CASE HISTORY - RESERVE GROWTH DUE TO HIGH VOLUME LIFT - ROPES (CANYON REEF) UNIT, TEXAS

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ABSTRACT

This paper discusses the results of high volume submersible lift equipment (HVL) installed in a West Texas carbonate reservoir.

Field-wide installation of HVL was made in a primary field in 1978 during the last stages of depletion. With a high capacity reservoir and a strong water drive, a significant increase in oil production was obtained. A reserve growth by HVL installation is documented with field results. Included is a historical overview of field installations with a post installation economic analysis and a summary of required facility revisions.

ROPES FIELD

Review of History

The Ropes (Canyon Reef) Unit located in Hockley County, Texas (Figure 1), was discovered in May, 1950 by Honolulu-Signal with a completion flowing 2236 barrels of oil per day. Major development continued through 1958 with 41 producers and 10 dry holes defining the productive limits of the field (Figure 2). The Ropes (Canyon Reef) Unit was formed in June 1959, preparatory to initiation of water injection for reservoir pressure maintenance. Prior to July 1967, production was controlled by market demand and wells typically flowed on-a-day; off-a-day. As top allowables were increased wells were flowed continuously, and pumping units had to be installed through 1969 and 1970. In March 1978, two submersible pumps were installed. The combined production of these two wells increased from 65 to 300 barrels of oil daily (Figure 3). Three more installations of submersibles were made in October 1978, resulting also in a significant oil increase. Unit wide HVL installation of the remaining 22 wells was completed throughout 1979. The number of injection wells were increased from two to nine as they were needed to handle the increased volume of water. Oil production due to high volume lift peaked in September 1979, and then declined at 47% annually. This decline in production continued through January 1982, when an upsizing program was initiated. Amoco Production Company presently operates the Ropes (Canyon Reef) Unit with 23 producers and 9 injectors.

Geology and Reservoir Characteristics

The Ropes Unit is producing from a Cisco-Canyon limestone of a Pennsylvanian age biohermal reef with an average depth of 9320 feet.

The reef is approximately 3-1/4 miles long and 1-1/4 miles wide. The average reef thickness is 645 feet with approximately 117 feet of reef section above the original oil-water contact (-6033').

The character of the oil producing reef section is quite erratic with large variations in porosity and permeability development. Horizontal permeability ranges from .1 millidarcy to 1800 millidarcies, averaging 69 millidarcies field wide. Likewise porosity ranges from 1% to 28% with a field wide average of 11%. The porosity and permeability development assumes such a random distribution pattern that the entire range of each can be seen in most every wellbore.

The reservoir has a strong bottom water drive and also exhibits characteristics of a limited edge water drive. Produced water is injected (usually on vacuum) below the original oil-water contact to maintain pressure. The field's average pressure is 2705 psi compared to an original pressure of 3752 psi at -5930 feet subsea datum. Reservoir temperature averages 160 degrees Fahrenheit.

High Volume Lift Equipment (HVL)

Electric submersible pumps (ESP) are the only type of HVL capable of lifting the fluid volumes produced in the Ropes (Canyon Reef) Unit. Fluid production per ESP ranges from 550-7200 BFPD with an average production of 2550 BFPD. There are currently 21 wells being produced with ESP equipment. Ten of these wells have 7" casing while the remaining eleven have 5-1/2" casing. The average production rate for wells with 7" casing is 3435 BFPD and for the wells with 5-1/2" casing the average rate is 1745 BFPD. These high production rates are attainable since the Productivity Index (PI) on most wells is quite high. The PI ranges from 75 to .2, averaging 6.3 BPD/psi.

Ranging between 5600' and 9300', the average pump setting depth is 7000' below the surface. A massive power requirement results from lifting such large amounts of fluid from these depths. The smallest ESP motor in use is 90 Hp with the largest being 490 Hp. Average horsepower for the 21 producing wells is 168 Hp. Due to large power consumption, 64% of the operating expenses for the Ropes (Canyon Reef) Unit are accounted for by electrical costs.

Effect of High Volume Lift

The typical ESP installation increased the flow rate from a well by a factor of twelve. The performance of an example well in which an ESP was installed is illustrated by a production curve shown in Figure 4. In sixty percent of the installations the producing oil cut increased by an average of eight percentage points. This increase in oil cut is typically maintained only for a short time before the well returns to its former oil cut. In total, the wells with HVL installation had a pre-ESP production rate of 827 BOPD and 4279 BWPD (16.2% oil cut).

After the HVL installation, the ESP production rate increased to 6116 BOPD and 51,845 BWPD (10.6% oil cut). The unit performance curve does not reflect this increase since the installations were staggered over two years. Installation of high volume lift equipment accelerated the unit's production decline rate from a 26% exponential decline yearly to approximately a 47% exponential decline yearly.

Figure 5 is a summary of the production increases resulting from the 27 submersible pump installations during 1978 and 1979. It is of interest to note that three wells which had previously "watered-out" had substantial increases in oil production on HVL.

Reserve Growth and Economics

A reserve growth of 1,504,000 barrels of oil has been realized due to the installation of the submersible pumps as calculated by decline curve analysis. March 1, 1978, was used as the installation date, and the table below summarizes the results.

	Base Case	HVL Case
Incremental Reserves as of March, 1978 (bbls.)	---------	1,504,000
Remaining Economic Life from March, 1978	9.6 years	6.8 years
Decline Rate	26%/year	47%/year
Economic Limit	4.5 BOPD/well	15 BOPD/well
Production March, 1978 thru December, 1982 (bbls.)	---------	2,840,000

As can be seen the economic limit for the high volume lift case is over three times that of the base case due to the increased operating costs. Significant increases in reserves have been realized with the installation of high volume lift equipment. Production has already surpassed the estimated ultimate recovery for the base case by 1,168,000 barrels of oil. With this incremental production, total recovery to date is 40 percent of the original oil in place.

An economic post installation analysis of the HVL program reveals some exceptional figures. After the cash flows were calculated, the base case was subtracted from the high volume lift case to give incremental economics. An economic summary indicates that a reserve growth of 1.5 million barrels of oil was accomplished with the expenditure of 2.5 million dollars. The investment yielded in excess of 100 percent rate of return and subsequently payout was achieved in 1.35 years.

ESP Resize Program

Quick payouts and increases in reserves have made upsizing submersible equipment an economically attractive operation. (Figure 6). In October 1981, an ESP resizing program was initiated. Initially, seven wells were identified as possible resize candidates. These candidates were selected on a well-by-well basis with the following criteria.

1. Will the casing diameter accommodate larger equipment?

2. Will the incremental oil production pay for increased electrical costs and the cost of new equipment?

The seven resizes were performed between October 1981 and November 1982. Ninety days after the upsizes total oil production had increased by 453 BOPD. The largest increase was 191 BOPD and the smallest was 17 BOPD, with an average increase of 67 BOPD per resize. With the individual wells remaining on essentially the same decline, decline curve analysis yields increased reserves of 455,000 barrels of oil. The resizes were relatively inexpensive and payouts averaged less than 30 days.

Resize Economics

At the present the economic limit of the Ropes Unit is 333 barrels of oil daily. Electrical power costs account for 64% of the operational budget. As production continues to decline, individual well economics become increasingly important. Figure 7 is a chart of motor horsepower versus BOPD. This chart represents the economic limit for an ESP equipped well. A particular oil production rate must be maintained to economically operate a certain horsepower of motor. For instance, a 400 horsepower motor requires an oil production rate of 22 BOPD just to pay for electrical operating cost. When the production rate drops below this limit, the well is operating at a revenue loss.

Operational Requirements and Problems

Two major prerequisites for the installation of HVL equipment are high volume fluid handling facilities and a large capacity electrical system. The electrical distribution system should be designed to handle any anticipated upsizing of the HVL equipment during the life of the field. High volume fluid handling facilities are required as well as high capacity injection wells to dispose of the water. The Ropes (Canyon Reef) Unit produces approximately 50,000 barrels of fluid daily. Oil-water separation is done with a 10' x 50' free-water knockout, a 1500 barrel tank and a 1000 barrel tank. Nine injectors dispose of the water (usually on vacuum) at rates of up to 10,000 BWPD each.

Most of the operational problems result from lightning or corrosion. Lightning is one of the worst enemies of electrical pumping equipment. Power surges, particularly from lightning activity account for the largest percentage of downtime within the Ropes (Canyon Reef) Unit. Three sources providing lightning protection are lightning arrestors in the regulators, top grounded transmission poles and lightning arrestors in the control boxes at each well. This protection, however, is useless against direct lightning strikes.

Soon after the initial installation of HVL at Ropes, corrosion was particularly evident on the motor housings of the equipment. To combat this problem the motor and seal sections of each ESP are coated with monel. The highly corrosion resistant monel is bonded to the exterior surfaces of the equipment. The coating has proven to be a very effective means of stopping the corrosion on the external surfaces.

Following electrical cost, repair cost on the submersible pumping equipment requires the largest expenditure. This cost, however, can be reduced significantly if the wells are properly monitored. The most expensive section of an electric submersible pump to repair is the motor. Motor damage from lightning strikes cannot be avoided, but damage from pump wear can be minimized. Wear in the pump section, when it becomes severe enough, will damage the motor and lead to costly repairs. Monitoring of fluid levels and production rates can prevent many of these repairs. A decrease in production and a rise in the amount of fluid above the pump usually signals excessive pump wear. Replacement of the worn pump before motor damage occurs will save thousands of dollars in repair costs.

Conclusion

The success of field-wide ESP installation in the Ropes (Canyon Reef) Unit illustrates that production rates as well as reserves can be increased significantly with favorable economics even in high water cut fields. Proper installation and monitoring of high volume lift equipment minimizes operational problems and costs.

Acknowledgements

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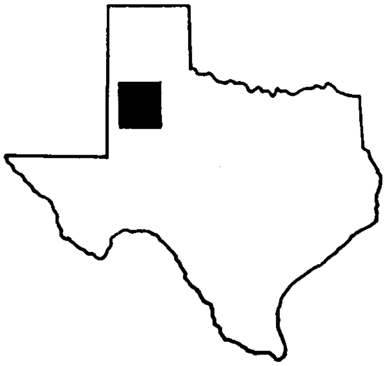

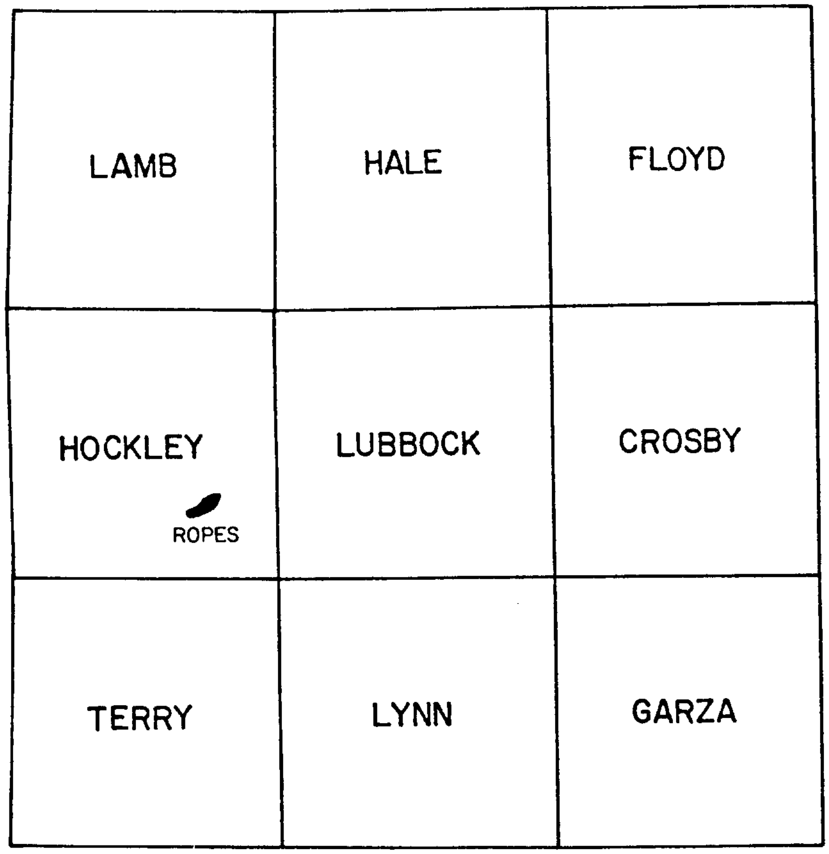

FIGURE 1

ROPES FIELD ORIENTATION MAP

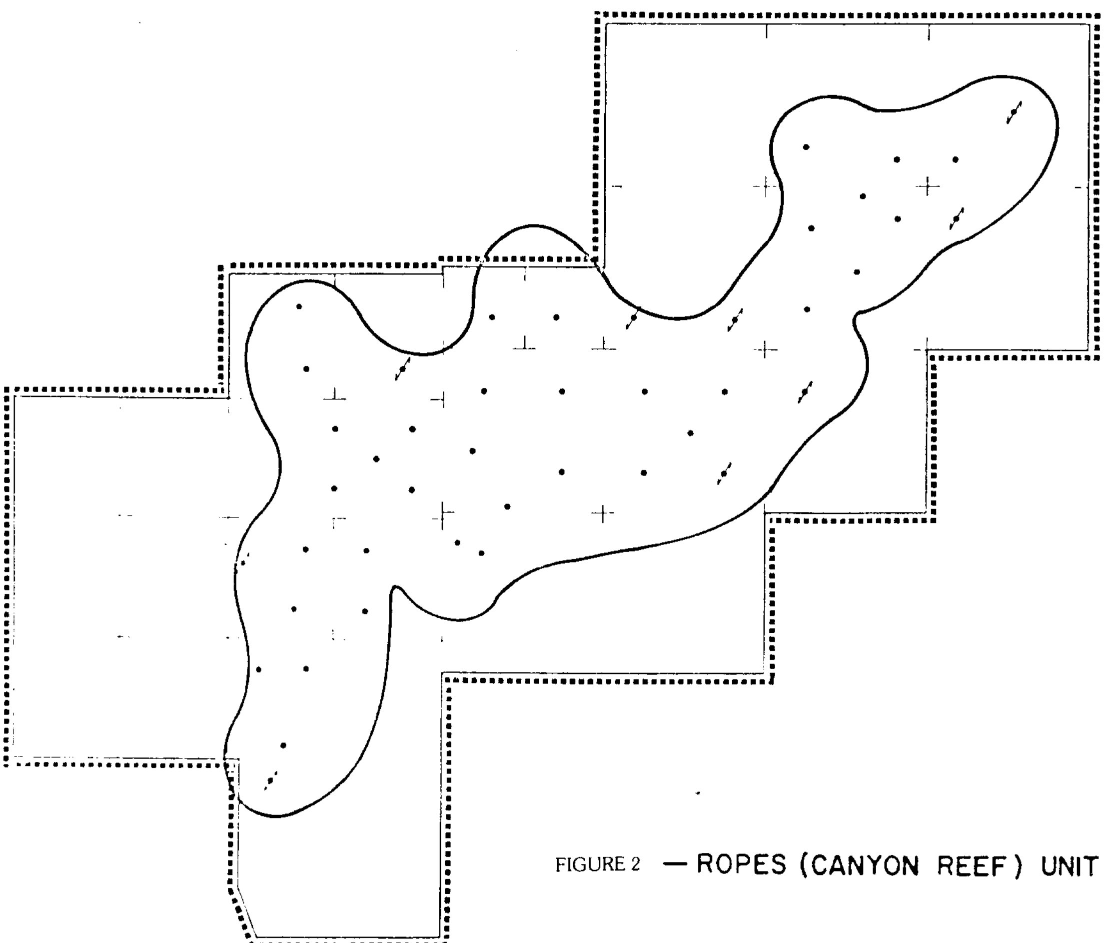

FIGURE 2 — ROPES (CANYON REEF) UNIT MAP

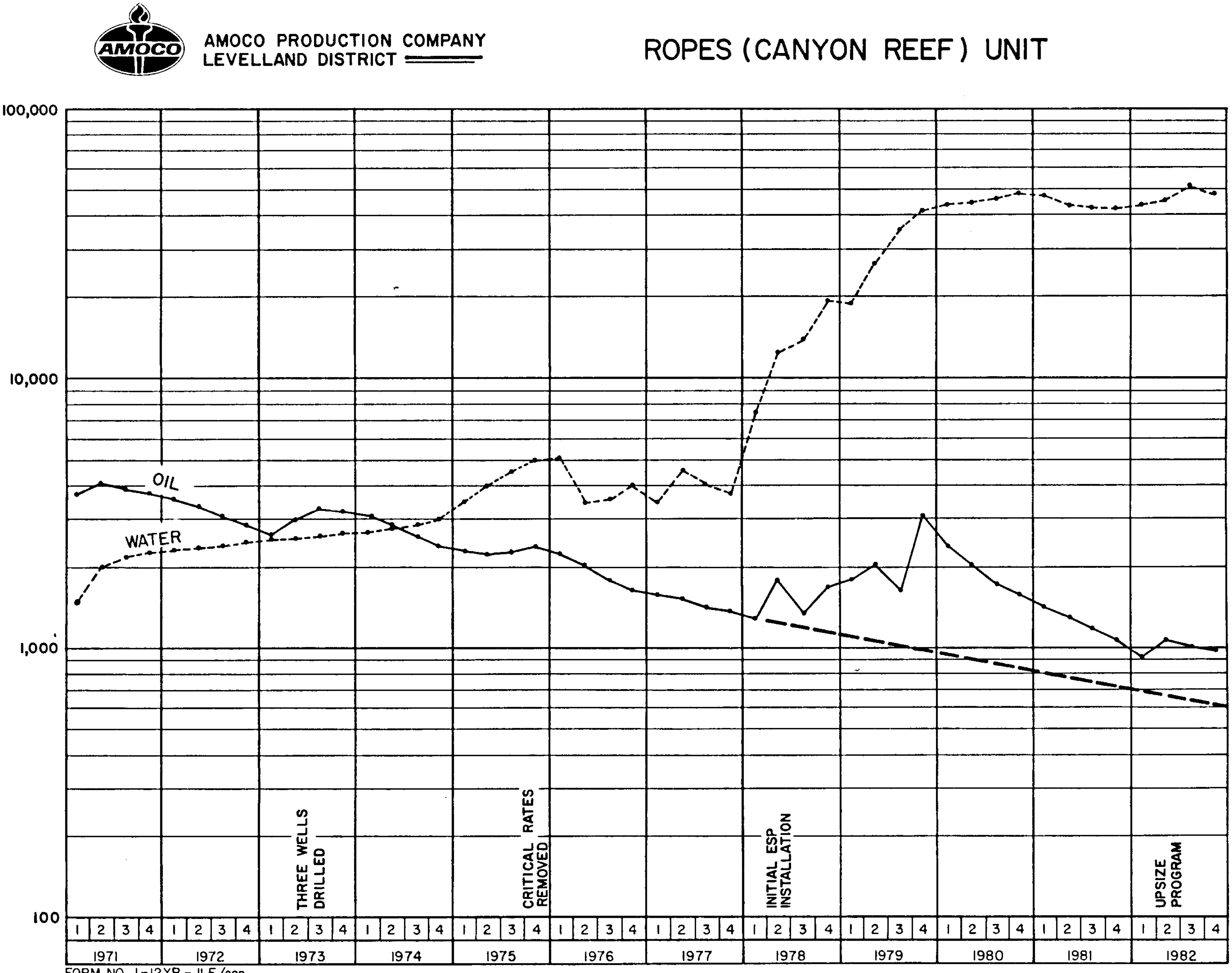

FIGURE 3 — ROPES UNTI PRODUCTION CURVE

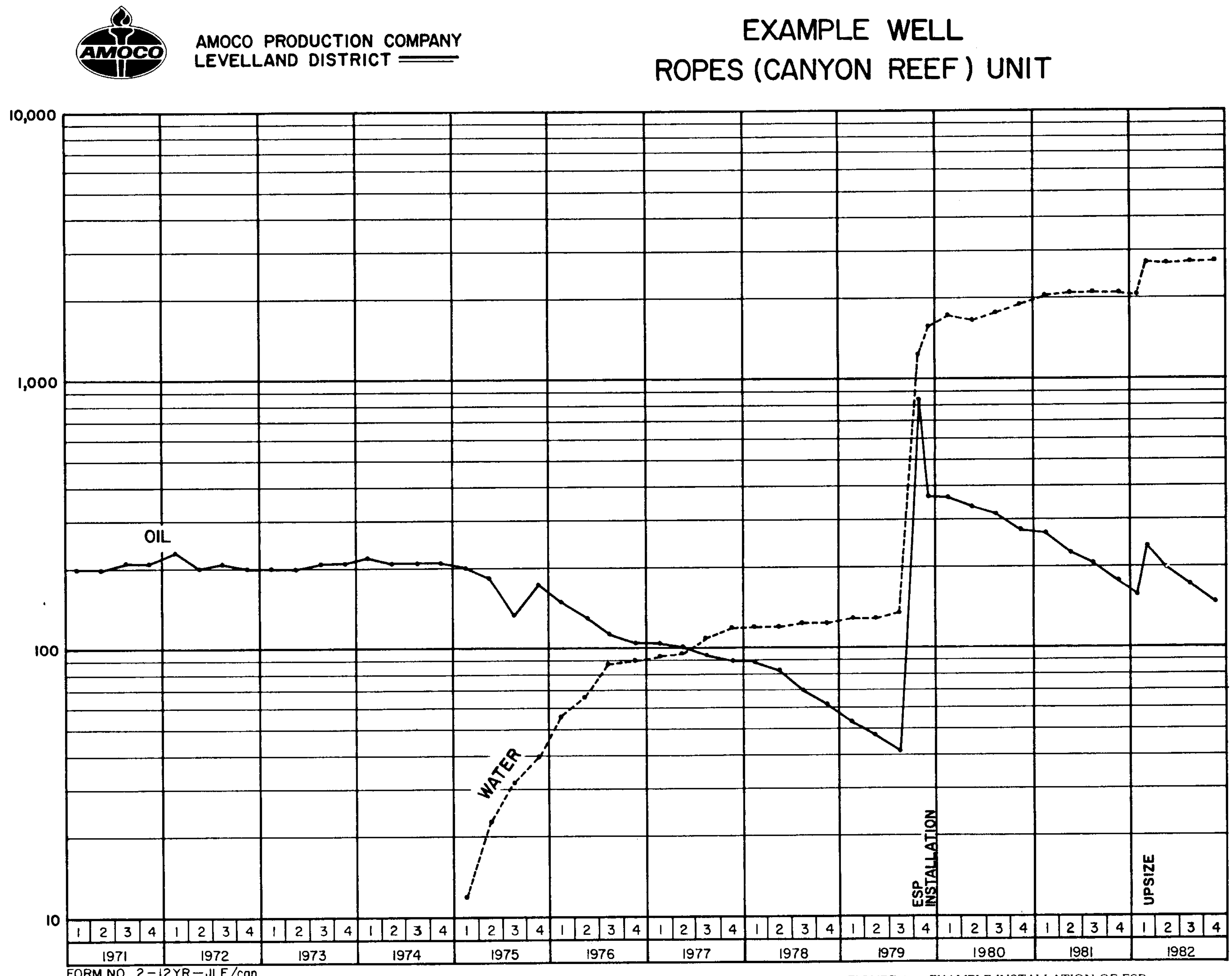

FIGURE 4 — EXAMPLE INSTALLATION OF ESP

ROPES (CANYON REEF) UNIT
ESP INSTALLATION RESULTS

DATE	PRODUCTION DATA (BOPD x BWPD) PRIOR	PRODUCTION DATA (BOPD x BWPD) 30 DAY	Oil Cut (Percent) PRIOR	Oil Cut (Percent) 30-Day
3/78	30 x 340	154 x 1755	8.1	8.0
3/78	35 x 370	152 x 8149	8.6	1.8
10/78	6 x 135	106 x 1458	4.2	6.7
10/78	91 x 180	247 x 788	33.5	23.8
10/78	5 x 440	241 x 3091	1.1	7.2
12/78	29 x 126	151 x 744	18.7	16.8
12/78	3 x 145	175 x 1406	2.0	11.0
12/78	60 x 180	247 x 966	25.0	20.3
3/79	21 x 190	376 x 1312	9.9	22.2
3/79	45 x 198	515 x 1247	18.5	29.2
5/79	1 x 280	87 x 2260	.3	3.7
5/79	11 x 120	12 x 1250	8.3	.9
5/79	50 x 190	206 x 1797	20.8	10.2
7/79	20 x 140	208 x 802	12.5	20.5
7/79	5 x 210	65 x 1566	2.3	3.9
8/79	SI	158 x 400	0.0	28.3
8/79	SI	40 x 577	0.0	6.4
8/79	23 x 215	378 x 793	9.6	32.2
8/79	60 x94	656 x 1476	38.9	30.7
8/79	120 x 140	949 x 1458	46.1	39.4
8/79	2 x 250	403 x 4133	.7	8.8
9/79	4 x 280	23 x 3410	1.4	.6
9/79	SI	4 x 950	0.0	.4
10/79	SI	6 x 1900	0.0	.3
11/79	2 x 130	55 x 710	1.5	7.1
11/79	35 x 95	481 x 1813	26.9	20.9
11/79	SI	21 x 1355	0.0	1.5
Field Average	827 x 4279	6116 x 51,845	16.2	10.6

FIGURE 5

ROPES (CANYON REEF) UNIT

Upsizing Results

Date	Prior Production (BOPD X BWPD)	Production After Upsizing (BOPD X BWPD) 30 Day	60 Day	90 Day	Payout (Days)	Reserve Growth (Barrels)
10/81	19 x 1400	40 x 1750	31 x 1730	38 x 1750	72	30,700
11/81	82 x 1210	125 x 1660	127 x 1680	136 x 1660	47	28,200
2/82	78 x 4050	165 x 6800	153 x 6860	150 x 6890	13	112,300
3/82	108 x 1020	184 x 1580	186 x 1570	159 x 1600	24	46,900
6/82	16 x 1950	33 x 3540	25 x 3540	37 x 3530	42	7,700
7/82	80 x 840	165 x 2010	145 x 2000	149 x 2000	13	118,300
11/82	39 x 1200	182 x 6350	230 x 6925	206 x 6860	61	110,900
Total	422 x 11,670	894 x 23,690	897 x 24,305	875 x 24,290		455,000
Total Increase		+472 BOPD	+475 BOPD	+453 BOPD		

FIGURE 6

ECONOMIC LIMIT IN BARRELS OF OIL / DAY Vs. MOTOR HORSEPOWER FOR ESP

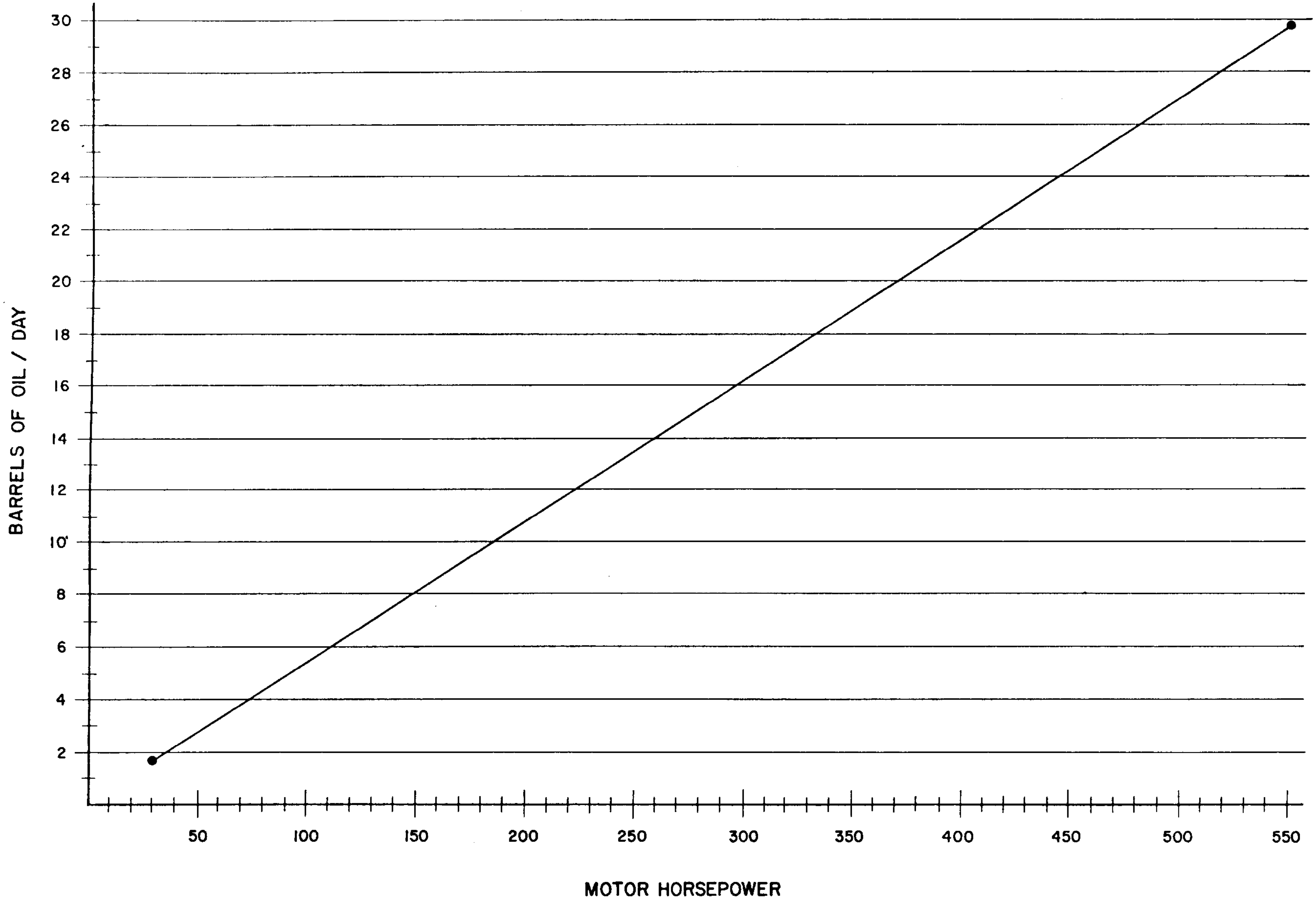

FIGURE 7