.60	.341	1.577
A-24-13	USSCO	2 1/2"	5	18	232	6,686.58	1,337.32	46.4	28.82	.387	.713
A-24-13	USSCO	2"	0	5	0	.00	.00	.0	.00	.000	.000
A-25-07	KOBE	2 1/2"	27	42	805	37,204.31	1,377.94	29.8	46.24	.363	1.905
A-25-07	OWHYD	2 1/2"	6	16	292	8,658.00	1,443.00	48.7	29.63	.171	1.057
A-25-07	USSCO	2 1/2"	7	22	204	6,743.68	963.38	29.1	33.11	.456	2.745
A-25-07	KOBE	2"	2	3	127	3,107.69	1,553.85	63.5	24.47	.772	1.465
A-25-07	OWHYD	2"	2	0	67	1,610.00	805.00	33.5	24.03	.883	1.819
A-25-07	USSCO	2"	4	4	131	4,576.85	1,144.21	32.8	34.88	1.188	2.379
A-26-07	KOBE	2 1/2"	7	24	237	11,415.22	1,630.75	33.9	48.10	1.561	5.953
A-26-07	OWHYD	2 1/2"	11	26	399	11,611.73	1,055.61	36.3	29.08	.870	1.862
A-26-07	USSCO	2 1/2"	8	17	137	5,537.53	692.19	17.1	40.48	.405	3.184
A-26-07	KOBE	2"	0	1	0	.00	.00	.0	.00	.000	.000
A-26-07	USSCO	2"	0	3	0	.00	.00	.0	.00	.000	.000
A-28-16	KOBE	2 1/2"	2	15	120	4,021.07	2,010.54	60.0	33.51	.669	1.184
A-28-16	OWHYD	2 1/2"	15	13	665	15,218.69	1,014.58	44.3	22.90	.387	1.345
A-28-16	USSCO	2 1/2"	0	3	0	.00	.00	.0	.00	.000	.000
A-28-16	OWHYD	2"	0	4	0	.00	.00	.0	.00	.000	.000
A-28-16	USSCO	2"	3	40	258	4,320.38	1,440.13	86.0	16.75	.679	2.481
A-34-01	KOBE	2 1/2"	3	12	133	5,504.42	1,834.81	44.3	41.42	.241	1.935
A-34-01	OWHYD	2 1/2"	16	18	505	14,844.36	927.77	31.6	29.36	.668	1.487
A-34-01	USSCO	2 1/2"	2	19	106	2,308.38	1,154.19	53.0	21.78	.560	1.276
A-34-01	KOBE	2"	0	5	0	.00	.00	.0	.00	.000	.000
A-35-07	KOBE	2 1/2"	2	18	244	4,418.10	2,209.05	122.0	18.11	.109	.396
A-35-07	OWHYD	2 1/2"	25	16	989	26,433.32	1,057.33	39.6	26.70	.116	.744
A-35-07	USSCO	2 1/2"	4	36	336	6,563.61	1,640.90	84.0	19.53	.103	.912
B-19-08	KOBE	2 1/2"	1	4	53	2,050.67	2,050.67	53.0	38.69	1.303	3.989

Figure 9 - Pump Repair Summary
Year of 1997

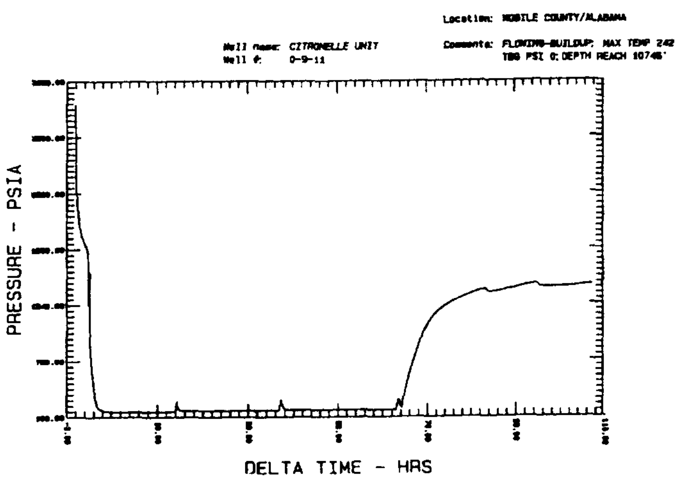


Figure 10 - Citronelle Unit

Central Tank Battery System

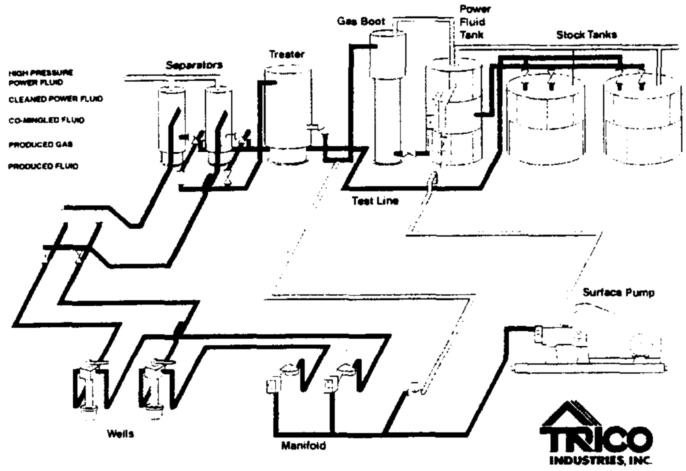


Figure A - Central Tank Battery System

Hydraulic Pump Operation

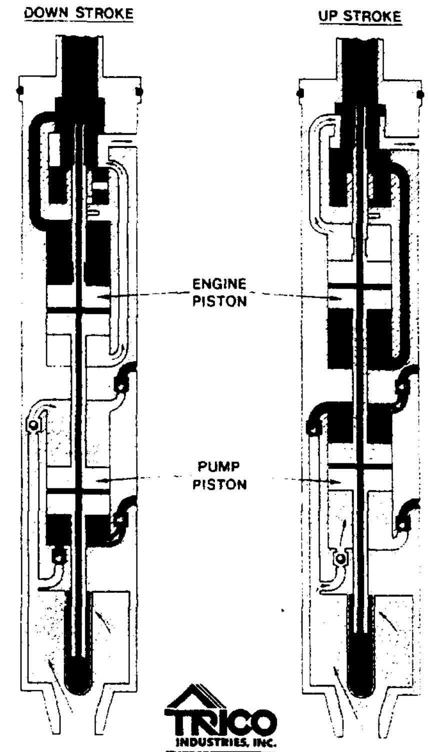


Figure B - Hydraulic Pump Operation

Basic Downhole Installations
Open Power Fluid Configurations

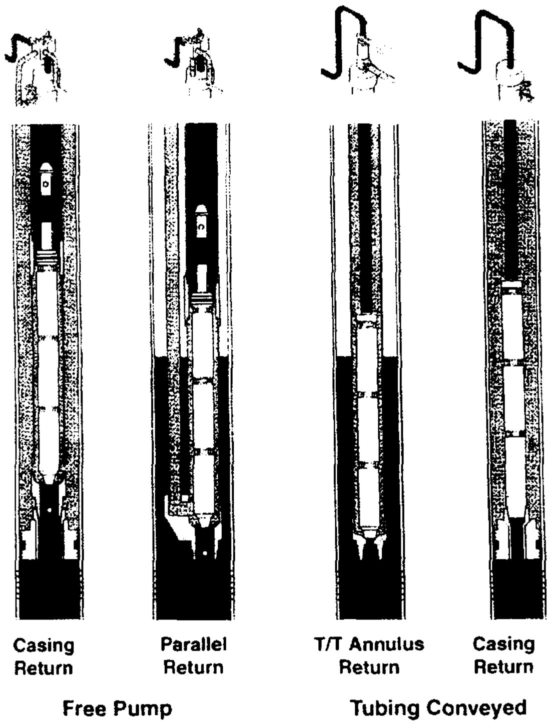


Figure C - Hydraulic Pumps

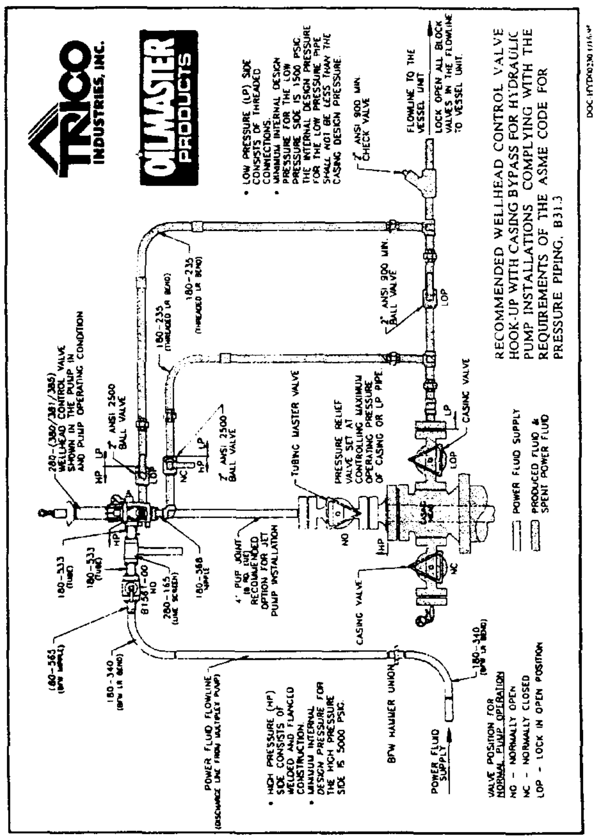
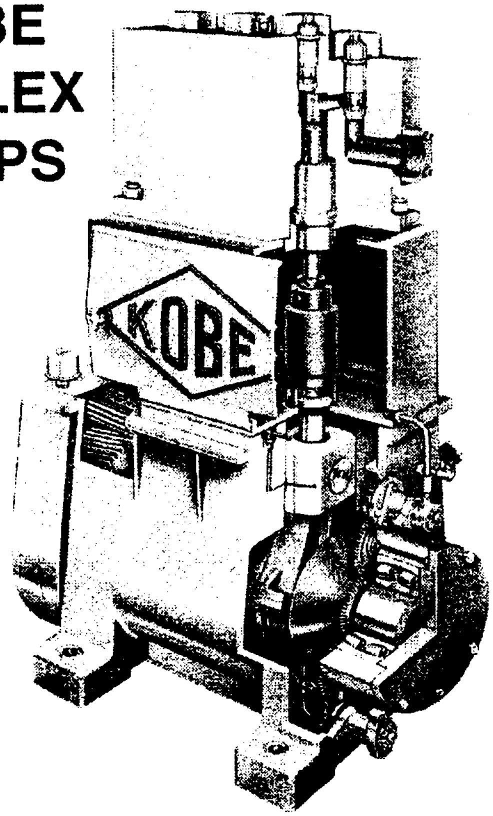


Figure D

KOBE TRIPLEX PUMPS



NATIONAL-OILWELL MULTIPLEX PLUNGER PUMPS

FOR HYDRAULIC PUMPING, WATER INJECTION/ DISPOSAL & INDUSTRIAL APPLICATIONS

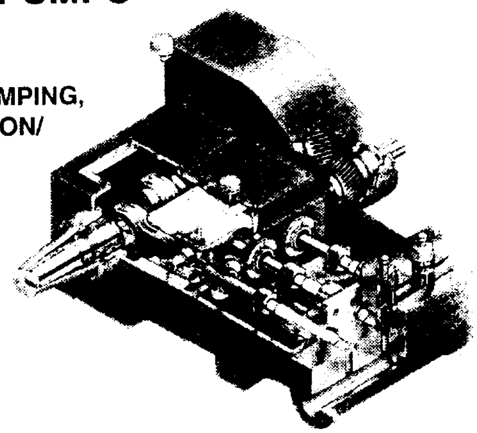


Figure E - National-Oilwell Multiplex Plunger Pumps

Figure F - Kobe Triplex Pumps

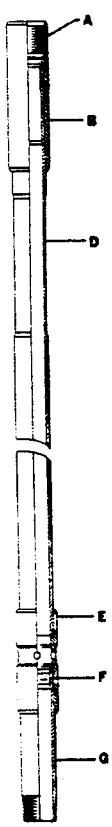


Figure G - 4/86

H

PUMP SIZE Nominal x Engine —Pump x Pump (inches)	Part Number	DISPLACEMENT: Pump End at Rated Speed (BPD)	DISPLACEMENT (BPD per SPM): Engine	DISPLACEMENT (BPD per SPM): Pump	Area Ratio: P/E	Area Ratio: E/P	Max. Fluid Lift (ft.)	Approx. Pump Length (in.)	Approx. Pump Weight (lb.)
TYPE A DOWNHOLE PUMPS									
Fits in 2-3/8" O.D. Tubing or Larger									
2 x 13/16—13/16	43-50-21	139	1.20	1.15	1.000	1.000	10,000	78	42
2 x 1—13/16	44-30-21	139	2.15	1.15	.545	1.834	15,000	78	42
2 x 1—1	44-40-21	255	2.15	2.10	1.000	1.000	10,000	78	42
2 x 1—1-3/16	44-50-21	393	2.15	3.25	1.546	.647	6,500	78	42
2 x 1-3/16—13/16	45-30-21	139	3.30	1.15	.353	2.831	15,000	78	42
2 x 1-3/16—1	45-40-21	255	3.30	2.10	.647	1.545	15,000	78	42
2 x 1-3/16—1-3/16	45-50-21	393	3.30	3.25	1.000	1.000	10,000	78	42
2 x 1-3/16—1 x 1	45-44-21	508	3.30	4.20	1.290	.775	7,700	132	70
2 x 1-3/16—1-3/16 x 1	45-54-21	647	3.30	5.35	1.647	.607	6,100	132	70
2 x 1-3/16—1-3/16 x 1-3/16	45-55-21	787	3.30	6.50	2.000	.500	5,000	132	70
Fits in 2-7/8" O.D. Tubing or Larger									
2-1/2 x 1—1	53-30-21	256	2.86	2.56	1.000	1.000	10,000	105	85
2-1/2 x 1-1/4—1	54-30-21	258	5.02	2.56	.520	1.923	15,000	105	85
2-1/2 x 1-1/4—1-1/8	54-30-21	387	5.02	3.67	.746	1.340	13,400	105	85
2-1/2 x 1-1/4—1-1/4	54-40-21	482	5.02	4.92	1.000	1.000	10,000	105	85
2-1/2 x 1-1/4—1-7/16	54-50-21	703	5.02	7.03	1.431	.700	7,000	105	85
2-1/2 x 1-7/16—1-1/8	55-30-21	367	7.13	3.67	.522	1.917	15,000	105	85
2-1/2 x 1-7/16—1-1/4	55-40-21	482	7.13	4.92	.700	1.428	14,300	105	85
2-1/2 x 1-7/16—1-7/16	55-50-21	703	7.13	7.03	1.000	1.000	10,000	105	85
2-1/2 x 1-1/2—1-1/2	56-60-21	745	7.56	7.45	1.000	1.000	10,000	105	85
2-1/2 x 1-5/8—1-1/4	57-40-21	482	9.27	4.92	.521	1.920	15,000	105	85
2-1/2 x 1-5/8—1-7/16	57-50-21	703	9.27	7.03	.770	1.290	13,000	105	85
2-1/2 x 1-5/8—1-1/2	57-60-21	745	9.27	7.45	.820	1.220	12,200	105	85
2-1/2 x 1-5/8—1-5/8	57-70-21	944	9.27	9.08	1.000	1.000	10,000	105	85
2-1/2 x 1-7/16—1-1/4 x 1-1/4	55-44-21	984	7.13	9.84	1.400	.714	7,200	175	140
2-1/2 x 1-7/16—1-7/16 x 1-1/4	55-54-21	1186	7.13	11.95	1.701	.588	5,800	175	140
2-1/2 x 1-7/16—1-7/16 x 1-7/16	55-55-21	1406	7.13	14.06	2.000	.500	5,000	175	140
2-1/2 x 1-5/8—1-5/8 x 1-5/8	57-77-21	1818	9.27	18.16	2.000	.500	5,000	175	140
Fits in 3-1/2" O.D. Tubing or Larger									
3 x 1-1/2—1-1/4	64-20-21	406	9.61	5.50	.598	1.666	15,000	136	160
3 x 1-1/2—1-3/8	64-30-21	646	9.61	7.43	.787	1.271	12,700	136	160
3 x 1-1/2—1-1/2	64-40-21	821	9.61	9.44	1.000	1.000	10,000	136	160
3 x 1-1/2—1-3/4	64-50-21	1218	9.61	14.00	1.480	.676	6,700	136	160
3 x 1-3/4—1-1/2	65-40-21	821	14.17	9.44	.676	1.480	14,800	136	160
3 x 1-3/4—1-3/4	65-60-21	1218	14.17	14.00	1.000	1.000	10,000	136	160
3 x 2—1-3/4	67-50-21	1218	19.35	14.00	.727	1.375	13,750	136	160
3 x 1-3/4—1-1/4 x 1-1/4	65-22-21	973	14.17	11.10	.808	1.240	12,500	223	280
3 x 1-3/4—1-1/2 x 1-1/2	65-44-21	1642	14.17	18.88	1.351	.740	7,400	223	280
3 x 1-3/4—1-3/4 x 1-1/2	65-54-21	2063	14.17	23.44	1.675	.597	6,000	223	280
3 x 1-3/4—1-3/4 x 1-3/4	65-55-21	2436	14.17	28.00	2.000	.500	5,000	223	280
Fits in 4-1/2" O.D. Tubing or Larger									
4 x 2—1-3/4	84-30-21	1109	21.44	14.40	.687	1.456	14,600	173	370
4 x 2—2	84-40-21	1617	21.44	21.00	1.000	1.000	10,000	173	370
4 x 2—2-3/8	84-50-21	2503	21.44	32.50	1.541	.649	6,500	173	370
4 x 2-3/8—2	85-40-21	1617	32.94	21.00	.649	1.549	15,000	173	370
4 x 2-3/8—2-3/8	85-50-21	2503	32.94	32.50	1.000	1.000	10,000	173	370
4 x 2-3/8—2 x 1-3/4	85-43-21	2726	32.94	35.40	1.094	.914	9,200	283	614
4 x 2-3/8—2 x 2	85-44-21	3234	32.94	42.00	1.290	.776	7,700	283	614
4 x 2-3/8—2-3/8 x 2	85-54-21	4130	32.94	53.50	1.680	.606	6,100	283	614
4 x 2-3/8—2-3/8 x 2-3/8	85-55-21	5005	32.94	65.00	2.000	.500	5,000	283	614

Figure H