An Updated Data Gathering System to Optimize Production Operations

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Abstract

Failure control is a critical path to optimizing operations in today's petroleum industry. Failure control in its simplest form is failure analysis with the goal of achieving corrective action. Accurate records and meaningful reports are a key part of any failure control program. This paper is the third in a series involving the data gathering and processing system used by Atlantic Richfield to optimize production operations and discusses the new PC system version. Application is demonstrated by identifying some rod pumping problems, suggested solutions, and results.

Background

The original Equipment Performance Reporting System (EPRS) was created in 1964 to serve Sinclair Oil operations. In 1969 when Atlantic Richfield and Sinclair merged to form the present organization it became part and parcel of the new Company's procedures through the Continental U. S. and Canadian operations. The EPRS consisted of four basic parts:

- Subsurface Failure Record-Keeping and Analysis
- Downhole Pump Selection and Performance
- Chemical Corrosion Inhibition
- Surface Equipment Failures

Data was entered into a mainframe data base via a three-part paper input form that was completed by the individual directly responsible for the operation (the foreman or the supervisor). By 1971 the EPRS had more than 34,000 records in its data banks; by the end of 1993, over 200,000. Note that records are more than just failures; they include activities associated with operations, i.e., well workovers, stimulation, chemical treating, etc.

The original paper[1] listed conclusions that are as applicable now as they were then, as follows:
A time and performance proven system is now in operation for gathering and putting to use equipment performance data. Plans are in effect to add to the usefulness of the system. The system was created primarily to aid in optimizing the profitability of producing properties. Surveys directed toward determining how well it is performing its function indicate that the system is doing well indeed. In the

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short time this system has been in operation, company-wide operating costs have been reduced on the order of 20 percent (20%) and in some operations by as much as 30 percent (30%). The greatest benefit, however, comes from an awareness on the part of operating personnel of the magnitude of the problems they face and the progress they have made toward solving them.

In 1987, a 14 year overview was published[2]. At that time, the system contained more than 181,000 records of which 115,000 were downhole failures. During that 14 year period the downhole performance improved significantly. Average time between rod failures increased from 19 to 43 months; time between any downhole failure in active wells increased from 12 to 21 months. Performance did not increase just because by better records were kept, but because by keeping better records problems could be identified and action could be taken.

The conclusions stated in the 1987 paper were:

The equipment performance system was created to aid in the optimization of profitability of producing properties and to monitor the results of remedial actions. The system has documented major improvements in the control of equipment failures. The improvements are the result of extensive personnel training, improved corrosion inhibition, extensive use of new and improved equipment and techniques, and cooperation between concerned personnel. The greatest benefit has come, however, from the increased awareness of operating personnel concerning the magnitude of the problems they face and the progress they have made toward solving them.

Again, **obtaining involvement and awareness remains the key to successful problem resolution.**

The input data form has changed somewhat with the times and the present version is shown in Figure 1. The goal, however, is still the same, namely **maximum profits, not minimum equipment failures**[3]. **Minimizing equipment failures does not always mean maximizing profitability.** The system as presently configured has served ARCO well; the latest step in optimization has been directed toward improving data acquisition, data transfer, and data access for analysis by incorporating it into a PC-based system.

PC Based System

With the rapid increase in the data processing capacity of personal computers (PCs) and with the growth of network technology to facilitate data sharing, it is obvious that there are advantages to adapting the EPRS to a networked PC environment. The mainframe data base required that monthly reports be run and mailed to the operating areas. Monthly reporting of the data was not as timely as desired. Reports using specific data sorting criteria required that a special program be run. The PC-based system goals are to permit multiple users easy and timely access to the data. For practical considerations, only records from 1986 on were transferred from the mainframe to a data base accessible by a PC format. Thus, this PC-based system started with a base of 30,000 records for properties operated by ARCO at the time of conversion. Data not transferred to the PC system is contained in the original data base located on mainframe.

The EPRS's ability to track **many** different well-related activities and record **all** possible well-related activities gives the user a more complete view of overall well performance. Choices are enhanced when they are available to field personnel on call, at the time of their choosing. Thus, the goal has been to provide reports and ultimately data entry at field office locations.

As presently configured, the PC-based EPRS has three specific functions: data reporting, data entry, and editing as follows:

- The **Permanent Data Viewer** is designed for report generation, for data viewing, and to create a variety of pre-defined reports using information contained in the permanent databases.

- The **Temporary Data Editor** allows new well activity information to be created and stored before it is transferred to permanent databases. This temporary data is available for editing and viewing from the **Temporary Data Editor** until it is transferred to a server's update directory or to a diskette for permanent database loading.

- The **Permanent Data Editor** allows the EPRS users to view, add, modify and delete information in the permanent database. Various utilities are available to **Permanent Data Editor** users to merge, move, and delete well or property information from a database.

The typical EPRS user has both the Permanent Data Viewer and the Temporary Data Editor available for use on their computer. The user at each District office who is responsible for maintaining the content of EPRS databases will have access to the Permanent Data Editor. This user will edit the database information for all other users.

Data Access and Integrity

The EPRS is available in three configurations allowing the system to be run on a wide area network, a local area network or on a stand-alone or laptop version; yet access is to a single **master data base** designed to maintain data integrity. The value of the tracking system employed is that any and all data can be accessed at the will of the user, and at high speed.

Data acquisition time is optimized by dividing a single data base into smaller pieces. Each operating area has been designated as a data base that includes all the ARCO operated leases for that area. In the Wide Area Network configuration, permanent EPRS database files reside on a network file server in a District office, currently located at Midland, Bakersfield, and Houston.

System performance is enhanced by moving all programs to the remote site's server and/or to the individual user's local machine. Thus, EPRS data is accessed using the programs located on the network server or from the users' own computers. EPRS access performance is further optimized by avoiding most of the remote access communication. When system performance is unacceptable because of the speed of the phone lines, then a copy of the permanent data base can be placed at the remote site. In short, the system can be configured many different ways, and each user has choices accessing and updating the permanent database.

System Requirements

The path chosen to bring the EPRS to the field is a Microsoft Windows based data management and reporting system. To use the EPRS, the following hardware is needed:

- A personal computer using an INTEL 80386 or higher processor.

- A minimum of 4.0 Megabytes of extended memory. Note: More extended memory will greatly enhance Windows and Equipment Performance System performance.

- One 3.5" (1.44 megabyte) diskette drive.

- A VGA or better color monitor.

- A Microsoft or compatible mouse is optional, but helpful.

The following software is needed:

- Microsoft Windows 3.1 (or higher).
- MS DOS 5.0 (or higher) operating system.

EPRS Reports and Report Formats

The Equipment Performance Reporting System provides several standard reports that suffice for most operating areas. Custom reports can be created easily. The standard reports are:

Problem Well Report (Figure 2)

The problem well report uses a rule base to scan the well activity listing for the specified lease(s) to determine those wells that are classified as problem wells. If at least one of the following criteria is true, then the well is considered a problem well:

- Rod pump life is less than 12 months.
- Tubing life is less than 12 months.
- Two or more rod failures (body, coupling, pin, etc.) in the last 12 months.
- Three or more failures of any type in the last 12 months.
- Electrical submersible pump life is less than two years.
- Hydraulic reciprocating pump life is less than four months.
- Hydraulic jet pump life is less than two years.
- Gas lift equipment (valves, mandrels) life is less than two years.

Summary information, as a percentage of total failures for tubing, and rod-end failures, is given at the end of each report for all wells on the lease(s).

Well Activity Listing (Figure 3)

The Well Activity Listing provides the user with a customized report containing failure data with specific, user defined characteristics. Characteristics are selected from menus such as well type, specific failing equipment (i.e., rods only), failure types (i.e., breaks only), failure locations (i.e., body only), failure causes, or a combination of the different criteria (i.e., rod body break failures). Only the records of wells that meet all the selected criteria are included in the report. If no criteria is defined, all records between the specified dates will be provided. At the end of the report the cost is provided in three categories: failure cost, stimulation cost and other cost.

Equipment Failure Summary (Figure 4)

The Equipment Failure Summary Report provides a one year review of well failures by month, ending with the user specified month and year of failure. Only failures are included in this report.

Failure Analysis Summary (Figure 5)

This report is a by-month summary of failures and costs over a three year period ending with the user specified month and year.

Active Wells By Type Report (Figure 6)

This report provides a listing by well type of the most recent active well counts for a property. The active well count includes those wells that are active for a given year; shut-in wells, temporarily abandoned wells, etc., are not included in this count. The total number of active wells is given for each well category by lease with a grand total for each type.

Equipment Performance Report (Figure 7)

The Equipment Performance Report allows the user to generate a report of the number of failures for all active wells of each type by year for the previous four years and up to the current month specified by the user. For example, the number of pump failures for each active rod pumped well for each of the preceding five years to date is included as a category in the Equipment Performance Report.

EPRS as a Comprehensive Data System

The EPRS data base contains well records from which reports can be generated which identify trends and problem wells. To improve equipment performance and prevent premature failures, additional information (loads, pump size, stroke length, strokes per minute, and production rates) is needed. This additional information is always available from pulling unit contractors, and chemical and pump company personnel.

Based on experiences acquired in over 20 years of failure control performance, recommended practices[4,5,6] have been developed which document successful paths to improving the performance of equipment. As shown in Figure 8, ARCO's downhole equipment performance has improved considerably over the years (data from 1970 to 1984 has been previously published[2]).

Examples of failure data follow:

Table 1 contains failure rates for different areas for three categories: pumps, rods and tubing. The cost per failure is shown in Table 2. Averages are useful to compare between areas, but ultimately failure control has to be applied down to the individual leases and then to individual wells. Two examples of analysis for specific failure control purposes follow:

- East Texas - The majority of the wells produce with high fluid levels and high oil cuts and these factors dominate the overall performance. Part of the field, however, is under waterflood and most of the failures occur in this area where production is at very high fluid rates and high water cuts. Wells are 3600' deep. High pumping speeds are the norm because small size units were originally installed. 26% of the wells (most producing from the waterflood area) had 71% of the total failure cost for 1993. These leases have a failure rate of 0.55 failures per well per year. The primary failure mechanism is wear and the weekly batch treatments with a corrosion inhibitor has been the most important factor to reduced failures.

- West Texas - Conditions range from a depth of 3500' to 6000'; production from 25 to 1000 BFPD with 0 to 99% water cuts, and with high H_2S and CO_2 production. Wells are typically batch treated for corrosion weekly. One large West Texas waterflood (5000' depth San Andres production) performance is shown in Figure 9. The bulk of the failures are bottom-joint tubing failures. Performance was improved by doing three things: anchoring the tubing, using bottom discharge valves, and using pull tube discharge pumps.

Minimizing equipment failures is an ongoing process that requires utilizing available information to understand and solve problems. Coupling the failure data and well information together provides a better understanding of the rod pumping environment and methods are still being developed for proactive failure reduction. The following examples show how failure data can be used to target failure causing factors. The EPRS approach can and does result in the development of failure control procedures that are applicable throughout ARCO's operations. Three examples follow:

Analysis of data from a high water producing area indicated that pitting-type failures are influenced by the fluid velocity across the couplings. Table 3 shows the data grouped in rod failures per well per year. This is an empirical relationship developed from wells with a water cut of more than 90% and are being inhibited for corrosion. Based upon this relationship 2" tubing should be used to 250 BFPD, 2.5" tubing to 500 BFPD and 3" tubing at rates greater than 500 BFPD.

The allowable range of loads on a rod string is defined by the Modified Goodman Diagram. However, there are installations which, although acceptable based on the Goodman Diagram, are questionable for good operations; this is particularly true if compression of the rod string occurs. Based on failure experience shown in Figure 10, rod and tubing failures increase as the ratio of the minimum polished rod load to the peak polished rod load (MPRL/PPRL) is reduced below 0.20.

Sorting data on polished rod failures revealed that some leases had very high polished rod failures. On discussion with operations, it was identified that these leases used 1-1/8" polished rods. Other leases used 1-1/4" polished rods. Based on this observation, the polished rods were changed out to the larger diameter as they failed. After these changes it was also noticed that the frequency of repacking the stuffing boxes decreased.

The conclusions described in the above examples were arrived at from singular experiences, **but are applicable throughout all rod pumping applications.**

Conclusions

The conclusions that follow assume that the Companies we work for compete in exploration and marketing only. Actions that benefit one producer will likely benefit other producers since we often partner in fields, leases and wells.

- The Equipment Performance Reporting System's goal is to provide:
  - Methods to optimize the profitability of producing properties by monitoring operation and equipment performance, implement remedial actions, and monitor the results of these actions.
  - Emphasis and trends for major problem areas, and solutions applicable to all areas with similar problems.
  - Focused efforts on individual problem wells, rather than on <u>all</u> wells, thus optimizing the failure control process.

- Similar approaches to failure control using this or a similar system in the hands of other Operators will benefit all Operators, ARCO included. Simply said: Many heads are better than one.

- Common criteria used to classify failure frequency can be valuable to allow Operators to "bench mark" equipment performance and to develop failure control measures that, again, will benefit all Operators, ARCO included.

Acknowledgments

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References

1. Bucaram. S. M. and Sullivan, J. H.: "A Data Gathering and Processing System To Optimize Producing Operations," JPT (February, 1972) 185-92.

2. Bucaram. S. M. and Yeary, B. J.: "A Data-Gathering System to Optimize Production Operations: A 14-Year Overview," JPT (April, 1987) 457-62.

3. Bucaram, S. M. and Patterson, J. C.: "Managing Artificial Lift," JPT (April, 1994) 335-340.

4. Patterson, J. C., Bucaram, S. M. and Curfew, J. V.: "Minimizing Equipment Failures in Rod Pumped Wells," Presented at the 40th Southwestern Petroleum Shortcourse, April 21-22, 1993.

5. *RP8, Recommended Practice on Rod Pump System Configuration and Material Selection,* ARCO E&P Technology, Plano, Texas.

6. *RP9, Recommended Practice on Rod Pumping Installation and Operation,* ARCO E&P Technology, Plano, Texas.

Table 1 - 1993 Rod Pumped Well Performance Data-Failures/well/year

Area	Number of Wells	All Failures	% Pump Failures	% Rod Failures	% Tubing Failures
East Texas	613	0.21	38 %	24 %	38 %
West Texas	584	0.74	48 %	26 %	26 %
New Mexico	279	0.36	64 %	28 %	8 %
North Texas & Oklahoma	128	0.51	31 %	45 %	24 %
California Heavy oil	2,155	0.48	79 %	17 %	4 %
California Light oil	56	1.11	31 %	49 %	20 %

Table 2 - 1993 Rod Pumped Well Performance Data-cost/failure

Sub	Number of Wells	cost per Pump Failure	cost per Pump Repair	cost por Rod Failure	cost per Tubing Failure	average cost per Failure	failure cost per well/yr
East Texas	613	$ 2,380	$ 282	$ 1,804	$ 4,445	$ 3,260	$ 685
West Texas	584	$ 2,996	$ 687	$ 2,532	$ 4,204	$ 3,470	$ 2,570
New Mexico	279	$ 2,509	$ 382	$ 2,134	$ 4,777	$ 2,840	$ 1,020
North Texas & Oklahoma	128	$ 2,151	$ 798	$ 2,680	$ 1,517	$ 2,390	$ 1,220
California Heavy oil	2,155	$ 1,506	$ 225	$ 290	$ 2,056	$ 1,374	$ 660
California light oil	56	$ 4,428	$ 682	$ 3,346	$ 10,748	$ 5,945	$ 6,600

Table 3 - Rod failures vs. fluid viscosity

rod failures per well per year	number of wells	Vrod ft/sec	Vfluid ft/sec	Vrelative ft/sec
0	19	3.2	3.2	0
0.5	11	3.3	4.9	1.6
1.0	6	3.4	5.9	2.5
3.5	10	4.0	8.6	4.6

Equipment Performance Report: Subsurface

Lease or unit name:

Well Descriptor

(1-2) 0 4 | (3-4) (5-11) Lease Accounting Code | Sub (12-15)

Tract or section (16-18) | Well (19-22) | Date (23-24) Mo. (25-26) Day (27-28) Yr. | Depth of failure in feet or in number of joints from surface. (29-33)

Note: Enter code numbers in squares above column (no code number, leave squares blank). (Explain) in squares labelled "Remarks".

Failure Descriptor

Type of well (34-35)

	NON	None
01	FO	Flowing oil
02	FG	Flowing gas
03	GL	Gas lift
04	PMP	Pumping (Rod, Hyd Piston, Hyd Jet, Submersible)
05	WI	Water injection
06	GI	Gas injection
07	WS	Water supply
08	WD	Water disposal
09	PLL	Plunger lift
10	ROT	Rotary
11	SI	Steam injection

Type of service (36-37)

	OTH	Other
01	ACD	Acidize/stimulate well *
02	FRC	Frac well *
03	WWR	Well workover
04	LTS	Test - log
05	ABA	Abandon
06	STM	Steam soak
09	PSI	Pressure survey
10	INH	Inhibit well
11	CAL	Caliper well
12	RES	Reseating pump

* Note: If stimulating, please complete Stimulation Section (below). Please record costs.

Failing equipment (38-39)

	NON	None
01	PMP	Rod pump
02	PMH	Hydraulic pump, piston
22	PMJ	Hydraulic pump, jet
03	ESP	Submersible pump
04	ROD	Rod
05	ROP	Rod failure, which caused pump damage
06	TBG	Tubing
07	TBP	Tubing failure, which caused pump damage
08	CSG	Casing
10	PKR	Packer
11	BJT	Blast joint
12	PRO	Polish rod or liner (explain which)
14	GLV	Gas lift valve
16	MDR	Mandrel
21	SSV	Safety valve
23	PLL	Plunger or catcher or stop
24	SNP	Seating nipple
25	STV	Standing valve
26	BHA	Bottom hole assembly, cavity
30	OTR	Other (explain)

Type of failure (40-41)

	NON	None
01	HOL	Hole
02	BRK	Break
03	STK	Stuck
04	SPT	Split or crack
05	PLG	Plugged
06	LEK	Leak, water in motor
15	WSH	Washed
07	DEF	Worn, deformed or collapsed
08	UNS	Unscrewed
13	COT	Plastic coating disbondment
14	ELC	Electrical
10	OTR	Other (explain)

Location of failure (42-43)

	NON	None
01	BDY	Body
02	PIN	Pin
03	CLP	Coupling
04	THD	Thread
05	UPS	Upset
21	UUP	Upper upset or wrench flat
06	PLN	Plunger
07	BRL	Barrel
08	VBS	Valve, balls, seats
09	CUP	Cups
10	PMP	Entire pump damaged
11	SEL	Seal
31	JNF	Jet nozzle (HYD)
32	JTH	Jet throat (HYD)
14	ENG	Engine end (HYD)
15	PRE	Production end (HYD)
16	STV	Standing valve (HYD)
17	EAP	Engine and production end (HYD)
19	PPR	Pump pull rod
20	PHD	Pump holdown
22	ESP	Pump end (ESP)
23	ESG	Gas separator (ESP)
24	ESS	Seal section (ESP)
25	ESM	Motor (ESP)
26	ESX	Motor lead extension (ESP)
27	ESH	Pot head (ESP)
28	ESC	Power cable (ESP)
30	OTH	Other (explain)

Cause of failure (44-45)

	NON	None
01	WER	Wear
02	ABR	Abrasion, fluid cut
03	COR	Corrosion
04	FAT	Fatigue
05	SND	Sand
06	MUD	Mud
07	SCL	Gyp or scale
08	PAR	Paraffin
09	RUB	Rubber (in the pump)
10	MET	Metal (in the pump)
12	IPA	Improper application
13	IPH	Improper handling
14	UNK	Unknown
15	CRH	Crooked hole
16	ELC	Electrical, lightning
17	OTR	Other (explain)

MFG (46-47)

	Not applicable
01	Axelson (rods)
02	UPCO (rods)
03	Continental - EMSCO (rods)
04	Norris (rods)
05	Oilwell (rods)
06	Tuboscope (coating)
07	BTS (coating)
08	Spincote (coating)
09	VETCO (coating)
10	Reda (ESP)
11	Centrilift - Hughes (ESP)
12	ODI (ESP)
13	Trico (ESP)
14	Baker - Lift (ESP)
15	Other (ESP)

Stimulation Section

Reason For (48)

1. Fines/clays
2. Mud damage
3. Scale
4. Bacteria
5. Emulsion
6. Paraffin/asphaltenes
7. Water block
8. Water reduction
9. Initial completion or other (explain in remarks)

Company Used (49)

1. BJ
2. Dowell
3. Halliburton
4. Baker
5. Western
6. Acid Eng.
7. SERFCO
8. Smith Energy
9. Other (explain in remarks)

If chemical stimulation

Type (50)

1. HCl:HF
2. HCl
3. Acetic
4. Bleach
5. Solvent
6. Scale Squeeze
7. Other (explain in remarks)

Type Acid (51)

1	HCl:HF	12:3%
2	HCl:HF	6:1.5%
3	HCl:HF	6:0.5%
4	HCl	28%
5	HCl	20%
6	HCl	15%
7	HCl	10%
8	HCl	7.5%
9	Acetic	10%

(52-56) If chemical stim: volume - Gals. If Frac: Frac Fluid Vol - Bbls

(57-60) If Frac: Frac Sand weight - M pounds

Costs

Cost - dollars only (Round cost to nearest dollar)

(61 → 66) Pump only | (67 → 73) All equipment other than pumps. | (74 → 80) All labor costs: Company + Contract + Workover + Stimulation + Other

Remarks

(1 ← 5 10 15 20 25 30 35 40)

Remarks (left justified, Please print): For permanent record enter information in remarks squares.

41 ← 45 50 55 60 65 70 75 80)

Remarks (continuation)

(1 ← 5 10 15 20 25 30 35 40)

Remarks (continuation)

41 ← 45 50 55 60 65 70 75 80)

Remarks (continuation)

Input to Data Base

For Field Record Keeping

Tubing		PMP, Rods		Field records:
Number of jts.		PMP size		
Size		PMP type		
Weight		Gas anchor		
Thread		Rod sizes		
Class		Number of rods		
Mud anchor		Rod class		
Seating Nipple		Subs		
Anchor Catcher				
Packer				

AR36-1162-R

Signed ______________________

Figure 1

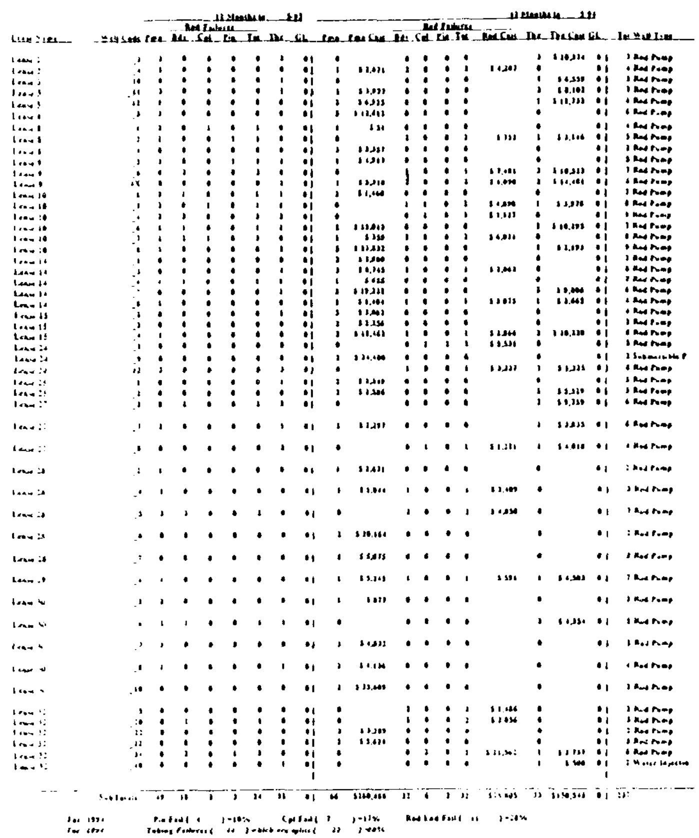

Figure 2 - Problem Well Analysis to Date: 5-94

Sub-District: Texas Lease: Lease 1

Tract/Sect.	Well	Well Type	Date	Fail Equipment	Fail Depth	Fail Type	Fail Location	Fail Cause	Pump $Cost	Other $Cost	Service $Cost	Total $Cost
	_1	Rod Pump	3/3/94	Rod Pump	0	Other (Explain)	Valve,balls,se	Corrosion	184	0	769	953
Remarks: PUMP CHANGE PULLED RODS & PUMP RAN RODS & PUMP LOADED TBG PUMPING PUMP STANDING VALVE CAGE BEATEN BALL&SEAT PITTED												
	_1	Rod Pump	3/17/94	Rod Pump	0	None	None	None	288	0	1559	1847
Remarks: POH W RODS PUMP TALLY TBG OUT RAN TBG W/ BAKER 4 1/2 LOC SET PACKER SET RAN RODS & PUMP RAN NEW PUMP CLEAN LOCATION PUMP PIN BEATEN T/V CORRODED CAGE BEATEN.												
Total Fail Cost: 2,800		Total Stimulation Cost: 0			Total Other Cost: 0				Total Cost: 2,800			
	_3	Rod Pump	3/30/94	Rod Pump	0	None	None	None	835	0	718	1553
Remarks: CHANGE PUMP. PUMP BALL SEAT CORRODED. BBL SPLIT BBL PITTED												
	_3	Pump (Generic)	4/19/94	None	0	None	None	None	48	0	974	1022
Remarks: NO FAILURE. MOVED LUFKIN 228 TO D-13-1. PULLED RODS. CHANGED PUMP, POLISH ROD, & POLISH ROD LINER.												
Total Fail Cost: 1,553		Total Stimulation Cost: 0			Total Other Cost: 1,022				Total Cost: 2,575			
	_4	Rod Pump	3/24/94	Rod Pump	0	None	None	None	107	0	718	825
Remarks: CHANGE PUMP-POLISH ROD LINER-3 3/4 ROD BOXES-POURED 5 GALS CHEM. SPACE WELL LOADED TBG PUMPING OK RIG DOWN CLEAN LOCATION.												
Total Fail Cost: 825		Total Stimulation Cost: 0			Total Other Cost: 0				Total Cost: 825			
	_7	Pump (Generic)	1/13/94	Tubing	6800	Other (Explain)	None	Wear	1664	930	2460	5054
Remarks: STRIPPED RODS&TBG PUMP STUCK HYDRO TEST TBG FOUND COLLAR LEAD AT 6800' RAN TBG SET TAC 17 FTS CHANGE PUMP JUNKED OLD PUMP SALVAGED PARTS RAN PROD STRING												
	_7	Rod Pump	3/14/94	Rod Pump	7865	Split or Crack	Body	Wear	574	2700	3578	6852
Remarks: HOLE IN TBG CLEAN WELL BORE USE HYDRO STATIC BAILER CLEAN TO TD RAN TBG HOT OIL TBG RAN PMP & RODS LOADED TBG COULD NOT GET PUMP TO PUMP. LEFT OVER NIGHT.												
	_7	Rod Pump	4/6/94	Rod Pump	0	None	Valve,balls,se	Sand	0	0	0	0
Remarks: PRESSURED UP PMP WOULD NOT PMP PULLED RODS & PMP TAG TO TD HAD 3' FILL PULLED TBG-1 JT MUST ANCHOR HAD 6' OF SAND. SAND SCN PLGD W SAND & SCALE. RAISED TBG 6JT												
	_7	Rod Pump	4/18/94	Tubing	490	Hole	Body	Wear	520	2438	1794	4752
Remarks: HOLE IN TBG 15JTS FROM SURF. HYDRO-TESTED TBG. REPLACED 6 JTS. RAN TBG SET TAC 14FTS. RAN PMP & RODS. POURED 5GALS CHEM. BEFORE RUNNING RODS. SPACED WELL LOADED												
Total Fail Cost: 16,658		Total Stimulation Cost: 0			Total Other Cost: 0				Total Cost: 16,658			
Lease Total Fail Cost: 21,836		Lease Total Stim Cost: 0			Lease Total Other Cost: 1,022				Lease Total Cost: 22,858			

Figure 3 - Well Activity Listing for Period January 1994 through May 1994

All Wells in 32 Leases of Texas Sub-District

Failure Summary For:	6-93	7-93	8-93	9-93	10-93	11-93	12-93	1-94	2-94	3-94	4-94	5-94	Totals:
Failures:	2	19	16	16	14	14	23	14	15	21	12	0	176
Total Cost: $	2700	75278	77092	96571	53697	62353	73692	50239	44568	42865	42123	0	621178
Rod Pumped Well Fails:	2	16	16	14	11	13	18	21	14	21	10	0	156
Cost, Rod Pump Wells: $	2700	38427	77092	82533	36003	60563	56736	42996	41710	42865	36226	0	517851
Rod Pmp Failures:	0	10	7	8	5	8	4	12	1	16	5	0	76
Rod Pmp Plunger Fail:	0	0	1	0	0	0	1	0	0	2	0	0	4
Rod Pmp Barrel Fail:	0	0	2	3	0	1	1	1	0	0	2	0	10
Rod Pmp Valve,Ball,Seat Fail:	0	3	1	1	2	0	0	4	0	1	1	0	13
Rod Pmp Other Fail:	0	7	3	4	3	7	2	7	1	13	2	0	49
Rod Pmp Fail Cost: $	0	17726	42924	44760	10814	47221	9168	20654	1434	37149	17548	0	249398
Total All Rod Failures:	2	2	3	2	1	2	8	5	9	4	2	0	40
Rod Body Failures:	0	1	1	1	1	2	7	3	6	2	2	0	26
Rod Pin or Coupling Failures:	1	1	2	1	0	0	0	2	2	2	0	0	11
Rod Other Failures:	1	0	0	0	0	0	1	0	0	0	0	0	2
Polished Rod Body Failures:	0	0	0	0	0	0	0	0	1	0	0	0	1
Polished Rod Pin or Coupling Failures:	0	0	0	0	0	0	0	0	0	0	0	0	0
Polished Rod Other Failures:	0	0	0	0	0	0	0	0	0	0	0	0	0
Total All Rod Failures Cost: $	2700	4188	3630	20790	992	3543	22457	10603	12611	4378	3918	0	89810
Hydraulic Pump Failures:	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydraulic Pump Failure Cost: $	0	0	0	0	0	0	0	0	0	0	0	0	0
All ESP Well Failures:	0	1	0	0	0	0	1	0	0	0	0	0	2
Electrical Failures:	0	1	0	0	0	0	0	0	0	0	0	0	1
Pump Failures:	0	0	0	0	0	0	1	0	0	0	0	0	1
All Other Failures:	0	0	0	0	0	0	0	0	0	0	0	0	0
ESP Pump Well Failure Cost: $	0	34400	0	0	0	0	0	0	0	0	0	0	34400
Gas Lift Well Failures:	0	0	0	0	0	0	0	0	0	0	0	0	0
Cost, Gas Lifted Wells: $	0	0	0	0	0	0	0	0	0	0	0	0	0
All Tubing Failures:	0	6	5	5	3	4	8	4	4	1	4	0	44
Tubing Failure Cost: $	0	18964	28437	30611	18919	11589	36713	16486	27665	1338	19637	0	210359
Tubing Fail(Rod Pump Only):	0	4	5	4	3	3	6	3	4	1	3	0	36
Cost, Tubing Fail(Rod Pump Only): $	0	16513	28437	16983	18919	9799	25111	11432	27665	1338	14760	0	170957
Casing Failures:	0	0	0	0	0	0	0	0	0	0	0	0	0
Cost Casing Failures: $	0	0	0	0	0	0	0	0	0	0	0	0	0
Wear-Corrosion-Handling Failures:	1	7	11	9	4	5	13	10	8	9	5	0	82
Wear-Corrosion-Handling Failure Cost: $	1950	23283	52117	45140	19716	45798	44325	29576	33197	16637	16870	0	328609
Scale Failures:	0	0	0	0	1	1	0	3	0	0	0	0	5
Scale Failure Cost: $	0	0	0	0	3466	1057	0	6202	0	0	0	0	10725
Failures Due to Sand:	0	3	2	4	1	1	0	2	0	4	3	0	20
Sand Failure Cost: $	0	6563	20654	29115	1396	2198	0	1894	0	15329	15068	0	92217
Paraffin Failures:	0	0	0	0	0	0	0	1	1	0	0	0	2
Paraffin Failure Cost: $	0	0	0	0	0	0	0	51	2858	0	0	0	2909
Stimulations:	0	0	1	0	0	0	0	0	0	0	1	0	2
Stimulation Cost: $	0	0	3628	0	0	0	0	0	0	0	1020	0	4648

Figure 4 - Equipment Failure Summary: 5/31/94

All Wells in 32 Leases of Texas Sub-District

	Rod Pumps Failure		Rod Pumps Repair		Hyd. Pumps		ESP Pump		Rods Total Rods		Rods Body	Rods Cpl.	Rods End		All Tubing		GL Valve		Total Failures	
Date	Num	Cost($)	Num	Cost($)	Num	Cost($)	Num	Cost($)	Num	Cost($)	Num	Num	Num	%	Num	Cost($)	Num	Cost($)	Num	Cost($)
1-92	5	9487	3	672	0	0	0	0	8	8257	4	1	4	50	2	7319	0	0	17	28071
2-92	4	5462	4	2917	0	0	0	0	3	3205	2	1	1	33	3	14343	0	0	10	23010
3-92	6	10589	4	2214	0	0	0	0	2	2554	0	0	1	50	7	21993	0	0	18	39837
4-92	3	233316	5	1232	0	0	0	0	1	6086	1	0	0	0	6	26834	0	0	13	271721
5-92	1	983	0	0	0	0	0	0	1	485	0	1	1	100	0	0	0	0	2	1468
6-92	4	8544	4	2300	0	0	0	0	0	0	0	0	0	***	4	14068	0	0	8	22612
7-92	4	14512	4	1164	0	0	0	0	0	0	0	0	0	***	3	13071	0	0	9	34201
8-92	6	9087	8	3088	0	0	0	0	4	8061	4	0	0	0	6	33102	0	0	16	50250
9-92	5	11132	4	1627	0	0	0	0	2	4734	1	1	1	50	4	115004	0	0	11	130870
10-92	4	14801	5	2934	1	3638	0	0	2	3224	1	1	1	50	3	20339	0	0	13	49220
11-92	10	22980	2	925	0	0	0	0	7	7637	2	3	5	71	0	0	0	0	17	30617
12-92	8	12685	9	4171	0	0	0	0	6	10171	5	0	0	0	2	5648	0	0	17	48308
Yr. Tot.	60	353578	52	23244	1	3638	0	0	36	54414	20	8	14	38	40	271721	0	0	151	730185
$/Failure		5,892		447		3,638		***		1,511						6,793		***		4,835
1-93	7	17789	2	418	0	0	0	0	6	24026	5	0	1	16	3	6266	0	0	16	48081
2-93	8	11988	4	2840	0	0	0	0	1	3724	1	0	0	0	2	7464	0	0	12	97381
3-93	10	23965	7	4270	0	0	0	0	1	1950	1	0	0	0	6	21081	0	0	17	46996
4-93	11	19867	3	1697	0	0	0	0	3	2194	3	0	0	0	3	11828	0	0	17	33889
5-93	0	0	2	294	0	0	0	0	1	1326	1	0	0	0	1	6160	0	0	2	7486
6-93	0	0	1	1200	0	0	0	0	2	2700	0	0	1	50	0	0	0	0	2	2700
7-93	10	12726	5	1179	0	0	1	34400	2	4188	1	1	1	50	6	18964	0	0	19	75278
8-93	7	42924	6	4842	0	0	0	0	3	3630	1	2	2	66	5	28437	0	0	16	77092
9-93	8	44760	4	4293	0	0	0	0	2	20790	1	1	1	50	5	30611	0	0	16	96571
10-93	5	10814	4	2828	0	0	0	0	1	992	1	0	0	0	3	18919	0	0	14	53697
11-93	8	47221	4	3817	0	0	0	0	2	3543	2	0	0	0	4	11589	0	0	14	62353
12-93	4	9168	10	11350	0	0	1	0	8	22457	7	0	0	0	8	36713	0	0	23	73692
Yr. Tot.	78	246222	52	39028	0	0	2	34400	32	91520	24	4	6	18	46	198032	0	0	168	675216
(93/92)%	30	-30			-100	-100	***	***	-11	68					15	-27	***	***	11	-7
$/Failure		3,156		750		***		17,200		2,860						4,305		***		4,019
1-94	12	20654	7	5230	0	0	0	0	5	10603	3	2	2	40	4	16486	0	0	24	50239
2-94	1	1434	9	6173	0	0	0	0	9	12611	7	1	2	22	4	27665	0	0	15	44568
3-94	16	37149	4	1300	0	0	0	0	4	4378	2	0	2	50	1	1338	0	0	21	42865
4-94	5	17548	4	2215	0	0	0	0	2	3918	2	0	0	0	4	19637	0	0	12	42123
5-94	0	0	0	0	0	0	0	0	0	0	0	0	0	***	0	0	0	0	0	0
6-94	0	0	0	0	0	0	0	0	0	0	0	0	0	***	0	0	0	0	0	0
7-94	0	0	0	0	0	0	0	0	0	0	0	0	0	***	0	0	0	0	0	0
8-94	0	0	0	0	0	0	0	0	0	0	0	0	0	***	0	0	0	0	0	0
9-94	0	0	0	0	0	0	0	0	0	0	0	0	0	***	0	0	0	0	0	0
10-94	0	0	0	0	0	0	0	0	0	0	0	0	0	***	0	0	0	0	0	0
11-94	0	0	0	0	0	0	0	0	0	0	0	0	0	***	0	0	0	0	0	0
12-94	0	0	0	0	0	0	0	0	0	0	0	0	0	***	0	0	0	0	0	0
Yr. Tot.	34	76785	24	14918	0	0	0	0	20	31510	14	3	6	30	13	65126	0	0	72	179795
(94/93)%	-56	-68			***	***	-100	-100	-37	-65					-71	-67	***	***	-57	-73
$/Failure		2,258		621		***		***		1,575						5,009		***		2,497

For 1994 : There were 0 Casing Failures at a cost of $0
: There were 0 Packer Failures at a cost of $0

Figure 5 - Failure Analysis Summary for Period
1/92 to 12/94 in one month intervals

Company: ARCO   Asset: ARCO   Sub-District: Texas

	Date	Rod Pump	Prog. Cavity	Hyd. Piston	Hyd. Jet	E.S.P.	Gas Lift	Plunger Lift	Inject/ Disposal	Flowing Oil	Flowing Gas	Total Active
Lease 1	May. 12,1993	0	0	0	0	0	0	0	0	1	0	1
Lease 2	Nov. 5,1992	3	0	0	0	0	0	0	0	0	0	3
Lease 3	Nov. 5,1992	7	0	0	0	0	0	1	0	0	0	8
Lease 4	Nov. 5,1992	2	0	0	0	0	0	0	0	0	0	2
Lease 5	May. 12,1993	0	0	0	0	0	0	0	1	0	0	1
Lease 6	Jun. 9,1994	0	0	0	0	0	0	0	0	0	0	0
Lease 7	May. 12,1993	0	0	0	0	0	0	0	0	1	0	1
Lease 8	Nov. 5,1992	3	0	0	0	0	0	0	0	0	0	3
Lease 9	Nov. 5,1992	3	0	0	1	0	0	0	1	0	0	5
Lease 10	Nov. 5,1992	8	0	0	0	0	0	0	0	0	0	8
Lease 11	May. 12,1993	1	0	0	0	0	0	0	0	0	0	1
Lease 12	May. 12,1993	1	0	0	0	0	0	0	0	1	0	2
Lease 13	Nov. 5,1992	2	0	0	0	0	0	0	0	0	0	2
Lease 14	Nov. 5,1992	7	0	0	0	0	0	0	1	0	0	8
Lease 15	Nov. 5,1992	4	0	0	0	0	0	0	0	0	0	4
Lease 16	Jun. 9,1994	0	0	0	0	0	0	0	0	0	0	0
Lease 17	May. 12,1993	1	0	0	0	0	0	0	1	0	0	2
Lease 18	Dec. 5,1993	2	0	0	0	0	0	0	0	0	0	2
Lease 19	Jun. 9,1994	0	0	0	0	0	0	0	0	0	0	0
Lease 20	May. 12,1993	0	0	0	0	0	0	0	0	1	0	1
Lease 21	May. 12,1993	0	0	0	0	0	0	2	0	1	0	3
Lease 22	May. 12,1993	0	0	0	0	0	0	0	0	2	0	2
Lease 23	Jun. 9,1994	0	0	0	0	0	0	0	0	0	0	0
Lease 24	Nov. 5,1992	7	0	0	0	2	0	0	0	0	0	9
Lease 25	May. 12,1993	1	0	0	0	0	0	0	0	0	0	1
Lease 26	May. 12,1993	1	0	0	0	0	0	0	0	0	0	1
Lease 27	Nov. 5,1992	4	0	0	0	0	0	0	1	0	0	5
Lease 28	Nov. 5,1992	5	0	0	0	0	0	0	0	0	0	5
Lease 29	Nov. 5,1992	5	0	0	0	0	0	0	1	0	0	6
Lease 30	Nov. 5,1992	7	0	0	0	0	0	0	0	0	0	7
Lease 31	Jun. 9,1994	0	0	0	0	0	0	0	0	0	0	0
Lease 32	Nov. 5,1992	11	0	0	0	0	0	2	8	2	5	28
Total Active for Sub-District:		85	0	0	1	2	0	5	14	9	5	121
Report Total:		85	0	0	1	2	0	5	14	9	5	121

Figure 6 - Active Well Counts by Type

		1990	1991	1992	1993	5/31/94
All Well Types	#Wells	121	121	121	121	121
	Tubing	0.12	0.25	0.33	0.38	0.26
	Casing	0.03	0.05	0.00	0.00	0.00
	All Failures	0.69	1.31	1.25	1.36	1.37
Rod Pump Wells	#Wells	85	85	85	85	85
	Pump	0.47	0.78	0.68	0.88	0.90
	Rods	0.21	0.60	0.42	0.38	0.54
	Tubing	0.13	0.25	0.41	0.47	0.31
Electrical Submersible Pump Wells	#Wells	2	2	2	2	2
	Pump	0.00	0.00	0.00	1.00	0.00
	Electrical	0.00	0.00	0.00	0.00	0.00
	Other	0.00	0.00	0.00	0.00	0.00
Hydraulic Jet Pump Wells	#Wells	1	1	1	1	1
	Pump	0.00	0.00	0.00	0.00	0.00
	Other	0.00	0.00	0.00	0.00	0.00
Hydraulic Piston Pump Wells	#Wells	0	0	0	0	0
	Pump	****	****	****	****	****
	Other	****	****	****	****	****
Gas Lift Wells	#Wells	0	0	0	0	0
	All Failures	****	****	****	****	****
Plunger Lift Wells	#Wells	5	5	5	5	5
	All Failures	0.00	0.00	0.00	0.00	0.00
Progressive Cavity Wells	#Wells	0	0	0	0	0
	Pump	****	****	****	****	****
	Rods	****	****	****	****	****
	Tubing	****	****	****	****	****
Flowing Gas Wells	#Wells	5	5	5	5	5
	All Failures	0.00	0.00	0.00	0.20	0.00
Flowing Oil Wells	#Wells	9	9	9	9	9
	All Failures	0.00	0.00	0.44	0.44	0.00
Injection/Disposal Wells	#Wells	14	14	14	14	14
	All Failures	0.14	0.64	0.43	0.14	0.17

Figure 7 - Equipment Performance Report: Number of Failures/Active Wells of that Type/Year All Active in 32 Leases of Texas Sub-District

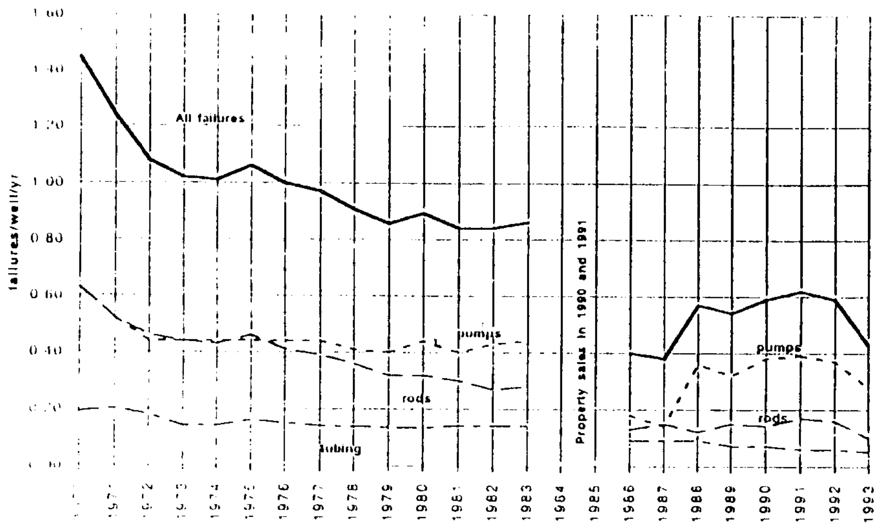

Figure 8 - Rod Pumped Wells In-hole failure performance (1970-1993)

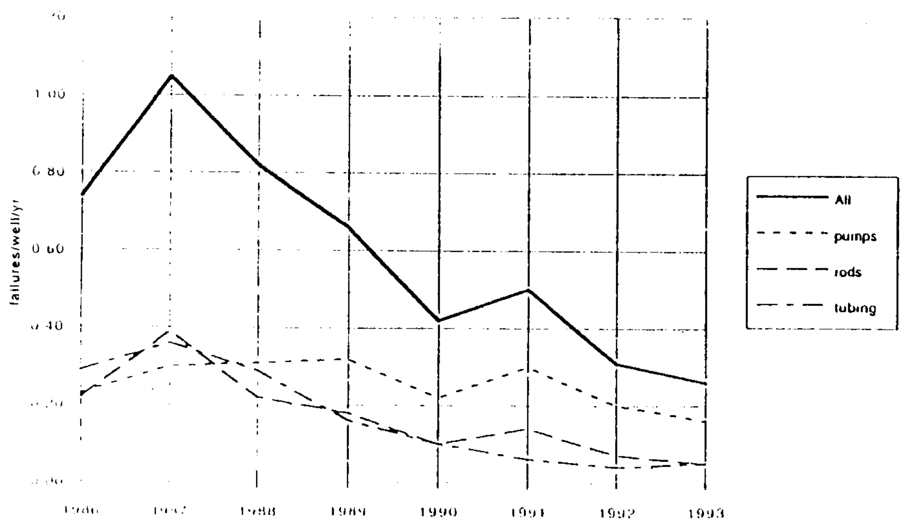

Figure 9 - West Texas Waterflood

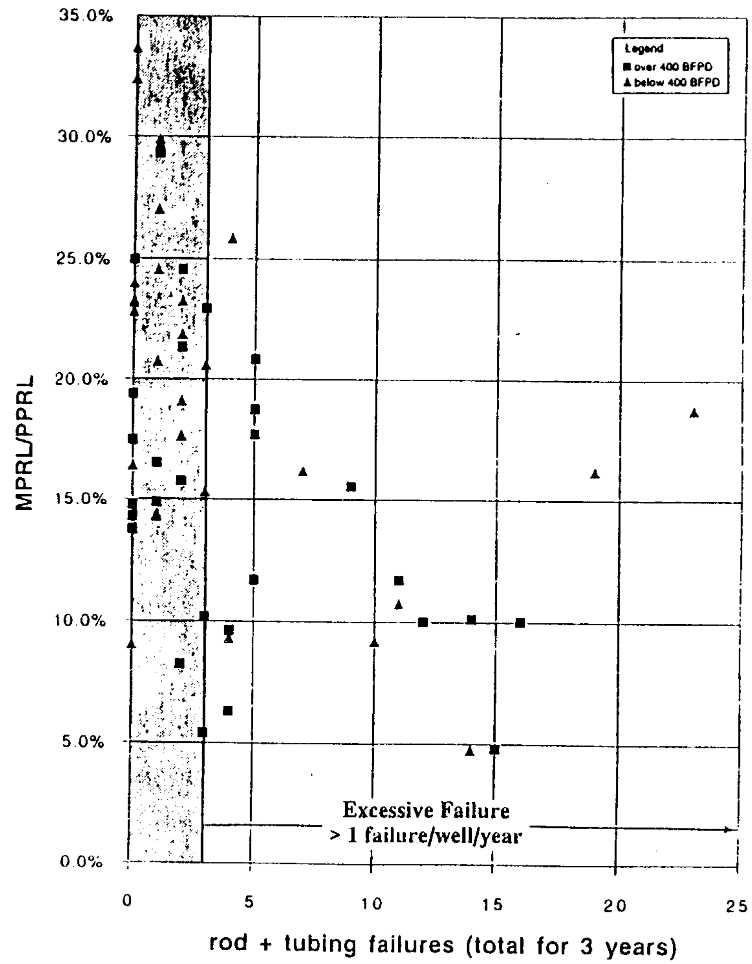

Figure 10 - Potential problem well; MPRL/PPRL <20%