A CASE STUDY OF THE SELECTION PROCEDURE FOR ARTIFICIAL LIFT IN A HIGH CAPACITY RESERVOIR

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Abstract:

This paper is a case study of the selection procedure for the various types of artificial lift equipment utilized in the Reinecke Unit, Reinecke Field, Borden County, Texas. The considerations involved in choosing a Jet pump, Submersible pump, or Rod pump for maintaining optimum production performance in a high capacity reservoir are reviewed and evaluated.

Conclusion:

After ten years of operating artificial lift systems at the Reinecke Unit, an evaluation of the initial investments and operating expenses showed the Rod pump to be the most economic lift method for lower volume wells.

For higher volume wells, a comparison between the Jet pump and the Submersible pump showed the Submersible to be the most economic in cases of pump intake pressure under 700 psi and production rates under 850 BPD. The Submersible pumps had lower than expected operating expenses because of the ideal operating conditions at Reinecke. As production rates increased above 850 BPD, the Jet pump became more economic because the power requirements increased more rapidly for the Submersible pump.

Besides being more economical at higher rates, the Jet pumps offered operating advantages due to their versatility with varying production volumes.

Introduction:

The Reinecke Unit is located thirty miles southwest of Snyder, Texas. The unit currently (1987) produces 3,200 BOPD and 37,500 BWPD with a GOR of 1400. There are 54 wells producing from the Canyon Reef formation at a depth of 6600' to 6850'. Sixteen of the wells are on Rod pump, twenty-seven of the wells are on Jet pump, eight of the wells are on Submersible pump, and three of the wells are flowing. Normal casing size is 5 1/2 inches.

The field was discovered in February, 1950 by W. Reinecke No. 1. As the field was developed, the wells flowed due to an adequate water drive for moderate production levels. Water injection for pressure maintenance commenced in May, 1972. By the late 1970's, increasing water production led to the need for artificial lift.

Wells producing less than 500 BPD were placed on Rod pumps. Wells producing more than 500 BPD were placed on Jet pumps or Submersible pumps. Jet pumps were predominantly used instead of Submersible pumps because of the availability of inexpensive fuel gas.

Initial Artificial Lift Installation:

In twenty-nine of the producing wells, no attempt was made to lower the pump intake pressure to increase oil production. Experience had shown that oil production remained constant during increases in total fluid. An initial production volume of 1500 BPD total fluid was chosen, and equipment was designed based only on fluid production.

Rod pumps were utilized on wells producing 500 BPD or less. This system was considered to be the most economic. However, it was limited in application due to strength and weight of the rod string.

Jet pumps and Submersible pumps were compared for wells producing more than 500 BPD. The decision was made to utilize Jet pumps because the required high pump intake pressure was not burdensome and the units could be powered by inexpensive natural gas.

Equipment Utilized at Reinecke Unit:

The Jet pump power fluids are generated by National Oilwell Unidraulic Units. The downhole systems are standard casing free. The pumps are normally 9A or 10A nozzle-throat systems. The surface equipment is a dual vessel cleaning unit with a 26"x6' 300 psi vertical accumulator vessel and a 60"x20' 240 psi horizontal reservoir vessel. The reservoir vessels are oversized so that the power fluid is not depleted during periods of high gas production. The power fluid is produced water because of foaming problems experienced with oil. The power fluid pump on twenty-one wells is a National Oilwell J-165 Triplex Pump with an aluminum bronze fluid end. The pump is rated for an input power of 165 HP with a maximum displacement of 3160 BPD at 2750 psi. The maximum pressure is 5000 psi at a rate of 1575 BPD. The equipment is powered by a Waukesha F1197 multicylinder natural gas engine rated for a maximum output of 300 BHP. For this evaluation, a maximum pressure of 4000 psi and power of 150 HP was used. The initial investment for this system is $158,600 (see Table 1).

Five wells operate with smaller Unidraulic units. They utilize a National Oilwell J-100 Triplex Pump. The pump is rated for an input power of 100 HP with a maximum displacement of 2210 BPD at 2500 psi. The maximum pressure is 5000 psi at a rate of 980 BPD. The units are powered with a Waukesha F817 which is rated for a maximum output of 233 BHP.

The Submersible pumps are provided by Centrilift. They are tapered pumps with motors averaging 75 HP in size. The initial investment for this system is $73,080 (see Table 2).

The Rod pumping wells utilize varying pumping unit sizes, with the largest being an M640-365-144 from Lufkin. The units are normally powered with electric motors for versatility of operation. The initial investment for this system, using the M640, is $103,030 (see Table 3).

Comparing the Three Artificial Lift Systems for Production of Less Than 500 BPD:

Wells in the Reinecke Unit can be powered with either processed field gas or electricity. The dry field gas is sold for $.50 an MCF. This calculates to an average cost of $.0058 per HP hour. The average electric cost is $.039 per KWHr, including power factor. This calculates to an average cost of $.029 per HP hour. The cost of electricity is five times the cost of gas.

A Reinecke Rod pump well costs an average of $470 per month for maintenance (see Table 4). To pump a well at 500 BPD with a pump intake pressure of 150 psi requires 51 HP. Using electricity as the power source, the monthly operating expense is $1,560.

To pump a well under the same conditions with a Submersible pump would require a downhole power of 50 HP. The monthly operating expense would be $2,460. To pump a well under these conditions with a Jet pump would require more than 150 HP, the maximum range set for the J-165. For this comparison, a Jet operating at a maximum output of 150 HP was used. The monthly operating expense would be $2,090 (these costs are discussed in detail in the next section).

Table 7 shows the comparison between the Rod pump, the Jet pump, and the Submersible pump. The Rod pump is the most economical means of artificial lift.

In recent years advancements have been made in fiberglass rods and pump off controllers. Utilizing this equipment will increase the range of a Rod pump above 500 BPD. This system will require a higher initial investment than the standard Rod pump, and possibly a higher monthly operating expense, but may still be more economical than the Jet or Submersible pump.

Comparing Jet Pumps to Submersible Pumps for Production of More Than 500 BPD:

1. Personnel

The Jet pumps require more man-hours of labor and supervision to be properly maintained. Once a Submersible pump is installed, it must be monitored at regular intervals to determine that it is operating. However, no daily servicing is needed. The engines and triplex pumps of the Unidraulic units require daily and monthly maintenance. The pumpers must service the units on a daily basis, checking the oil and anti-freeze, and adjusting the units to the proper operating pressures. A roustabout crew performs routine oil changes and makes minor repairs.

A full time roustabout crew spends 75% of their time servicing the Unidraulic units. This cost is an additional expense of operating the Jet pumps. Including personnel and transportation, this service costs $280 a month per Unidraulic.

2. Oil and Anti-freeze

The Unidraulic units use oil and anti-freeze at a cost of $130 a month per unit. This cost includes oil needed for both daily use and routine oil changes, year round anti-freeze for better heat transfer, and contract steam cleaning of the radiators to remove oil and debris from the vents.

3. Chemicals

Both the Jet pumps and the Sub pumps are treated with a corrosion chemical. The Jet pumps are treated continuously with a small chemical pump at each unit, and the Sub pumps are treated biweekly by a chemical truck. The monthly chemical cost for the Jet pump is $290 versus $70 for the Sub pump. The difference in cost is due to the treatment of the power fluid.

4. Overhauling Parts and Labor

In addition to the routine maintenance performed by the company personnel, the Waukesha engines require an overhaul an average of every 26,000 operating hours. The costs of replacement parts, outside labor, and engine replacement average $240 a month per engine.

The cost of replacement parts for the triplex pumps averages $270 a month per pump.

5. Downhole Repairs

The Jet pump is the most convenient means of artificial lift with respect to downhole repairs. In most cases, the pump can be retrieved by reversing the flow and circulating the pump to the surface. If the pump is stuck due to a small amount of scale or iron sulfide, it can be retrieved with a sand line. This situation also makes it easy to run downhole pressure surveys to determine proper pump sizing. The pumps have no moving parts to wear, and are made of corrosion resistant materials. The downhole repair costs have averaged $90 per month per unit.

The Submersible pumps at the Reinecke field have had exceptional service lives. The pumps are operated with a high pump intake pressure, at a moderate downhole temperature of 130 deg F, in a non-corrosive environment, and on a continuous basis. The pumps have had a service life of seven years, and the motors have had a service life of three years. The majority of service calls performed by Centrilift are to replace fuses and repair other damage from electrical storms. The total downhole and servicing expenses have averaged $740 per month per pump.

Based on these considerations, the total operating cost, excluding power, is $1,430 per month per unit for the Jet pump (see Table 5), and $940 per month per unit for the Sub pump (see Table 6).

6. Power Requirements and Economic Comparisons

In order to compare the two systems on an equal basis, a standard well situation was formulated, and computer programs were used to determine horsepower needs. The following input information, based on conditions at the Reinecke field, was used:

Pump Depth:	6850	Feet
Water Cut:	90	%
Oil Gravity:	42.5	Deg. API
Water Gravity:	1.05	Specific Gravity
Oil Viscosity:	1.5	Centipoise
Water Viscosity:	1	Centipoise
Gas Oil Ratio:	0	
Flowline Pressure:	125	PSI
Tubing Size:	2	Inch
Casing Size:	5 1/2	Inch
Power Fluid:	Water	
Form. Vol. Fac.:	1.72	

The only input value that is not representative of the actual conditions at Reinecke was the GOR of zero. Normally, the wells have GOR's in the range of 900 to 1400 Cubic Feet per Barrel. However, this value was set to zero because the Jet pump program is only accurate for small amounts of gas. The zero GOR was also used in the calculations for the Submersible pump. The assumption was made that the energy requirements for each system under higher GOR's would change in the same magnitude.

The maximum size Jet pump that can be used at Reinecke with a J-165 Unidraulic is a 10A. This is based on a maximum input of 150 HP and a maximum pressure of 4,000 psi. Chart 1 shows the maximum production that can be reached at varying pump intake pressures. This chart is based on calculations presented by Petrie, Wilson, and Smart in their paper at the 1983 Southwestern Petroleum Short Course (2).

At 600 BPD with a pump intake pressure of 700 psi, the Jet pump requires an operating power of 107 HP, and the Submersible pump requires 46 HP. Table 8 shows the economic comparison. The Submersible pump is more economic. The lower monthly operating expense of the Jet pump is offset by the higher initial investment.

At 850 BPD with a pump intake pressure of 700 psi, the Jet pump requires an operating power of 150 HP, and the Submersible pump requires 57 HP. Table 9 shows the economic comparison. Except for the 0% discount rate, the Submersible pump is more economic. Once again, the lower monthly operating expense of the Jet pump is offset by the higher initial investment.

At 1200 BPD with a pump intake pressure of 1400 psi, the Jet pump requires 150 HP and the submersible pump requires 67 HP. Table 10 shows the economic comparison. Except for the 20% discount rate, the Jet pump is more economic. The power requirements for the Submersible pump rose faster than those for the Jet pump.

These comparisons show that the economics begin to favor the Jet pump as the fluid volume increases.

Operational Considerations:

Jet pumps have operational advantages over Submersible pumps. The Submersible pump has a greater risk of becoming lodged in the well, due to the power cable. The Submersible pump can be damaged if it reaches a pumped off condition. The Jet pump can be quickly and inexpensively adjusted for changing production rates. In a corrosive environment, the Jet pump provides better distribution of corrosion inhibition. Downhole Jet pumps can normally be exchanged in less than three hours. In addition, downhole pressure data can be obtained easily.

Acknowledgments

Although it is not the intention of this paper to endorse the services of any particular company, the authors would like to thank Ed Peet of Centrilift, David Devine of Electrical Submersible Pump, Jack King of National Oilwell, and David Mayes of Reef Chemical for their help.

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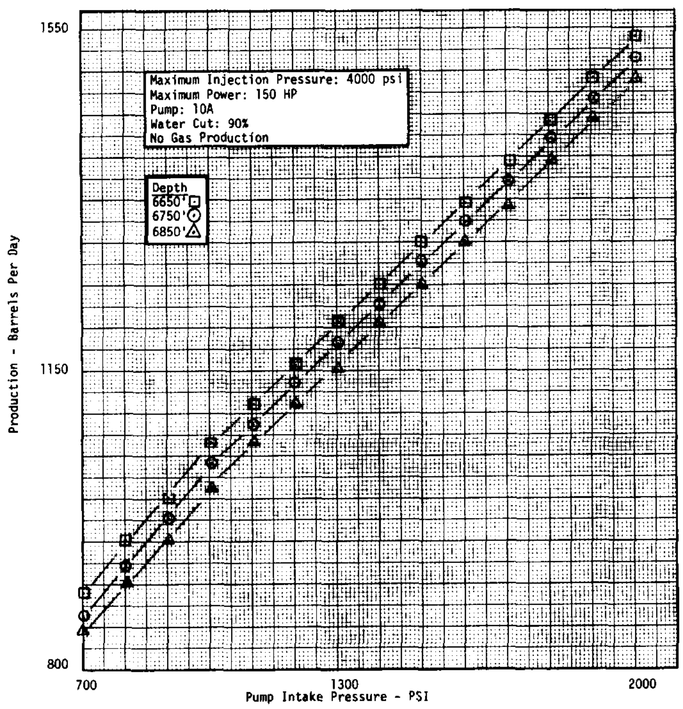

Chart 1
REINECKE UNIT
Maximum Production with Unidraulic J-165

Table 1
Jet Pump Installation Costs

Flow & Gas Lines:	
3" Fiberglass - 2000'	$ 3,780
Labor	1,500
2" Fiberglass - 2000'	2,800
Labor	1,500
	$ 9,580
Equipment Costs:	
J-165 Unidraulic	$ 76,700
Engine - Waukesha 1197	36,000
2 3/8" Tubing - 6850'	21,000
Packer	2,900
Tubing Value	920
Flow Meter	620
Chemical Pump	570
Gauges & Muffler	500
Pressure Regulator	600
Plate Pump Cavity	150
Connections	3,000
	$ 142,960
Labor for Equipment:	
Construction Crew & Equipment	$ 2,800
Company Crew (for Engine)	470
Pulling Unit	1,750
BOP	350
Pump Truck	190
Tandum	500
	$ 6,060
Total	$ 158,600

Table 2
Submersible Pump Installation Costs

Flow & Gas Lines:	
3" Fiberglass - 2000'	$ 3,780
Labor	1,500
Power Line - 2000'	4,000
	$ 9,280
Equipment Costs:	
Submersible Pump w/ Cable	$ 36,500
2 3/8" Tubing - 6850'	21,000
Well Head	2,200
Connections	1,000
	$ 60,700
Labor for Equipment:	
Pulling Unit	$ 1,750
Spooler	600
BOP	350
Well Head	400
	$ 3,100
Total	$ 73,080

Table 3
Rod Pump Installation Costs

Flow & Gas Lines:	
3" Fiberglass - 2000'	$ 3,780
Labor	1,500
Power Line - 2000'	4,000
	$ 9,280
Equipment Costs:	
Pumping Unit - M640-365-144	$ 45,200
Electric Motor - 60 HP	5,500
2 7/8" Tubing - 6850'	25,500
Rods - 86 taper	7,500
Rod Pump	1,000
Tubing Anchor	1,000
Beam Switch	250
Well.Head Connections	2,200
	$ 88,150
Labor for Equipment:	
Setting Pumping Unit	$ 3,000
Pulling Unit	1,750
BOP	350
Trucking	500
	$ 5,600
Total	$ 103,030

Table 4
Rod Pump Monthly Maintenance Expense

Pumper		$ 130
Chemical		70
Grease & Misc.		20
Downhole Repairs		
Pulling Unit	(3 jobs / 2 yrs)	130
Pump Repairs	(3 / 2 yrs)	70
Rod Repairs	(1 / yrs)	40
Tubing Repairs	(1 / 2 yrs)	10
		$ 470

Table 5
Jet Pump Monthly Mantenance Expense

Pumper	$ 130
Maintenance Crew	280
Oil & Antifreeze	115
Steam Cleaning	15
Chemical	290
Parts & Overhauls	510
Downhole Repairs	90
	$ 1,430

Table 6
Submersible Pump Monthly Operating Expense

Pumper		$ 130
Service Calls	(2 calls / yr)	60
Chemical		70
Downhole Repairs	(Motor - 3 yrs, Pump - 7 yrs)	680
		$ 940

Table 7
Economics for Artificial Lift in the Reinecke Unit
500 BPD

Water Cut:	90 %
Pump Intake Pressure:	150 psi

	Rod	Jet	Submersible
Initial Investment	$103,030	$158,000	$73,080
Monthly Oper. Expense	$1,560	$2,090	$2,460
Vol. Fluid Lifted - Bbl	500	450	500
Lift Cost - $/Bbl	$.10	$.15	$.16

Before Tax Present Worth Cost Over A Ten Year Period

	Present Worth		
0% Discount Rate	$365,453	$504,863	$477,872
10% Discount Rate	$272,827	$382,236	$334,301
20% Discount Rate	$224,582	$318,440	$259,650

Incremental Savings of Rod Pump

	Discount Rate		
	0%	10%	20%
Rod vs. Jet	$139,409	$109,408	$93,858
Rod vs. Submersible	$112,418	$61,473	$35,067

Table 8
Economics for Artificial Lift in the Reinecke Unit
600 BPD

Water Cut:	90 %
Pump Intake Pressure:	700 psi

	Jet	Submersible
Initial Investment	$158,000	$73,080
Monthly Oper. Expense	$1,900	$2,350
Vol. Fluid Lifted - Bbl	600	600
Lift Cost - $/Bbl	$ .10	$ .13

Before Tax Present Worth Cost Over A Ten Year Period

	Present Worth	
0% Discount Rate	$474,807	$460,471
10% Discount Rate	$362,935	$323,127
20% Discount Rate	$304,714	$251,703

Incremental Savings of Submersible pump

	Discount Rate		
	0%	10%	20%
Submersible vs. Jet	$14,336	$39,808	$53,011

Table 9
Economics for Artificial Lift in the Reinecke Unit
850 BPD

Water Cut:	90 %
Pump Intake Pressure:	700 psi

	Jet	Submersible
Initial Investment	$158,000	$73,080
Monthly Oper. Expense	$2,090	$2,670
Vol. Fluid Lifted - Bbl	850	850
Lift Cost - $/Bbl	$ .08	$ .10

Before Tax Present Worth Cost Over A Ten Year Period
Present Worth

0% Discount Rate	$504,863	$511,091
10% Discount Rate	$382,236	$355,633
20% Discount Rate	$318,440	$274,820

Incremental Savings of Submersible pump

	Discount Rate		
	0%	10%	20%
Submersible vs. Jet	-$6,228	$26,603	$43,620

Table 10
Economics for Artificial Lift in the Reinecke Unit
1200 BPD

Water Cut:	90 %
Pump Intake Pressure:	1400 psi

	Jet	Submersible
Initial Investment	$158,000	$73,080
Monthly Oper. Expense	$2,090	$2,980
Vol. Fluid Lifted - Bbl	1200	1200
Lift Cost - $/Bbl	$ .06	$ .08

Before Tax Present Worth Cost Over A Ten Year Period
Present Worth

0% Discount Rate	$504,863	$560,129
10% Discount Rate	$382,236	$387,123
20% Discount Rate	$318,440	$297,215

Incremental Savings of Jet pump

	Discount Rate		
	0%	10%	20%
Jet vs. Submersible	$55,266	$4,887	-$21,225