TOTAL SYSTEM COST COMPARISON (ESP vs. BEAM PUMP) IN AMOCO'S NORTHERN PERMIAN BASIN OPERATING AREA

Keith Cheatham

Amoco E & P, Levelland, TX

Abstract

This paper presents the results of a Total System Cost Comparison program between Electric Submersible Pump's (ESP's) and Beam Lift Pumps that are typical within Amoco's northern Permian Basin operating areas. This program calculates a common variable of, $/BFPD, for Total System Cost and Operating and Maintenance Cost. This common variable may be used to help the operator make the best decision regarding economics, on which type lift to use. The calculation takes into account all equipment cost, all installation cost, all repair cost and all operating cost for a typical 10 year period of time at a specified depth and volume. Also considered in calculating the repair cost for a 10 year period of time is the type failures, cost per type failure and frequency of these failures that are typical within these operating areas.

Conclusions

The important conclusion in system cost comparison determined by this study is that the failure frequency of the two lift systems is the one most important variable to consider as the determining factor. The other components of the system, equipment, servicing, power consumption cost, are much more stable, than the failure frequency, especially on beam lift wells.

When considering the failure frequencies, power consumption, service cost and equipment cost that are typical in this operating area, the following conclusions can be made. For producing depths of 4800 ft and wells with 5.5" casing and when considering "Total System Cost", the Beam Pump lift is most economical for volumes up to approximately 320 BFPD, with the ESP lift becoming the most economical for volumes over approximately 320 BFPD. However, for this same depth and casing size, when considering only the "Operating and Maintenance Cost", the Beam Pump lift is most economical for volumes up to approximately 500 BFPD, with the ESP lift becoming the most economical for volumes over approximately 500 BFPD.

These break over points in volume, where the ESP lift becomes more economical than the Beam Pump lift becomes less as the producing depth increases. For example: At 6300 ft and 5.5" casing and considering "Total System Cost", the ESP lift becomes more economical at approximately 300 BFPD and when considering only the "Operating and Maintenance Cost", the ESP lift becomes more economical at approximately 430 BFPD.

Introduction

The northern Permian basin operating area is located in West Texas as illustrated in Figure 1. The main fields, reservoir conditions and oil properties in this operating area is listed in Figure 2.

There have been many comparisons made in the past between beam pumping units and ESP's. However, when considering the reasons mentioned below, it became an obvious benefit to produce this cost comparison program.

This study is not intended to eliminate the need to evaluate each well on a case by case basis as to the most economical type lift to use. However, this study is intended to illustrate that ESP type lift can be the most economical type lift for volumes low as 300 BFPD when considering total system cost detailed in this paper. Another important thought to keep in mind while interpreting the comparisons made in this paper is that there are many variables in these comparisons and it is not the intention of this study to project these comparisons to be appropriate for other operating areas. One of the big benefits of the program developed which is the source of the comparisons reported in this paper, is that it provides the user the opportunity to adjust the $/KWH, equipment cost, service cost, failure frequencies, etc. to fit the area, field or specific well you are interested in evaluating.

The most common objection against the use of ESP's has been the electrical power cost, and as you will see, the comparisons presented in this paper, will indicate, there is in some instances, a substantial operating cost difference. As you will see in this study, this operating cost difference is largest at the smaller volumes and depths. Also note, that this operating cost difference is becoming less (reference Figure 3), with the reduction in cost/KWH from the power supply companies.

In this operating area, as you will see in this paper, with alliance pricing structures established in our ESP and Beam Pump operations, the one variable that becomes the most important determining factor in cost comparison is the failure frequency of the two type lifts. The ESP failure frequency varies very little from one field to the other, but on the other hand the beam pump failure frequency can vary drastically from one well to the next within the same field. As a result, the cost comparison conclusions in this paper will not be representative of all wells in this operating area.

Listed below is a summary of the many reasons considered in the decision to develop this cost comparison program:

1. The increased emphasis on reducing operating cost created a situation where the ESP and it's higher KWH usage, made it a quick and easy target for reducing electrical power cost.
2. There is a need for a quick, easy way to make lift revision economic recommendations.
3. The excellent and continued improving ESP failure frequency needs to be considered when comparing economics to other type lift systems.

4. The lower KWH rates that are being obtained from our power supply companies has reduced the operating cost difference from ESP to Beam. Reference Figure 3.
5. The newly acquired Centrilift alliance pricing structure created a situation where the ESP equipment cost could be figured exactly and counted on to stay the same at least for the near future.
6. The more mature the cost reduction efforts have become, the more the need to analysis "Total System Cost" to attain continued cost reductions.

ESP History

The history of the number of ESP installations in this operating area is illustrated in Figure 4. As you can see the total number of installations at any one point in time peaked in 1987 at approximately 355 wells. Due to property divestment, CO2 flooding, less water production, lower FAP's and the emphasis on cutting the electrical power cost, the current number of ESP installations has been reduced to 183 wells as of Jan. 1, 1996.

The history of our number of ESP failures by year and the corresponding failure frequency (failures/well/year) by year is illustrated in Figure 5. As you can see, the number of failures follow along with the number of installations to a degree. However, the failure frequency curve illustrates that our ESP failures per installation, per year has been on a steady decline since 1979. Since 1990, this decline rate has increased. The average ESP failure frequency for the last four years (1992-1995) is 0.231.

Another measure of our ESP performance we use in our operating area is the actual runtime and in-service runtime in days for each failure. You can see as illustrated in Figure 6 that our runtime per failure average per year has over the years increased from around 175 days in 1975 to 944 days in 1995. Also you will notice that the in-service runtime (accumulated in-hole service days) of the failed component has increased from 175 days in 1975 to 1479 days in 1995.

As you will see later in this paper the "Total System Cost" comparison program uses the failure figures as an important component in calculating the resulting $/BFPD. With this in mind, the ESP failure frequency will be used in the program to calculate the repair and maintenance cost. Also, since the different type failures have a wide range of repair cost, this program uses the failure frequency of each type failure. This results in much more accurate results in the final analysis. The actual average frequency for the last 4 years (1992-1995), of all type pulling jobs performed on our ESP wells can be seen in Figure 7. You will notice that the pull frequency relating to failures will add up to our average failure frequency for the last 4 years of 0.231 failures per well per year.

Beam Pump Performance History

In our operating area with as many fields and wells as there are, and with the organizational structure as it is, and with the geographic location between these fields as it is, there is not one specific individual dedicated to maintaining Beam pump performance records. As a result, in an effort to obtain as accurate

Beam pump failure rates as possible, several sources were used: CRWS reports, input from lift coordinators, scorecards from the various operating centers, previous papers, etc..

As illustrated in an excerpt from a Dec. 17, 1991 memorandum entitled "Operating Expense Comparison of Electrical Submersible Pumps (ESP's) and Beam Pumping Units for High Volume Lift Applications" by Joseph D. Minissale, which is included as Attachment No 1, the beam pump failure frequencies are strictly dependent on volume and depth. With all of the above mentioned sources considered, the beam pump failure frequency at 4800 ft depth and 300 BFPD for this cost comparison, is 0.70. This might be considered a liberal failure frequency in some areas, and not so liberal in others. Considering spot checks from recent history on wells and the Attachment No. 1 described above, the beam pump failure frequency will increase with increased depth and volume based on the rate of increase illustrated in Attachment No. 1.

Listed in Figure 8 is the breakdown of pull frequencies for beam pumped wells producing 300 BFPD at a depth of 4800 ft. The surface equipment failures such as the motor failures, sheave failures and belt failures will stay the same for all depths and volumes assuming the proper size motors and belts are used in each application.

"Total System Cost" Program

The Total System Cost program was developed in Excel 5.0. It consists of a main menu screen as seen in Figure 9, where the user can enter the time period of the valuation, the current $/KWH to use for the evaluation, and then select the corresponding button for the volume and casing size of the particular well being evaluated.

When the user selects an ESP button, a cost comparison summary screen as seen in Figure 10 will appear, where all on the same screen the user can edit the ESP KWH/Day and the ESP failure frequencies and simultaneously view the resulting cost comparison, for the time period chosen, in electrical, Total System Cost and Operating and Maintenance Cost. From this summary screen the user can, if needed, view the detailed section of this volume and casing size selected, as seen in Figure 11. In this detailed section the user would be able to view the entire section and edit the ESP equipment cost and service cost if needed. From the summary or detailed screen the user returns to the main menu.

If, from the main menu, the user selects a Beam Lift button, a cost comparison summary screen as seen in Figure 12 will appear. This Beam lift summary screen is similar to the ESP summary screen except for the different type failures that occur on Beam lift wells. From this summary screen the user can view the detailed section of this volume selected, as seen in Figure 13. Again in this detail section, the user can view the entire section and edit the beam lift equipment cost and service cost if needed. From this summary or detailed screen the user returns to the main menu.

The only other option the user has from the main menu is to select a graph display button that will display a set of three graphs as seen in Figure 14, for the resulting Electrical, Total System Cost and Operating and Maintenance Cost comparison for the casing size and depth selected. There is a set of these graphs for each depth and casing size used in this comparison program. The results in these graphs will be based on the cost component variables as they are set at the time the graphs are produced. As the variables are changed in the summary screens or detail sections of the program, these graphs will simultaneously reflect the new results. Each set of graphs consist of the following:

1. **Electrical Cost Per Year:** This graph plots a line representing the resulting electrical cost per year for each volume considered in the program for the beam lift system and the ESP lift system.
2. **Total System Cost:** This graph plots a line for the resulting total system cost $/BFPD variable for each volume considered for the beam lift system and the ESP lift system. You may notice in Figure 14, that for this particular instance, if considering total system cost, the ESP lift system becomes more economical at approximately 320 BFPD. This is where the ESP curve drops below the beam lift curve.
3. **Operating & Maintenance Cost:** In this graph there is a line plotted for the resulting operating and maintenance $/BFPD variable for each volume considered in the program for the beam lift system and the ESP system. If the user is more interested in comparing the operating and maintenance cost for this same well, you will notice in Figure 14, that in this particular instance, the beam lift system is the most economical up to approximately 500 BFPD. This is the approximate point where the beam lift curve moves above the ESP curve.

This program calculates cost comparisons in three ways. One of these is the electrical power consumption cost comparison, and as a result of the initial complete new unit cost of the ESP system being substantially less than a Beam Pump system, there is two system cost comparisons made.

- **"Total System Cost":** This is where all equipment for a complete new installation is considered. Assuming the operator has nothing on the well at the time and purchases the entire system, from the transformers to the downhole pump. This complete new installation is considered one time in addition to the operating and maintenance cost for the remaining 10 year period of time.

- **"Operating & Maintenance Cost":** This is where the operating & maintenance cost for the 10 year period of time is considered without the one time complete new installation cost. This cost comparison is more appropriate in an operating area such as this, where there is surplus equipment available for both type systems, and day to day operating cost becomes more important.

ESP Total System Cost Details

The three cost comparisons as mentioned above (Electrical, Total System Cost and Operating & Maintenance Cost) are calculated on one spreadsheet as seen in Figure 11 for each of the casing sizes and volumes considered. It is in this spreadsheet, where all the components of total system cost come together to determine a resulting $/BFPD variable that can be used for comparing. You will notice some values are not shown to protect our commitment, and the rights of our alliance partners and suppliers. This paper is not intended to be used as a pricing comparison from one area to the next. The following is an itemization of all the components of the ESP lift system, with a brief description and procedure for determining the value used for each.

1. **Equipment Cost:** Every component of the system is considered, including the pump, intake, seal, motor, motor lead cable, main cable, tubing, wellhead, controller and transformers. A specific design has been made for each volume, depth and casing size. The actual prices for each component of the resulting design is entered. The list prices, system discounts and component discounts are used in many different ways in this spreadsheet.
2. **Pull/Install:** This is where the pump service, spooling/banding, pulling unit and trucking cost are entered for the typical job. The cost entered for each of these services is the average cost for a normal job for this volume, depth and casing size. The depth of the well is especially considered in these costs. Abnormal job cost are not considered.
3. **Cable Repair:** This is the typical cable repair cost for jobs where the cable has failed or failed hypot test after pulling. The normal cable work cost is included in the spooling/banding under Pull/Install, but for the few jobs we have determined by our cable failure frequency, this cable repair cost is also considered. This cable repair cost is adjusted in this program by depth and cable size were applicable.
4. **Corrosion Coating:** This is the typical corrosion coating expense for the motors and seals. This expense is used in the calculation only when applicable. Also this expense is dependent on the size and length of the equipment.
5. **Testing Equipment:** Another cost associated with our ESP operations is the equipment testing expense. This expense is entered and considered in the calculation where it is applicable. The size of the unit is also considered.
6. **Trade In Value:** When a downhole component of the ESP system fails, and it is changed out with a new component or a tested good, used component, the failed component is bought by our alliance partner at a set percentage of list price. This credit is considered in these calculations where applicable.
7. **Operating Cost:** This is where the electrical power consumption cost is considered in the calculation. This calculation is based on the $/KWH and the KWH/Day, both of which can be edited by the user. For the comparisons presented in this paper, $0.03 was used as the $/KWH and the KWH/Day was determined by the spreadsheet as seen in Figure 15. In this spreadsheet a calculation was used to determine a calculated KWH/Day for each of the depths and volumes considered in this paper. Then actual metered KWH usage for various depths and volumes were entered. An average difference between the calculated KWH and metered KWH was determined and this was used as a multiplying factor to all the calculated KWH figures. This adjusted KWH/Day was used in these comparisons for ESP lift systems. Also you will notice in this spreadsheet the electrical $/BFPD is shown. You can see that using the final adjusted KWH/Day figures, that the electrical $/BFPD will range from $0.05 to $0.09.
8. **Controller Maintenance:** This is simply an actual average expense incurred per well per year on the ESP wells in our operating area. This includes replacing motor protectors, fuses, etc. It is a minor part, but it is considered.
9. **Typical Cost/Job:** This is the typical job cost for all the various jobs incurred in this operating area on ESP wells. The equipment, pull/install, cable repair, corrosion coating, testing and trade in credit entries are used, as appropriate, in each of these type jobs to calculate a typical total job cost.
10. **Failure/Frequency Job Cost:** This is where the ESP lift system failure frequencies which can be edited by the user, is used to calculated total job cost for the evaluation time period which also can be

selected by the user. The number of jobs for the selected evaluation time period is calculated for each type job using the entered failure frequency. The calculated number of jobs is multiplied times the previously calculated typical cost/job, to determine the total job cost for the evaluation time period for each type job.

11. **Total System Cost:** In this section of the spreadsheet the resulting total system cost in $/BFPD is calculated. The total job cost including the complete new installation, electrical power cost and controller maintenance cost for the evaluation time period are added, then divided by the number of days in the time period and by the BFPD to determine the $/BFPD.
12. **Operating & Maintenance Cost:** This is a $/BFPD calculation which is determined in the exact same manner the total system cost $/BFPD is determined except that the one time, complete new installation cost is excluded. The resulting $/BFPD figure is more representative of the day to day operating and maintenance cost.

Beam Lift Total System Cost Details

The electrical, total system cost and operating & maintenance cost variables for the equivalent beam lift system is calculated in a similar way to that of the ESP lift. The typical spreadsheet used for this calculation can be seen in Figure 13. In this operating area the casing sizes common to beam lift and ESP lift has no bearing on lift system cost in regards to beam list systems. As a result the variation in cost calculations for the beam lift is based only on volume and depth. Again, you will notice some values are not shown to protect our commitment, and the rights of our alliance partners and suppliers. The following is an itemization of all the components considered in the beam lift system, with a brief description and procedure for determining the value used for each.

1. **Equipment Cost:** Every component of the system is considered, including all the downhole and surface equipment. A specific design has been made for each volume and depth. The actual prices for each component of the resulting design is entered. These prices are used in many different ways in this spreadsheet as appropriate.
2. **New Installation:** This is where the unit installation, trucking and pulling unit cost are entered for the typical job. The cost entered for each of these services is the average cost for a normal job for this volume and depth. The depth of the well is especially considered in these costs. Abnormal job cost is not considered.
3. **Operating Cost:** This is where the electrical power consumption cost is considered in the calculation. This calculation is based on the $/KWH and the KWH/Day, both of which can be edited by the user. For the comparisons presented in this paper, $0.03 was used as the $/KWH and the KWH/Day was determined by the spreadsheet as seen in Figure 16. In this spreadsheet the predicted KWH/Day generated by BLAP (Beam Lift Analysis Program) is entered as the calculated KWH/Day for each particular design for the depths and volumes considered in this paper. Then some actual metered KWH usage's for various depths and volumes were entered. An average difference between the calculated KWH and metered KWH was determined and this was used as a multiplying factor to all the calculated KWH figures. This adjusted KWH/Day was used in these comparisons for the beam lift systems. You can see that using the final adjusted KWH/Day figures, that the electrical $/BFPD for beam lift systems will range from $0.03 to $0.06.

4. **Typical Cost/Job:** This is the typical job cost for all the various jobs incurred in this operating area on beam lift wells. The equipment, installation, pulling and trucking cost are used as appropriate in each of these type jobs to calculate a typical total job cost.
5. **Yearly Service:** This is an actual average expense incurred per well, per year on beam lift wells in our operating area to service and maintain the pump jack. This is only the contracted labor cost for this service. It does not include any equipment replacement cost. It is a minor part of the total system cost, but it is considered.
6. **Failure/Frequency Job Cost:** This is where the beam lift system failure frequencies that can be edited by the user, is used to calculated total job cost for the evaluation time period that also can be selected by the user. The number of jobs for the selected evaluation time period is calculated for each type job using the entered failure frequency. The calculated number of jobs is multiplied times the previously calculated typical cost/job, to determine the total job cost for the evaluation time period for each type job.
7. **Total System Cost:** This is where the resulting total beam lift system cost in $/BFPD is calculated. The total job cost including the complete new installation, electrical power cost and yearly service cost for the evaluation time period are added, then divided by the number of days in the time period and by the BFPD to determine the $/BFPD.
8. **Operating & Maintenance Cost:** This is a $/BFPD calculation which is determined in the same manner the total system cost $/BFPD is determined except that the one time complete new installation cost is excluded. This resulting $/BFPD figure is more representative of the day to day operating and maintenance cost for beam lift wells in this operating area

Total System Cost Comparisons

The structure, flexibility and details of this program allow the resulting comparisons to illustrate just why the comparisons between beam lift systems and ESP lift systems are dependent on casing size, depth and volume. It would be impossible, or at least not practical, to illustrate each of these various combinations. As a result, there will be 4 case comparisons presented in this paper to illustrate the effect that various failure frequency rates have on total system cost:

- **Case 1:** In this case, the equipment, service and electrical cost will be as described in this paper, the average figures for this operating area. The failure frequencies for the beam lift systems and ESP lift systems will also be as determined as the average figures for this operating area. Figure 14 shows the graphs of the 3 cost comparison results for 5.5" casing and 4800 ft depths. As you can see in the "Electrical Cost Per Year" graph, the beam lift system has a lower electrical cost up to 1200 BFPD. As seen in the "Total System Cost" graph, the beam lift system is the most economical up to approximately 320 BFPD when considering total system cost. When considering the operating and maintenance cost, as seen in the "Operating & Maintenance Cost" graph, the beam lift system is the most economical up to approximately 500 BFPD, where the calculated operating and maintenance cost $/BFPD is approximately $0.063.
- **Case 2:** All the variables are exactly the same in this case with the exception of the beam lift failure frequencies. The 0.70 frequency used in Case 1 for the beam lift failures is doubled in this case to

1.4 failures per well per year. As you can see in Figure 17, when considering the operating and maintenance cost, as seen in the "Operating & Maintenance Cost" graph, the beam lift system is the most economical up to approximately 350 BFPD, where the calculated operating and maintenance cost $/BFPD is approximately $0.075.

- **Case 3:** Again all the variables are exactly the same in this case as in Case 1, with the exception of the ESP lift failure frequencies. The 0.231 frequency used in Case 1 for the ESP lift failures is doubled in this case to 0.462 failures per well per year. As you can see in Figure 18, when considering the operating and maintenance cost, as seen in the "Operating & Maintenance Cost" graph, the beam lift system is the most economical up to approximately 600 BFPD, where the calculated operating and maintenance cost $/BFPD is approximately $0.07.
- **Case 4:** Again all the variables are exactly the same in this case as in Case 1, with the exception of the beam lift and ESP lift failure frequencies. The 0.7 frequency used in Case 1 for the beam lift failures is doubled in this case to 1.4 failures per well per year. The 0.231 frequency used in Case 1 for the ESP lift failures is doubled in this case to 0.462 failures per well per year. As you can see in Figure 19, when considering the operating and maintenance cost, as seen in the "Operating & Maintenance Cost" graph, the beam lift system is the most economical up to approximately 440 BFPD, where the calculated operating and maintenance cost $/BFPD is approximately $0.08.

References

1. Minissale, Joseph D. (Amoco), "Operating Expense Comparison of Electrical Submersible Pumps (ESP's) and Beam Pumping Units for High Volume Lift Applications, 1991.

2. Miller, T.G. (Texaco), "Operating Cost of Artificial Lift Systems on the Wharton Unit, 1987.

3. Lea, J.F. (Amoco) and Wilson, B.L.(ODI), "The Role of Power Cost in the Selection of Artificial Lift Systems".

Acknowledgments

The author wishes to extend sincere gratitude and thanks to Rick Waygood and Marvin Voss (Amoco), for their extensive data input regarding the beam lift system. A very special thanks goes to Centrilift, for their comments, data input and power consumption testing. The author also wishes to thank the Amoco - Centrilift Alliance Steering Committee Team for their help, input and support of this paper.

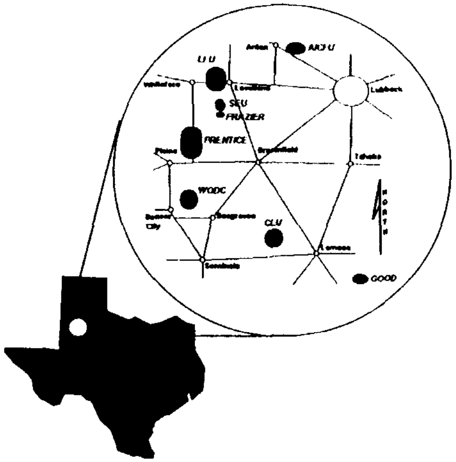


Figure 1 - Location of Operating Area

Amoco E & P
Northern Permian Basin Area

LEASE	Anton Irish Clearfork Unit	Levelland Unit	Slaughter Estate Unit	Frazier Unit	Prentice Central Clearfork Unit	Prentice CWC	Prentice Central Glorietta Unit	Prentice Southwest Unit	Cedar Lake Unit	T.J. Good
FORMATION	Clearfork	San Andres	San Andres	San Andres	Clearfork	Clearfork	Glorietta	Clearfork	San Andres	Canyon Reef
DEPTH	6100	4900	5000	5020	6300	6300	6000	6300	4600	8000
API	28	32	32	32	28	28	28	28	32	37 7
RESV TEMP	115	105	90	90	119	119	119	119	100	135
RESV PSI	2150	2250	2100	2100	2200	2200	2200	2200	2000	2000
BUBBLE POINT	1452	2000	1710	1710	2000	2000	2000	200	326	1800
GOR	250	460	760	600	400	400	400	400	250	1000
H2S	3%	1%	1%	1%	1%	1%	1%	1%	8%	sweet

Figure 2. Operating Area Conditions and Properties.

Figure 2 - Operating Area Conditions and Properties

Example:

		Beam	ESP	Difference	
Assume:	KWH/Day	720	1069	349	
	$/KWH	$0.0400	$0.0400	0	
	$/Year	$10,512	$15,607	$5,095	*

		Beam	ESP	Difference	
Assume:	KWH/Day	720	1069	349	
	$/KWH	$0.0275	$0.0275	0	
	$/Year	$7,227	$10,730	$3,503	*

*** Assuming the$/KWH is reduced from $0.04 to $0.0275, the difference in power cost from the ESP to Beam is reduced by $1,592.**

Figure 3 - Example of Lower $/KWH Rates Reducing Operating Cost Difference From ESP to Beam

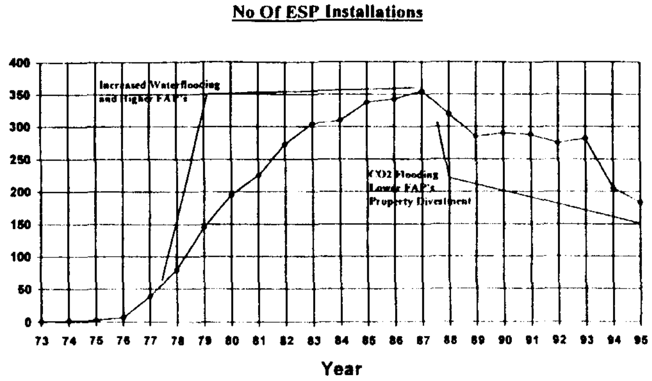


Figure 4 - No.of ESP Installations

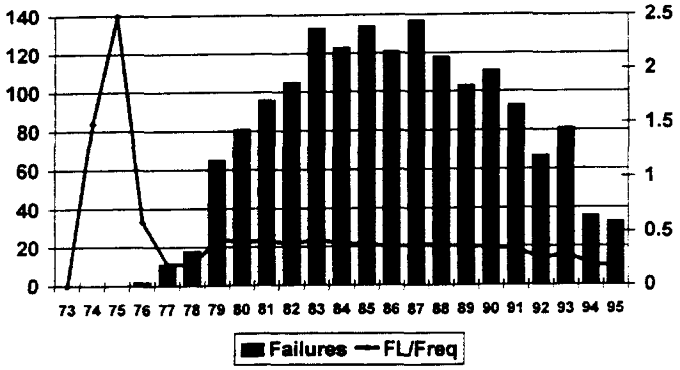


Figure 5 - No.of ESP Failures and Frequency

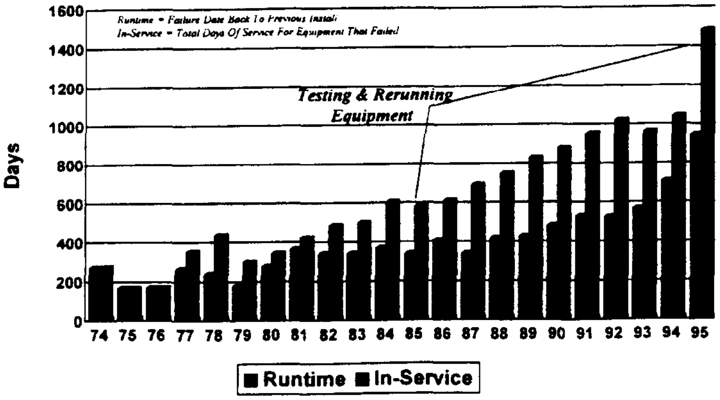


Figure 6 - ESP Failure Runtime and In-Service Time.

Amoco E & P
Northern Permian Basin Area

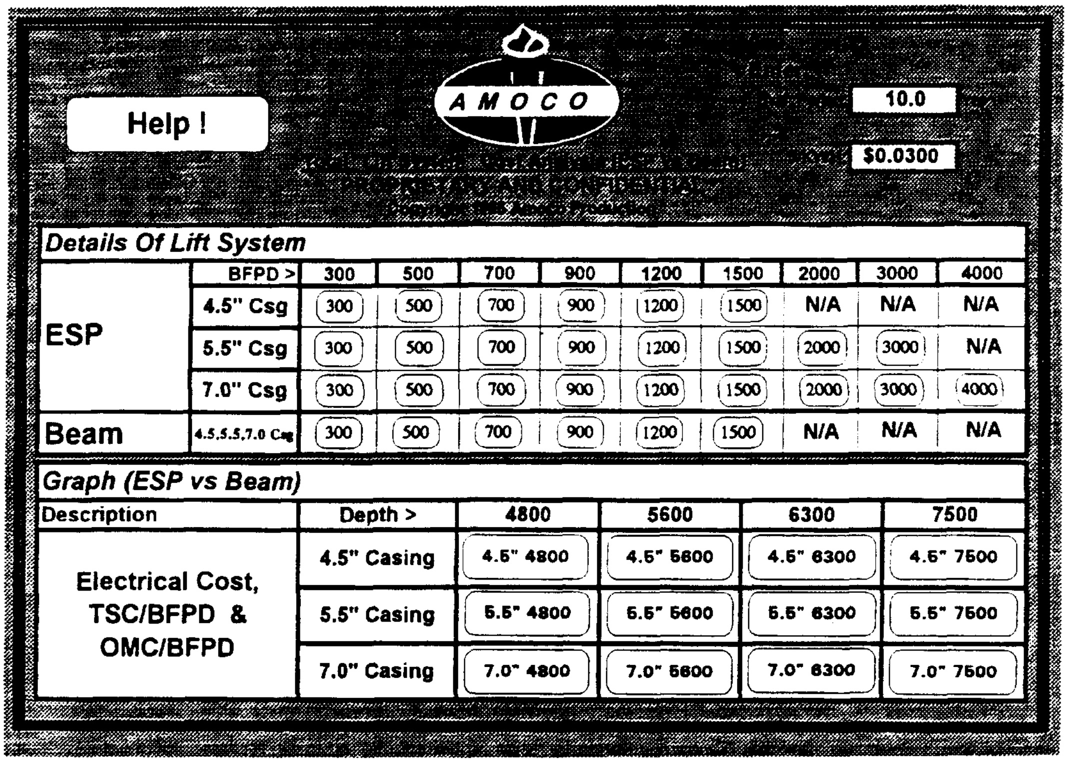
Type Failure or Pull	Avg. No Of Pulls/Year	Pull Frequency (Pulls/Well/Year)
Motor or Pothead Failure	25.3	0.107
Pump or Intake Failure	5.7	0.024
Cable Failure	14.3	0.060
Tubing Failure	9.5	0.040
Resizes	8.7	0.037
Workovers	13.8	0.058

Figure 7 - Average ESP Pull Frequency

Amoco E & P
Northern Permian Basin Area

Type Failure or Pull	Pull Frequency (Pulls/Well/Year)
Motor Failures	0.250
Rod Failures	0.200
Pump Failures	0.400
Tubing Failures	0.100
Resheaving	0.120
Belt Failures	0.250
Workovers	0.058

Figure 8 - Average Beam Lift Pull Frequency



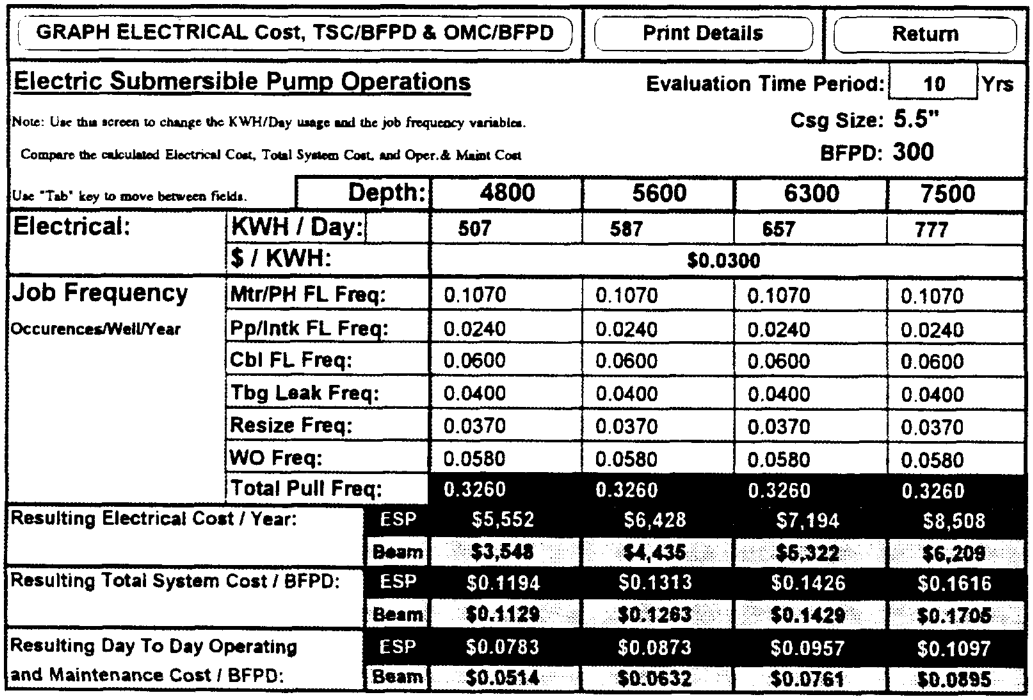
Details Of Lift System

	BFPD >	300	500	700	900	1200	1500	2000	3000	4000
ESP	4.5" Csg	300	500	700	900	1200	1500	N/A	N/A	N/A
	5.5" Csg	300	500	700	900	1200	1500	2000	3000	N/A
	7.0" Csg	300	500	700	900	1200	1500	2000	3000	4000
Beam	4.5,5.5,7.0 Csg	300	500	700	900	1200	1500	N/A	N/A	N/A

Graph (ESP vs Beam)

Description	Depth >	4800	5600	6300	7500
Electrical Cost, TSC/BFPD & OMC/BFPD	4.5" Casing	4.5" 4800	4.5" 5600	4.5" 6300	4.5" 7500
	5.5" Casing	5.5" 4800	5.5" 5600	5.5" 6300	5.5" 7500
	7.0" Casing	7.0" 4800	7.0" 5600	7.0" 6300	7.0" 7500

Figure 9 - Main Menu Screen



Electric Submersible Pump Operations

Evaluation Time Period: 10 Yrs

Note: Use this screen to change the KWH/Day usage and the job frequency variables.

Compare the calculated Electrical Cost, Total System Cost, and Oper.& Maint Cost

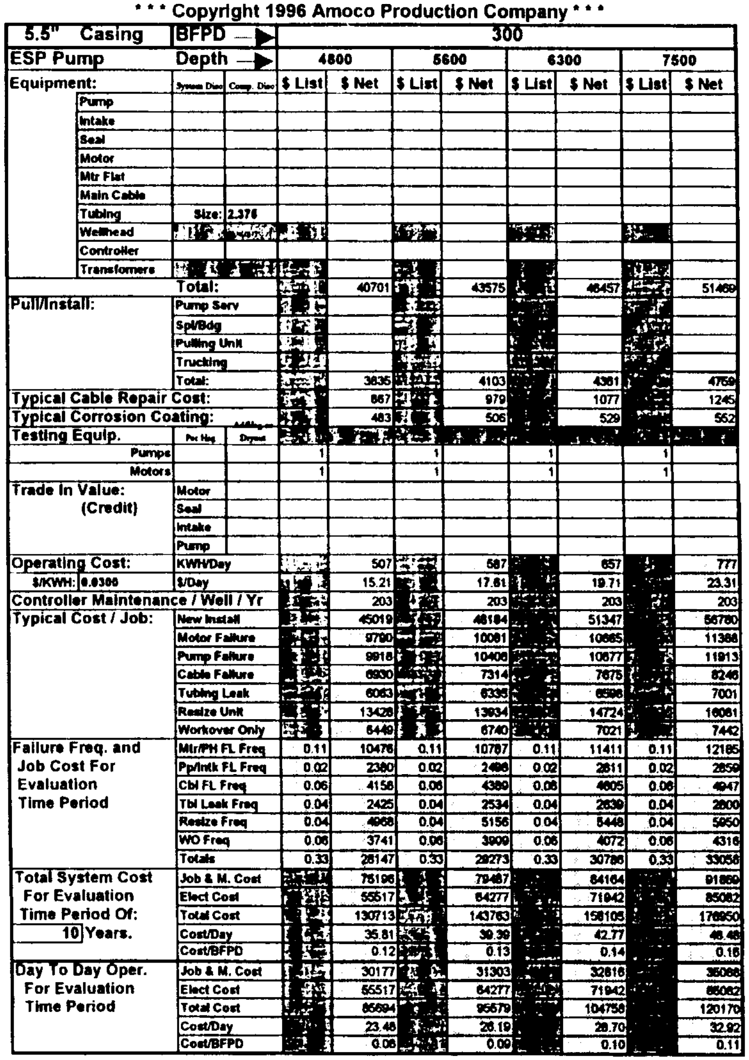
Csg Size: 5.5"

BFPD: 300

Use "Tab" key to move between fields.

		Depth:	4800	5600	6300	7500
Electrical:	KWH / Day:		507	587	657	777
	$ / KWH:		$0.0300			
Job Frequency Occurences/Well/Year	Mtr/PH FL Freq:		0.1070	0.1070	0.1070	0.1070
	Pp/Intk FL Freq:		0.0240	0.0240	0.0240	0.0240
	Cbl FL Freq:		0.0600	0.0600	0.0600	0.0600
	Tbg Leak Freq:		0.0400	0.0400	0.0400	0.0400
	Resize Freq:		0.0370	0.0370	0.0370	0.0370
	WO Freq:		0.0580	0.0580	0.0580	0.0580
	Total Pull Freq:		0.3260	0.3260	0.3260	0.3260
Resulting Electrical Cost / Year:		ESP	$5,552	$6,428	$7,194	$8,508
		Beam	$3,548	$4,435	$5,322	$6,209
Resulting Total System Cost / BFPD:		ESP	$0.1194	$0.1313	$0.1426	$0.1616
		Beam	$0.1129	$0.1263	$0.1429	$0.1705
Resulting Day To Day Operating and Maintenance Cost / BFPD:		ESP	$0.0783	$0.0873	$0.0957	$0.1097
		Beam	$0.0514	$0.0632	$0.0761	$0.0895

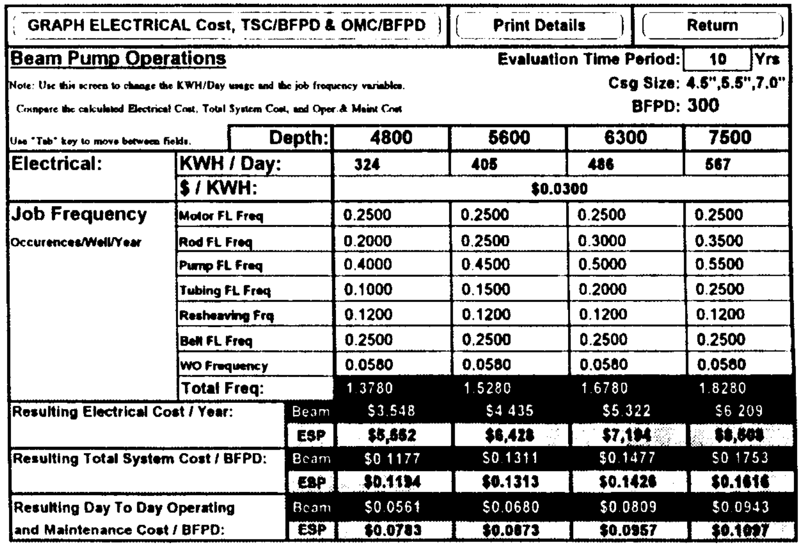
Figure 10 - ESP Summary Screen



* * * Copyright 1996 Amoco Production Company * * *

5.5" Casing	BFPD ▶			300							
ESP Pump	Depth ▶			4800		5600		6300		7500	
Equipment:		System Disc	Comp. Disc	$ List	$ Net	$ List	$ Net	$ List	$ Net	$ List	$ Net
	Pump										
	Intake										
	Seal										
	Motor										
	Mtr Flat										
	Main Cable										
	Tubing	Size:	2.375								
	Wellhead	[redacted]	[redacted]	[redacted]		[redacted]		[redacted]		[redacted]	
	Controller										
	Transformers	[redacted]	[redacted]	[redacted]		[redacted]		[redacted]		[redacted]	
	Total:			[redacted]	40701	[redacted]	43575	[redacted]	46457	[redacted]	51469
Pull/Install:	Pump Serv			[redacted]		[redacted]		[redacted]		[redacted]	
	Spl/Bdg			[redacted]		[redacted]		[redacted]		[redacted]	
	Pulling Unit			[redacted]		[redacted]		[redacted]		[redacted]	
	Trucking			[redacted]		[redacted]		[redacted]		[redacted]	
	Total:			[redacted]	3835	[redacted]	4103	[redacted]	4361	[redacted]	4769
Typical Cable Repair Cost:				[redacted]	867	[redacted]	979	[redacted]	1077	[redacted]	1245
Typical Corrosion Coating:				[redacted]	483	[redacted]	506	[redacted]	529	[redacted]	552
Testing Equip.		Per Hsg	Dryout	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Pumps			1		1		1		1	
	Motors			1		1		1		1	
Trade In Value: (Credit)	Motor										
	Seal										
	Intake										
	Pump										
Operating Cost:	KWH/Day			[redacted]	507	[redacted]	587	[redacted]	657	[redacted]	777
$/KWH: 0.0300	$/Day			[redacted]	15.21	[redacted]	17.61	[redacted]	19.71	[redacted]	23.31
Controller Maintenance / Well / Yr				[redacted]	203	[redacted]	203	[redacted]	203	[redacted]	203
Typical Cost / Job:	New Install			[redacted]	45019	[redacted]	48184	[redacted]	51347	[redacted]	56780
	Motor Failure			[redacted]	9790	[redacted]	10081	[redacted]	10665	[redacted]	11388
	Pump Failure			[redacted]	9918	[redacted]	10406	[redacted]	10677	[redacted]	11913
	Cable Failure			[redacted]	6930	[redacted]	7314	[redacted]	7675	[redacted]	8246
	Tubing Leak			[redacted]	6063	[redacted]	6335	[redacted]	6598	[redacted]	7001
	Resize Unit			[redacted]	13428	[redacted]	13934	[redacted]	14724	[redacted]	16081
	Workover Only			[redacted]	6449	[redacted]	6740	[redacted]	7021	[redacted]	7442
Failure Freq. and Job Cost For Evaluation Time Period	Mtr/PH FL Freq			0.11	10476	0.11	10787	0.11	11411	0.11	12185
	Pp/Intk FL Freq			0.02	2380	0.02	2496	0.02	2611	0.02	2859
	Cbl FL Freq			0.06	4158	0.06	4389	0.06	4605	0.06	4947
	Tbl Leak Freq			0.04	2425	0.04	2534	0.04	2639	0.04	2800
	Resize Freq			0.04	4968	0.04	5156	0.04	5448	0.04	5950
	WO Freq			0.08	3741	0.08	3909	0.08	4072	0.08	4316
	Totals			0.33	28147	0.33	29273	0.33	30786	0.33	33056
Total System Cost For Evaluation Time Period Of: 10 Years.	Job & M. Cost			[redacted]	75196	[redacted]	79487	[redacted]	84164	[redacted]	91869
	Elect Cost			[redacted]	55517	[redacted]	64277	[redacted]	71942	[redacted]	85082
	Total Cost			[redacted]	130713	[redacted]	143763	[redacted]	156105	[redacted]	176950
	Cost/Day			[redacted]	35.81	[redacted]	39.39	[redacted]	42.77	[redacted]	48.48
	Cost/BFPD			[redacted]	0.12	[redacted]	0.13	[redacted]	0.14	[redacted]	0.16
Day To Day Oper. For Evaluation Time Period	Job & M. Cost			[redacted]	30177	[redacted]	31303	[redacted]	32816	[redacted]	35088
	Elect Cost			[redacted]	55517	[redacted]	64277	[redacted]	71942	[redacted]	85082
	Total Cost			[redacted]	85694	[redacted]	95579	[redacted]	104758	[redacted]	120170
	Cost/Day			[redacted]	23.48	[redacted]	26.19	[redacted]	28.70	[redacted]	32.92
	Cost/BFPD			[redacted]	0.08	[redacted]	0.09	[redacted]	0.10	[redacted]	0.11

Figure 11 - Detail Section of Total System Cost Calculation for ESP Lift.



Beam Pump Operations

Evaluation Time Period: 10 Yrs

Note: Use this screen to change the KWH/Day usage and the job frequency variables.

Compare the calculated Electrical Cost, Total System Cost, and Oper.& Maint Cost

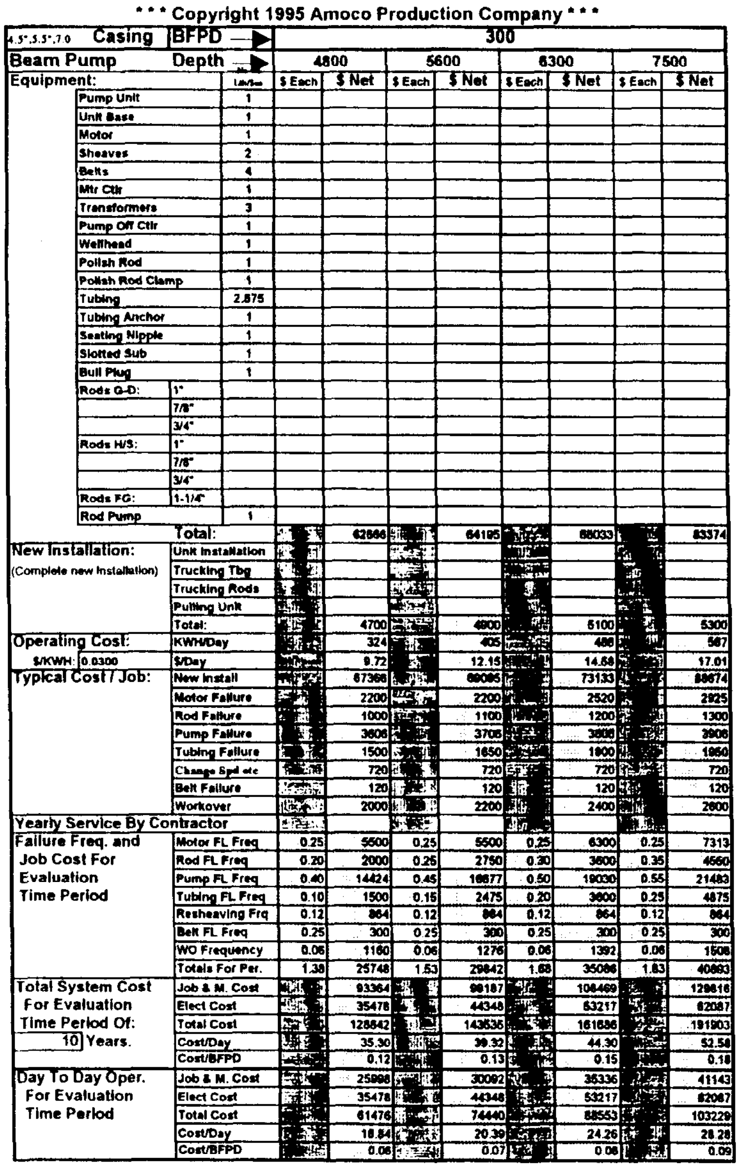
Csg Size: 4.5",5.5",7.0"

BFPD: 300

Use "Tab" key to move between fields.

	Depth:	4800	5600	6300	7500
Electrical:	KWH / Day:	324	405	486	567
	$ / KWH:	$0.0300			
Job Frequency Occurences/Well/Year	Motor FL Freq	0.2500	0.2500	0.2500	0.2500
	Rod FL Freq	0.2000	0.2500	0.3000	0.3500
	Pump FL Freq	0.4000	0.4500	0.5000	0.5500
	Tubing FL Freq	0.1000	0.1500	0.2000	0.2500
	Resheaving Frq	0.1200	0.1200	0.1200	0.1200
	Belt FL Freq	0.2500	0.2500	0.2500	0.2500
	WO Frequency	0.0580	0.0580	0.0580	0.0580
	Total Freq:	1.3780	1.5280	1.6780	1.8280
Resulting Electrical Cost / Year:	Beam	$3,548	$4,435	$5,322	$6,209
	ESP	$5,552	$6,428	$7,194	$8,508
Resulting Total System Cost / BFPD:	Beam	$0.1177	$0.1311	$0.1477	$0.1753
	ESP	$0.1194	$0.1313	$0.1426	$0.1616
Resulting Day To Day Operating and Maintenance Cost / BFPD:	Beam	$0.0561	$0.0680	$0.0809	$0.0943
	ESP	$0.0783	$0.0873	$0.0957	$0.1097

Figure 12 - Beam Pump Summary Screen



* * * Copyright 1995 Amoco Production Company * * *

4.5",5.5",7.0	Casing	BFPD →		300							
Beam Pump		Depth →		4800		5600		6300		7500	
Equipment:			No. Lth/Sze	$ Each	$ Net	$ Each	$ Net	$ Each	$ Net	$ Each	$ Net
	Pump Unit		1								
	Unit Base		1								
	Motor		1								
	Sheaves		2								
	Belts		4								
	Mtr Ctlr		1								
	Transformers		3								
	Pump Off Ctlr		1								
	Wellhead		1								
	Polish Rod		1								
	Polish Rod Clamp		1								
	Tubing		2.875								
	Tubing Anchor		1								
	Seating Nipple		1								
	Slotted Sub		1								
	Bull Plug		1								
	Rods G-D:	1"									
		7/8"									
		3/4"									
	Rods H/S:	1"									
		7/8"									
		3/4"									
	Rods FG:	1-1/4"									
	Rod Pump		1								
		Total:			62666		64195		68033		83374
New Installation:	Unit Installation										
(Complete new Installation)	Trucking Tbg										
	Trucking Rods										
	Pulling Unit										
	Total:				4700		4900		5100		5300
Operating Cost:	KWH/Day				324		405		486		567
$/KWH: 0.0300	$/Day				9.72		12.15		14.58		17.01
Typical Cost / Job:	New Install				67366		69095		73133		88674
	Motor Failure				2200		2200		2520		2925
	Rod Failure				1000		1100		1200		1300
	Pump Failure				3606		3706		3806		3906
	Tubing Failure				1500		1650		1800		1950
	Change Spd etc				720		720		720		720
	Belt Failure				120		120		120		120
	Workover				2000		2200		2400		2600
Yearly Service By Contractor											
Failure Freq. and Job Cost For Evaluation Time Period	Motor FL Freq			0.25	5500	0.25	5500	0.25	6300	0.25	7313
	Rod FL Freq			0.20	2000	0.25	2750	0.30	3600	0.35	4550
	Pump FL Freq			0.40	14424	0.45	16677	0.50	19030	0.55	21483
	Tubing FL Freq			0.10	1500	0.15	2475	0.20	3600	0.25	4875
	Resheaving Frq			0.12	864	0.12	864	0.12	864	0.12	864
	Belt FL Freq			0.25	300	0.25	300	0.25	300	0.25	300
	WO Frequency			0.06	1160	0.06	1276	0.06	1392	0.06	1508
	Totals For Per.			1.38	25748	1.53	29842	1.68	35086	1.83	40893
Total System Cost For Evaluation Time Period Of:	Job & M. Cost				93364		99187		108469		129816
	Elect Cost				35478		44348		53217		62087
	Total Cost				128842		143536		161686		191903
10 Years.	Cost/Day				35.30		39.32		44.30		52.58
	Cost/BFPD				0.12		0.13		0.15		0.18
Day To Day Oper. For Evaluation Time Period	Job & M. Cost				25998		30092		35336		41143
	Elect Cost				35478		44348		53217		62087
	Total Cost				61476		74440		88553		103229
	Cost/Day				16.84		20.39		24.26		28.28
	Cost/BFPD				0.06		0.07		0.08		0.09

Figure 13 - Detail Screen of Total System Cost Calculation for Beam Lift.

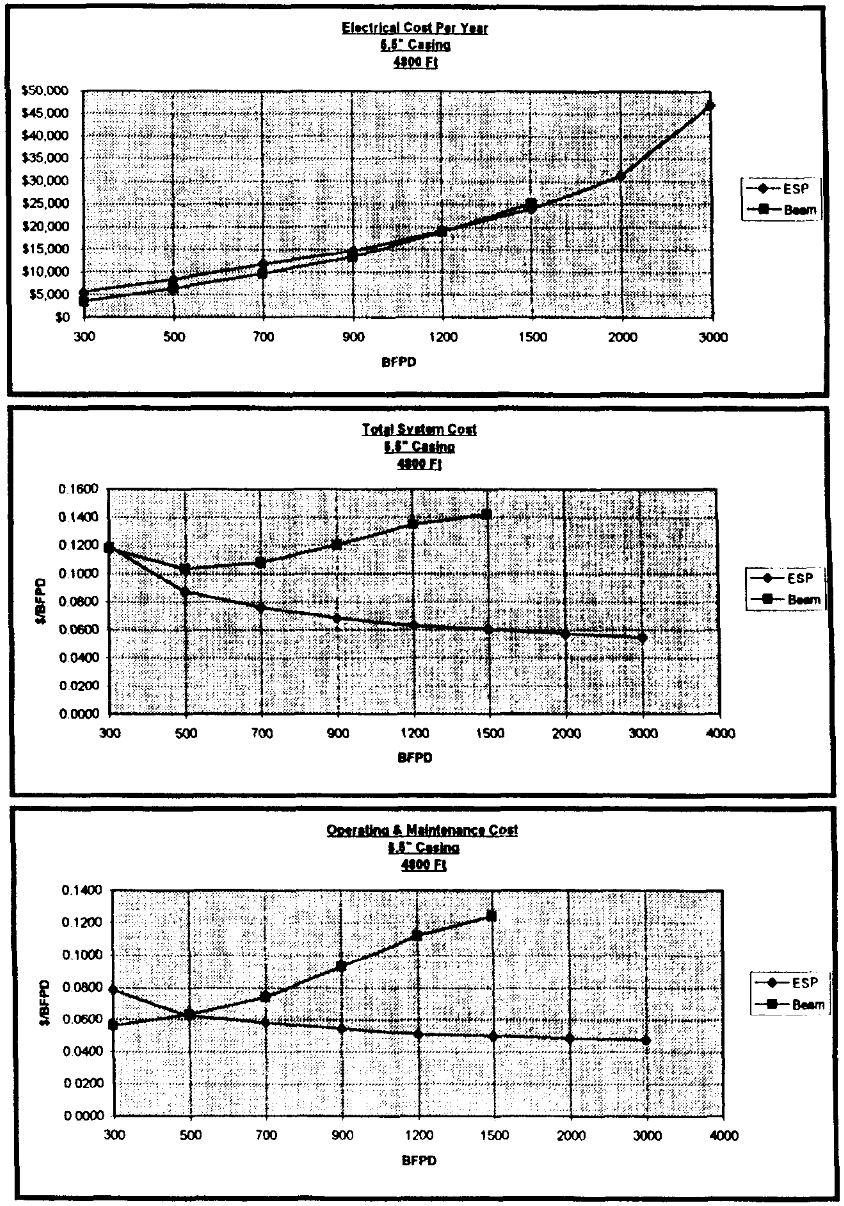


Figure 14 - Typical Cost Comparison Graphs

ESP Electrical Power Usage

$/KWH= 0 Average difference from calculated KWH: 0.205

DEPTH >	4800				
	KWH/Day				
BFPD v	Calc	Test	Test		Use
300	507	849	702	0.38	611
KWH/BFPD	1.69	2.83	2.34		2.04
$/BFPD	0.05	0.08	0.07		0.06
500	766	890	940	0.16	923
KWH/BFPD	1.53	1.78	1.88		1.85
$/BFPD	0.05	0.05	0.06		0.06
700	1067	1099	1106	0.03	1286
KWH/BFPD	1.52	1.57	1.58		1.84
$/BFPD	0.05	0.05	0.05		0.06
900	1336	1629	0	0.22	1610
KWH/BFPD	1.48	1.81			1.78
$/BFPD	0.04	0.05	0		0.05
1200	1739	2040	0	0.17	2096
KWH/BFPD	1.45	1.7			1.75
$/BFPD	0.04	0.05	0		0.05
1500	2181	0	0	0	2629
KWH/BFPD	1.45				1.75
$/BFPD	0.04	0	0		0.05
2000	2852	0	0	0	3438
KWH/BFPD	1.43				1.72
$/BFPD	0.04	0	0		0.05
3000	4288	0	0	0	5169
KWH/BFPD	1.43				1.72
$/BFPD	0.04	0	0		0.05
4000	5524	0	0	0	6656
KWH/BFPD	1.38				1.66
$/BFPD	0.04	0	0		0.05

DEPTH >	5600				
	KWH/Day				
BFPD v	Calc	Test	Test		Use
300	587	795	870	0.35	708
KWH/BFPD	1.96	2.65	2.9		2.36
$/BFPD	0.06	0.08	0.09		0.07
500	887	1120	880	-0.01	1069
KWH/BFPD	1.77	2.24	1.76		2.14
$/BFPD	0.05	0.07	0.05		0.06
700	1237	1365	1393	0.1	1491
KWH/BFPD	1.77	1.95	1.99		2.13
$/BFPD	0.05	0.06	0.06		0.06
900	1548	0	0	0	1866
KWH/BFPD	1.72				2.07
$/BFPD	0.05	0	0		0.06
1200	2014	0	0	0	2427
KWH/BFPD	1.68				2.02
$/BFPD	0.05	0	0		0.06
1500	2526	0	0	0	3045
KWH/BFPD	1.68				2.03
$/BFPD	0.05	0	0		0.06
2000	3303	0	0	0	3981
KWH/BFPD	1.65				1.99
$/BFPD	0.05	0	0		0.06
3000	4967	0	0	0	5987
KWH/BFPD	1.66				2
$/BFPD	0.05	0	0		0.06
4000	6445	0	0	0	7766
KWH/BFPD	1.61				1.94
$/BFPD	0.05	0	0		0.06

DEPTH >	6300				
	KWH/Day				
BFPD v	Calc	Test	Test		Use
300	657	0	0	0	792
KWH/BFPD	2.19				2.64
$/BFPD	0.07	0	0		0.08
500	994	1085	1090	0.09	1198
KWH/BFPD	1.99	2.17	2.18		2.4
$/BFPD	0.06	0.07	0.07		0.07
700	1386	1407	1358	-0.02	1671
KWH/BFPD	1.98	2.01	1.94		2.39
$/BFPD	0.06	0.06	0.06		0.07
900	1734	2610	0	0.51	2090
KWH/BFPD	1.93	2.9			2.32
$/BFPD	0.06	0.09	0		0.07
1200	2256	0	0	0	2719
KWH/BFPD	1.88				2.27
$/BFPD	0.06	0	0		0.07
1500	2830	4950	0	0.75	3411
KWH/BFPD	1.89	3.3			2.27
$/BFPD	0.06	0.1	0		0.07
2000	3707	0	0	0	4468
KWH/BFPD	1.85				2.23
$/BFPD	0.06	0	0		0.07
3000	5560	0	0	0	6702
KWH/BFPD	1.85				2.23
$/BFPD	0.06	0	0		0.07
4000	7392	0	0	0	8910
KWH/BFPD	1.85				2.23
$/BFPD	0.06	0	0		0.07

DEPTH >	7500				
	KWH/Day				
BFPD v	Calc	Test	Test		Use
300	777	0	0	0	936.56
KWH/BFPD	2.59				3.1219
$/BFPD	0.08	0	0		0.0937
500	1173	0	0	0	1413.9
KWH/BFPD	2.35				2.8278
$/BFPD	0.07	0	0		0.0848
700	1630	0	0	0	1964.8
KWH/BFPD	2.33				2.8068
$/BFPD	0.07	0	0		0.0842
900	2041	1917	0	-0.06	2460.2
KWH/BFPD	2.27	2.13			2.7335
$/BFPD	0.07	0.06	0		0.082
1200	2655	0	0	0	3200.3
KWH/BFPD	2.21				2.6669
$/BFPD	0.07	0	0		0.08
1500	3330	0	0	0	4013.9
KWH/BFPD	2.22				2.676
$/BFPD	0.07	0	0		0.0803
2000	4362	0	0	0	5257.9
KWH/BFPD	2.18				2.6289
$/BFPD	0.07	0	0		0.0789
3000	6543	0	0	0	7886.8
KWH/BFPD	2.18				2.6289
$/BFPD	0.07	0	0		0.0789
4000	8800	0	0	0	10607
KWH/BFPD	2.2				2.6518
$/BFPD	0.07	0	0		0.0796

Figure 15 - ESP Electrical Power Usage

Beam Electrical Power Usage

$/KWH= 0.03 Average difference from calculated KWH: -0.1

DEPTH >	4800				
	KWH/Day				
BFPD v	Calc	Test	Test		Use
300	360	372	0	0.033	324
KWH/BFPD	1.2	1.24			1.08
$/BFPD	0.036	0.037	0		0.032
500	650	750	600	-0.08	585
KWH/BFPD	1.3	1.5	1.2		1.17
$/BFPD	0.039	0.045	0.036		0.035
700	980	770	0	-0.21	882
KWH/BFPD	1.4	1.1			1.26
$/BFPD	0.042	0.033	0		0.038
900	1350	0	0	0	1215
KWH/BFPD	1.5				1.35
$/BFPD	0.045	0	0		0.041
1200	1920	0	0	0	1728
KWH/BFPD	1.6				1.44
$/BFPD	0.048	0	0		0.043
1500	2550	0	0	0	2295
KWH/BFPD	1.7				1.53
$/BFPD	0.051	0	0		0.046

DEPTH >	5600				
	KWH/Day				
BFPD v	Calc	Test	Test		Use
300	450	0	0	0	405
KWH/BFPD	1.5				1.35
$/BFPD	0.045	0	0		0.041
500	800	0	0	0	720
KWH/BFPD	1.6				1.44
$/BFPD	0.048	0	0		0.043
700	1190	0	0	0	1071
KWH/BFPD	1.7				1.53
$/BFPD	0.051	0	0		0.046
900	1620	0	0	0	1458
KWH/BFPD	1.8				1.62
$/BFPD	0.054	0	0		0.049
1200	2280	0	0	0	2052
KWH/BFPD	1.9				1.71
$/BFPD	0.057	0	0		0.051
1500		0	0	0	0
KWH/BFPD	0				0
$/BFPD	0	0	0		0

DEPTH >	6300				
	KWH/Day				
BFPD v	Calc	Test	Test		Use
300	540	540	570	0	486
KWH/BFPD	1.8	1.8	1.9		1.62
$/BFPD	0.054	0.054	0.057		0.049
500	950	1000	0	0.053	855
KWH/BFPD	1.9	2			1.71
$/BFPD	0.057	0.06	0		0.051
700	1400	0	0	0	1260
KWH/BFPD	2				1.8
$/BFPD	0.06	0	0		0.054
900	1890	0	0	0	1701
KWH/BFPD	2.1				1.89
$/BFPD	0.063	0	0		0.057
1200		0	0	0	0
KWH/BFPD	0				0
$/BFPD	0	0	0		0
1500		0	0	0	0
KWH/BFPD	0				0
$/BFPD	0	0	0		0

DEPTH >	7500				
	KWH/Day				
BFPD v	Calc	Test	Test		Use
300	630	0	0	0	567
KWH/BFPD	2.1				1.89
$/BFPD	0.063	0	0		0.0567
500	1100	0	0	0	990
KWH/BFPD	2.2				1.98
$/BFPD	0.066	0	0		0.0594
700	1610	0	0	0	1449
KWH/BFPD	2.3				2.07
$/BFPD	0.069	0	0		0.0621
900		0	0	0	0
KWH/BFPD	0				0
$/BFPD	0	0	0		0
1200		0	0	0	0
KWH/BFPD	0				0
$/BFPD	0	0	0		0
1500		0	0	0	0
KWH/BFPD	0				0
$/BFPD	0	0	0		0

Figure 16 - Beam Lift Electrical Power Consumption.

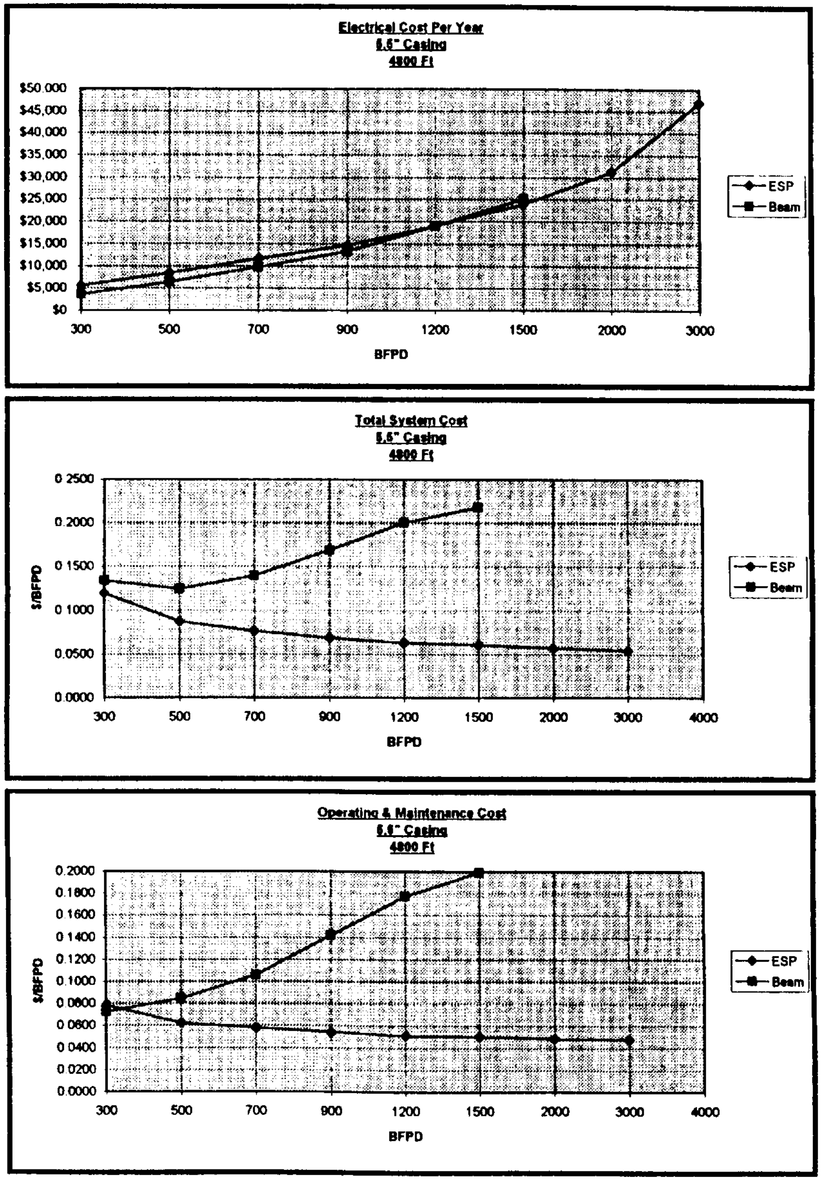


Figure 17 - Example Graphs with ESP F1/Freq as is And Beam Lift F1/Freq At 1.4.

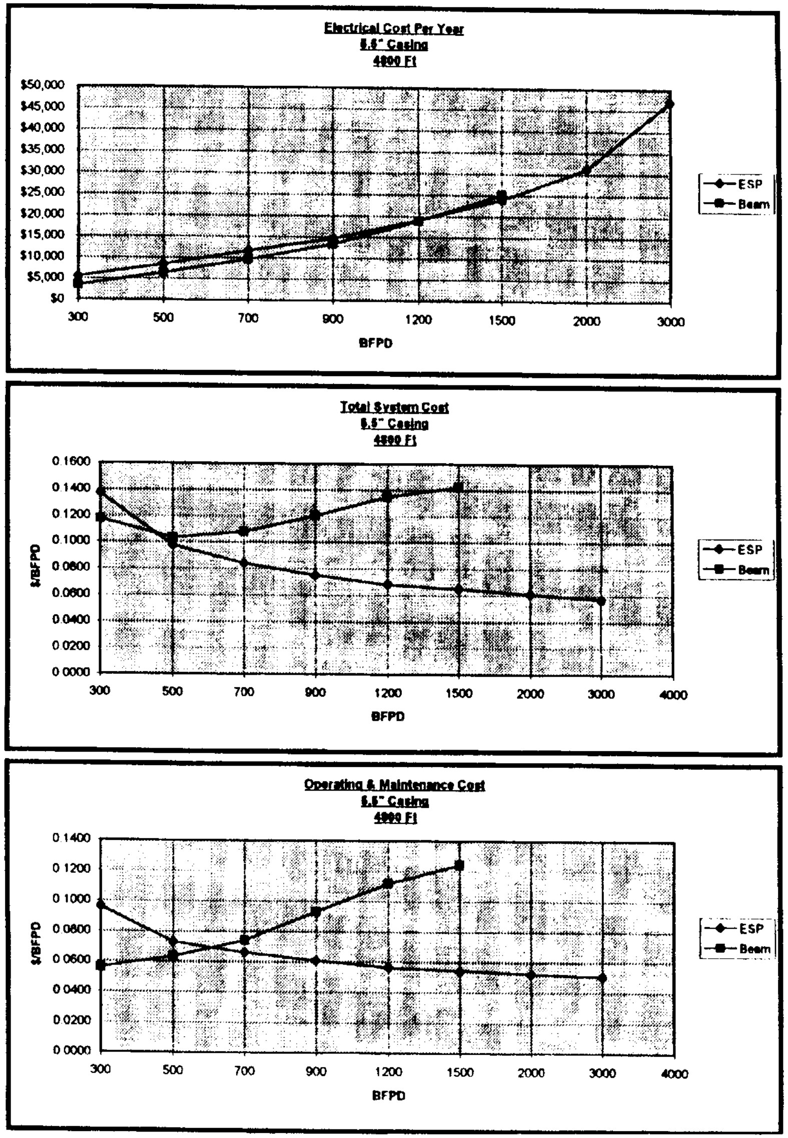


Figure 18 - Example Graphs with ESP F1/Freq at .462 and Beam Lift F1/Freq at .70.

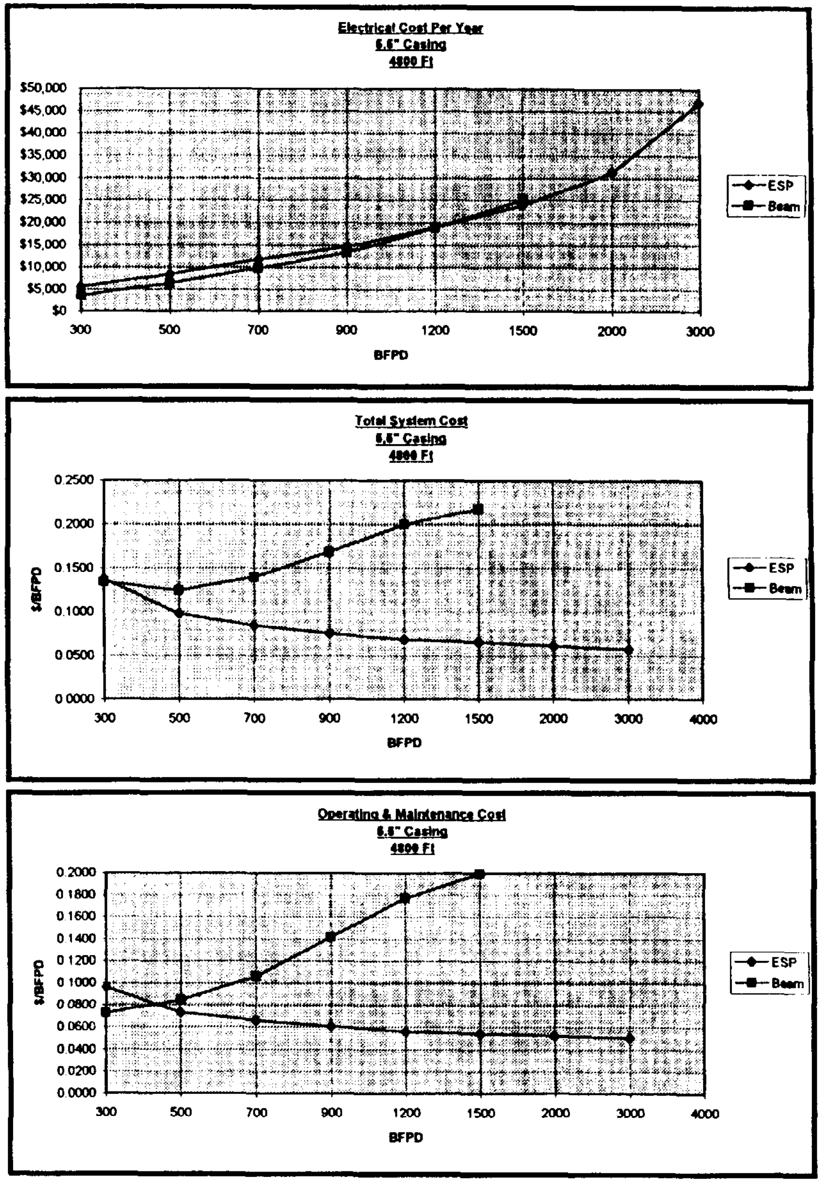
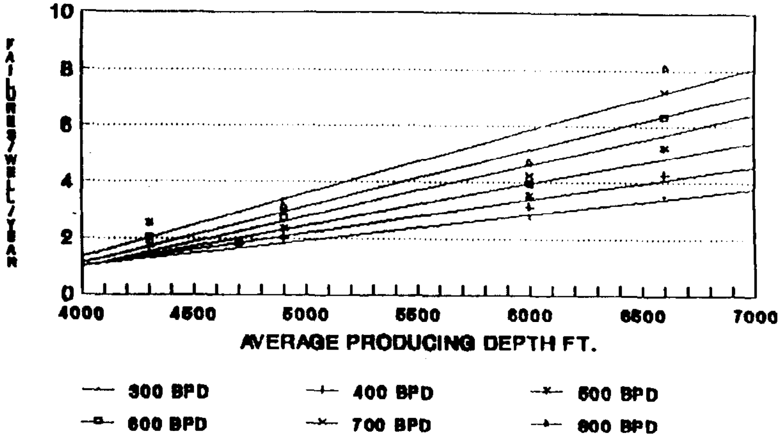


Figure 19 - Example Graphs with ESP F1/Freq At .462 and Beam Lift F1/Freq at 1.4.

THE EFFECT OF DEPTH AND RATE ON BEAM PUMPING UNIT FAILURE RATES



BASED ON TRENDED FAILURE RATES
FOR 5 WEST TEXAS UNITS

Attachment 1