SUCKER ROD PUMP METALS IN SOUR BRINE SERVICE

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ABSTRACT

One of the principal causes of subsurface failures is corrosion. Corrosivity of well fluids is primarily related to hydrogen sulfide and/or carbon dioxide gases in the produced water. Optimum utilization of corrosive-resistant materials for component parts of sucker rod pumps has been the more economical practice in Exxon's operation as compared with the use of corrosion inhibitors and less expensive metals. Past performance of pump part metals was studied to provide guidelines in upgrading the pump part metallurgy. Using a computerized data bank, over 8,000 pump runs were analyzed from 26 major fields within the West Texas and Oklahoma areas, most of which contained hydrogen sulfide in the produced fluid. General guidelines for pump part metals selection were established. The study indicated that average pump part service of at least 12 months should be expected with proper metallurgy selection.

INTRODUCTION

One of the principal causes of subsurface pump failures is corrosion. Pump corrosion is water dependent, and damages normally occur when the produced fluid contains greater than 20% water. The corrosivity of well fluids is primarily related to the amount of hydrogen sulfide and/or carbon dioxide gases dissolved in the produced water. There is a choice in the selection of metal components used in subsurface pumps for handling the corrosive fluids: one may use (1) inexpensive pump metals and depend upon corrosion inhibitors for protection or (2) pump metals and alloys that are sufficiently corrosion-resistant to the acid gases. Optimum utilization of corrosion-resistant materials has been the preferred practice in Exxon's Midcontinent Division, as corrosion inhibitors have not provided a high degree of pump protection. Corrosion inhibitors are adversely affected by the mechanical action of the barrel, plunger and valves, and higher fluid velocities within the pump. Also, with certain pump designs, some pump parts are not sufficiently contacted by the inhibitors.

This study was made to provide a basis for improved selection of pump part metals for sour brine service. Past performances were used to establish guidelines in upgrading pump part metallurgy to increase service life.

COMPUTER DATA BANK

The basis of this pump study was data accumulated in a computerized data bank for the period of six years, 1969 through 1975. The computer file, one of several for artificial lift surveillance,[1] was developed and maintained through the use of two simplified field entry forms. Figure 1 is an input form for recording data associated with a pump installation (run) and Figure 2 is an input form for pump service (pull). The forms are completed by the pump company repairing the pumps.

The input form for a pump "run" provides data on the proper pump identification and pump metallurgy. Recorded on this form are the lease and well number, "run" date, API pump classification, metallurgy of each pump component, and other pertinent information as shown in Figure 1. The pump "pull" record (Figure 2) provides identification data similar to the "run" report; and in addition, it indicates the failing part and the cause of failure. Code numbers are used for metallurgies and failure types. Both reports are required to constitute a completed pump record for analysis.

The computer data bank is built from data on input forms. The data bank is assessed with a computer program to collect and arrange the data as required for analysis. For this study, the average

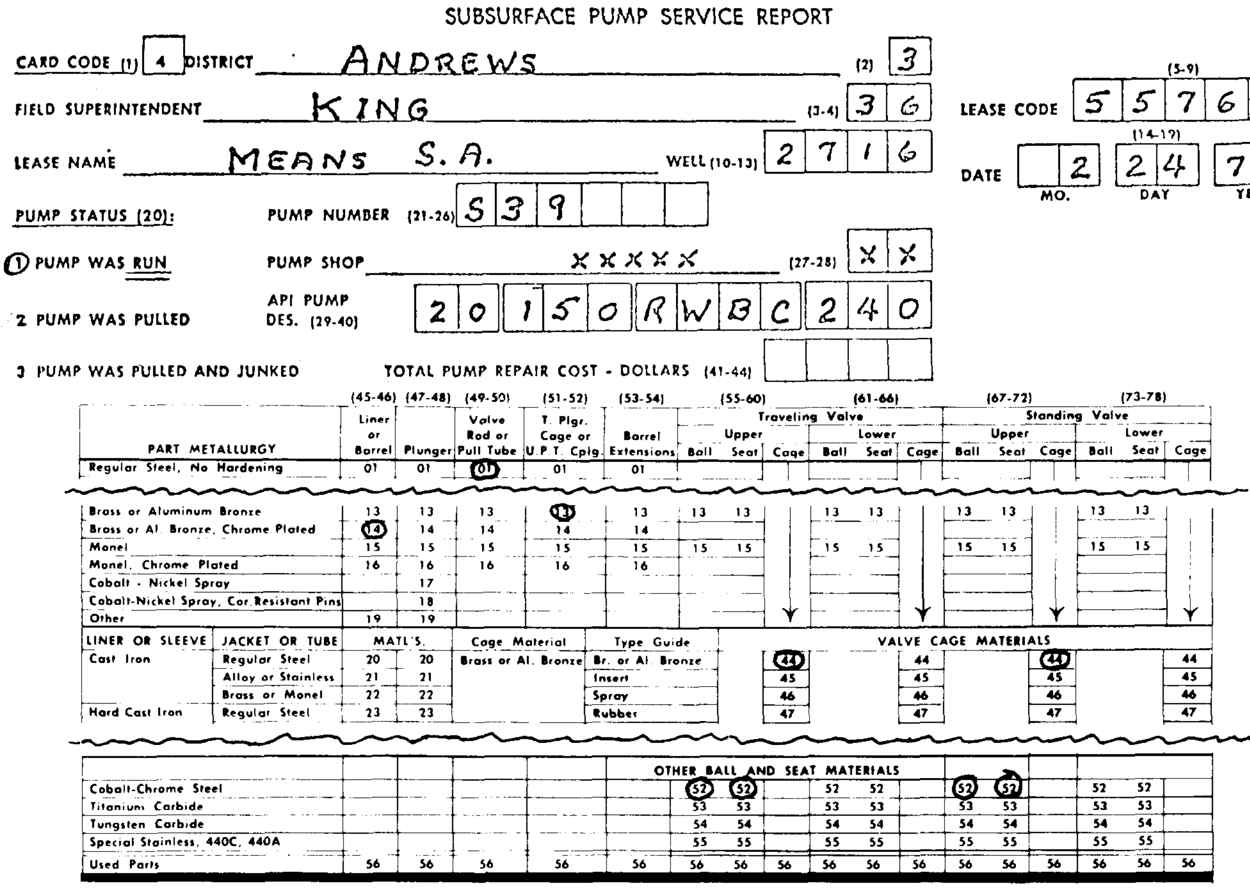

FIGURE 1—DATA FORM - REPLACEMENT PUMP

lives of failures and non-failures by metallurgies were summarized for the barrels, plungers, valves, cages, and pull rods or pull tubes (Table 1). Guidelines for pump-part service by metallurgies were based primarily on the service life of failing parts. Service life of non-failures was considered when such life exceeded the service life of failing parts.

TABLE 1—SUBSURFACE PUMP: COMPONENT PUMP PART LIFE AND METALLURGY

District: "C"
Field: No. 1

Pump Component	Metallurgy	Number Failures	Average Life-Days	Number Non-Failures	Average Life-Days
Barrel or Liner	Alloy Steel - Chr. Plt.	2	462	11	326
	Adm. Brass - Chr. Plt.	50	534	370	567
	Reg. Steel - Hardened	257	310	109	160
	Reg. Steel - Nickel Plt.	28	540	9	112
	Total	337	363	499	460
Plunger	Cobalt Nickel Spray	45	515	325	480
	Hard Cast Iron**Reg. Steel	37	379	138	501
	Ni-Hard**Reg. Steel	28	554	163	47[illegible]
	Total	110	480	626	481

PUMP AND PART SERVICE

Service of pumps and parts, subsurface pump types, and average pumping conditions were summarized for 26 major fields that produce sour fluids (Table 2). The average of completed pump runs ranged from 3 to 10 months in these fields while the range for average part-life was 5 to 14 months. Pump run and part life do not necessarily relate. To illustrate, Field No. 1, District C, experienced a 4.5 month average pump run and a 13.8 month average part life for a ratio of 0.32, while at Field No. 2, District B, similar values were 8.5 months and 8.7 months, respectively, for a 0.98 ratio. This ratio generally reflected the effect of well servicing for other types of subsurface failures—rod breaks, tubing leaks, workovers, etc.—and the field practices on pulling and shopping pumps for cleanup, inspection, or replacement. Consequently, a low ratio indicates that other subsurface failures dominate well servicing and should receive more attention. Eight of the 26 fields with moderate to severe pump-

SUBSURFACE PUMP SERVICE REPORT

CARD CODE (1) 4 DISTRICT ANDREWS (2) 3

FIELD SUPERINTENDENT KING (3-4) 3 6 LEASE CODE (5-9) 5 5 7 6 6

LEASE NAME MEANS S. A. WELL (10-13) 2 7 1 6 DATE (14-19) 2 24 75 (MO. DAY YEAR)

PUMP STATUS (20): PUMP NUMBER (21-26) S 3 9

1 PUMP WAS RUN PUMP SHOP XXXXX (27-28) X X

2 PUMP WAS PULLED API PUMP DES. (29-40) 2 0 1 5 0 R W B C 2 4 0

3 PUMP WAS PULLED AND JUNKED TOTAL PUMP REPAIR COST - DOLLARS (41-44) 2 6 0

FAILURE CODE	Liner or Barrel (45-46)	Plunger (47-48)	Valve Rod or Pull Tube (49-50)	T. Plgr. Cage or U.P.T. Cplg. (51-52)	Barrel Extensions (53-54)	Traveling Valve Upper Ball (55-60)	Traveling Valve Upper Seat	Traveling Valve Upper Cage	Traveling Valve Lower Ball (61-66)	Traveling Valve Lower Seat	Traveling Valve Lower Cage	Standing Valve Upper Ball (67-72)	Standing Valve Upper Seat	Standing Valve Upper Cage	Standing Valve Lower Ball (73-78)	Standing Valve Lower Seat	Standing Valve Lower Cage
Worn	01	01	01	01	01			01			01			01			01
Break	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02
Split	03	03	03	03	03			03			03			03			03
Cracked	04	04	04	04	04	04	04	04	04	04	04	04	04	04	04	04	04
Grooved or Scored	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05
Fluid Cut	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06
Plating Flaked	07	07	07		07												
Beat Out				08		08	08	08	08	08	08	08	08	08	08	08	08
Bent	09	09	09		09												
Thread Damage	10	10	10	10	10			10			10			10			10
Internal Pits	11	11	11	11	11			11			11			11			11
External Pits	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Other	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Re-work and Re-use	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

FIGURE 2—DATA FORM - DAMAGED PUMP

ing conditions showed an average pump-part life on the order of 12 months and greater. This would appear to be a reasonable goal for all of the fields, and pump metallurgy should be upgraded accordingly. Costs of various metallurgies are generally not a major factor in metals selection since well servicing costs $250 to $900 per job and production losses greatly exceed the incremental costs of upgraded replacement parts.

Average service life of major pump component parts was determined and typical data are shown in Table 3 and graphically in Figure 3. The average service represents the service life for failing parts only, unless otherwise indicated. For each component part, the two metallurgies most widely used in each specific field and their corresponding service are presented. This service represents the average life for parts that failed in service, except in certain cases where the life of non-failed parts exceeded that of failed parts; then the average life of both failed and non-failed parts is used. Figure 3 presents a comparison of part service and readily reveals which individual components are experiencing shorter service lives. These are candidates for upgrading to improve service. A description of metal codes is presented in the Appendix.

TABLE 2—SUBSURFACE PUMP PERFORMANCE: 1969 THROUGH 1975

District: / Field:	"B" 1	"B" 2	"B" 4	"C" 1
No. Runs	96	118	142	2625
Avg. Pump Run - Months	9.6	8.5	6.9	4.5
Avg. Part Service - Months	12.7	8.7	12.3	13.8
Ratio - Pump/Part Life	.76	.98	.56	.32
Type Pump	RWT, RWB	RWT, RWB	RWT, RWB	RWB, RWH
Pump Depth - Avg. Feet	5000	2200	2500	7000
H_2S - PPM (Prod. Wtr.)	30	300	80	200

TABLE 3—PUMP PART PERFORMANCE: 1969 THROUGH 1975

District: / Field:	"B" 1		"B" 2		"B" 4		"C" 1	
	Code	Serv. Mos.	Code	Serv. Mos.	Code	Serv. Mos.	Code	Serv. Mos.
A. Pump Barrel								
Avg. Service - Months	13		[illegible]		9		12	
Metals - Most Used								
1st	1	15	15	7	6	9	14	18+
2nd	6	6	2	13	-	-	2	10
B. Plunger								
H. Pull Tube or Rod								
Avg. Service - Months	16		9		13		13	
Metals - Most Used								
1st	1	18	15	7	1	13	1	18+
2nd	2	6+	1	14	-	-	-	-

Note: + Service of non-failures exceeds failures; service months are average of both.

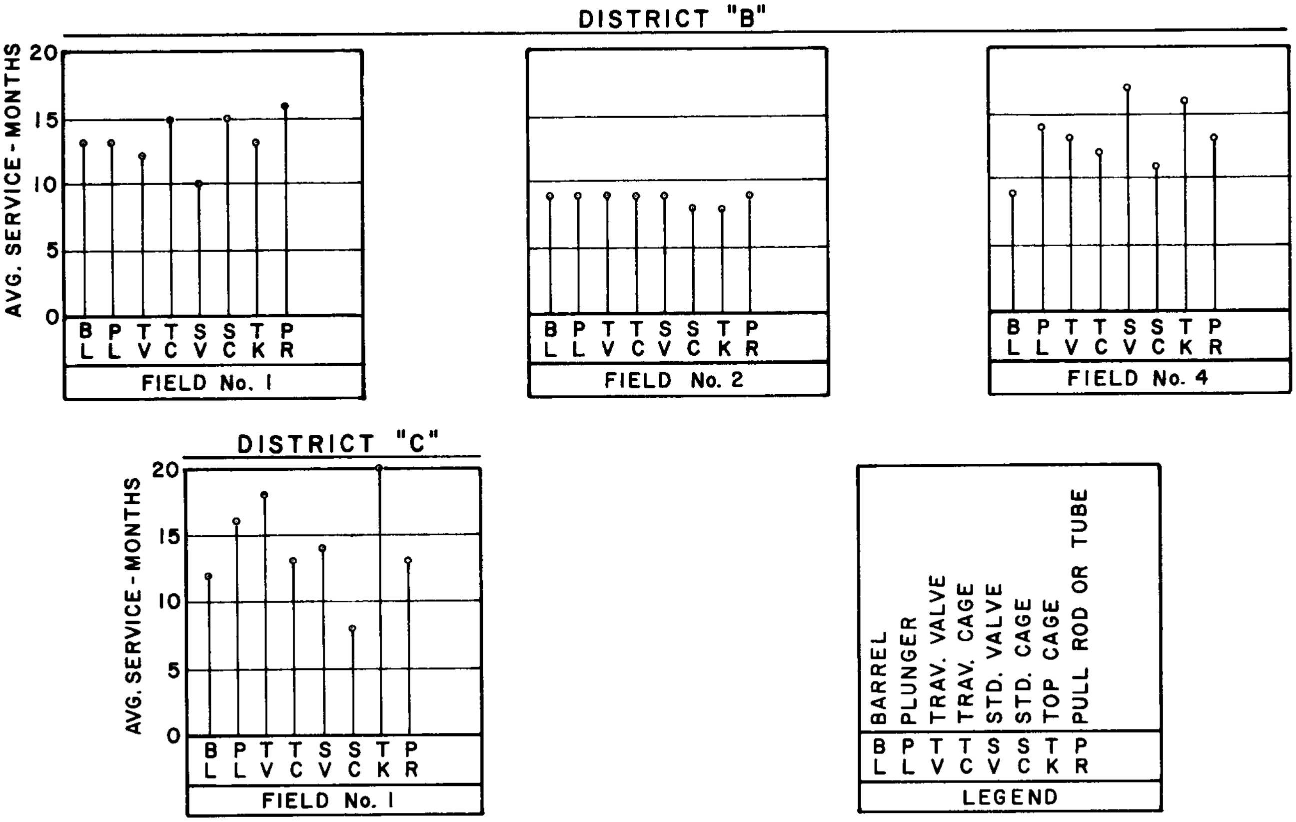

FIGURE 3—SUBSURFACE PUMP PERFORMANCE

METALS SELECTION

Performance of component pump parts is presented in Tables 4 through 12. The parts are identified as to metallurgy and rated according to their service record as follows:

RATING	MONTHS SERVICE
A-Good	Over 10 months in 2 or more districts
A-Qualified	Over 10 months in one district
B-Fair	8 through 10 months in one or more districts
C-Poor	Less than 8 months in one or more districts

The A-qualified rating is included because satisfactory service of a metal in one field or district may not extend to other areas.

These tables provide guidelines on metals selection for upgrading of pump parts. Generally, the past performance data indicate that the best service for pump barrels is attained with corrosion-resistant base metals plated with chrome or nickel on the inside diameter. Regular steel plungers with spray metal coatings of chrome, nickel, and certain metallic carbides on the external surface perform well. Also, regular steel appears to be satisfactory for other fittings—cages, pull rods, and pull tubes. The best valve service is obtained with stellite, a non-ferrous alloy. Certain metals with lower ratings show good service in specific fields, and continued use of the materials in these fields would be prudent. These tables can be used to reduce the "trial and error" effort and expense in selecting a right combination of parts to improve pump service.

Performance of different metals and alloys is discussed by pump parts below:

Barrels (Table 4)

Barrels of corrosion-resistant base metal, plated with chrome or nickel on the internal diameter have provided the best service in our pumping environments. A nickel-plated, regular steel barrel has performed satisfactorily in one field. However, steel base metal has few corrosion-resistant properties and normally should be used in mild corrosive environments. The plating materials are beneficial on wear surfaces in that they possess corrosion- and abrasion-resistant properties. Occasionally, erratic performance may be experienced with plated barrels due to improper application of the plate. Failures occur as "flaking" of the plate material or galvanic corrosion of the base metal part.

The majority of our subsurface pumps are of the bottom holddown design, and selection of a base metal to resist corrosion is important to good service. With this type of pump, a "dead space" in the tubing-barrel annulus exists and extends from the discharge at the top of the pump to the bottom holddown. Corrosion products settle in this space to set up concentration cell corrosion, and inhibitors cannot be effectively applied to the area. So, both barrel and tubing corrosion damage can occur. This is one reason that corrosion inhibitors have not been highly effective in controlling pump corrosion.

Where tubing corrosion is a problem in this dead space, an internal plastic coating on the joint of tubing containing the pump has been successful. A top seal on the pump barrel can alleviate this corrosive area and permit the use of a cheaper base metal for the barrel. With pumping depth above 5,000 ft, a top holddown or travel-barrel design can eliminate this corrosive condition.

TABLE 4—SUBSURFACE PUMP METALS EVALUATION: BARRELS

Material Rating	Metal Code*	Description	Average Service - Months				Total No. Runs
			District			Total	
			"A"	"B"	"C"		
'A' - Good	14	Brass - Chr. Plt.	5+	10+	18+	15+	724
'A' - Qualified	4	Reg. Steel - Ni. Plt.	-	-	12	12	85
	12	Stainless - Chr. Plt.	-	13+	-	13+	28
	16	Monel - Chr. Plt.	-	13	-	13	26
'B' - Fair	1	Reg. Steel	-	9+	8+	9+	363
	2	Reg. Steel - Harden	6	12	9	9	609
	3	Reg. Steel - Chr. Plt	8	9+	-	8	267
	6	Alloy Steel - Harden	9	9+	-	9	316
	9	Special Alloy - Harden	8+	11	-	9	91
'C' - Poor	7	Alloy Steel - Chr. Plt.	-	6+	-	6+	29
	15	Monel	-	7+	-	7+	59
Not Rated	13	Al. Bronze	Insufficient Data				
	27-Sec.	Ni-Hard - Stainless	Insufficient Data				

\+ Life of non-failed parts exceed failures; service months are an average of both.

* See Appendix for code.

Plungers (Table 5)

Both the one-piece and composite plungers of specific metallurgy have provided satisfactory service. The tendency within the Division and Industry is to use the one-piece plunger. This trend probably results from the additional work required to manufacture and assemble the composite, difficulties in maintaining alignment, particularly in deeper wells, and the slight increase of restriction because of the smaller I.D. of the plunger tube.

The spray-metal (Cobalt-Nickel), one-piece plunger has provided the best performance record of the one-piece plungers. Two types of spray-metal plungers are available: a plunger with the pins (threaded ends) protected by a plating or by means of a monel connector, and a plunger without protection. The ones without protection have performed better than the plungers with corrosion resistant pins. This may be due to a reduction in pin strength caused by the metal spraying process or, in the case of those with a monel connector, a reduction of metal strength. Of the composite plungers, the nickel cast iron (Ni-Hard) has performed satisfactorily. The cast iron (regular and hard) has provided good service in one District.

TABLE 5—SUBSURFACE PUMP METALS EVALUATION: PLUNGERS

Material Rating	Metal Code	Description	Average Service - Months				Total No. Runs
			District			Total	
			"A"	"B"	"C"		
'A' - Good	17	Cobalt-Ni. - Spray	9+	14+	14+	12+	877
	26-Sec.	Ni-Hard - Reg. Steel	-	8+	16+	13+	280
'A' - Qualified	20-Sec.	C. I. - Reg. Steel	-	-	16+	16+	175
	23-Sec.	H. C. I. - Reg. Steel	-	-	13+	13+	97
'B' - Fair	2	Reg. Steel - Harden	-	10+	-	10+	76
	18	Cobalt-Ni. Spray - CRP	7+	11+	9	10+	536
	24-Sec.	H. C. I. - Stainless	-	8	-	8	27
	30-Sec.	Stainless - Stainless	-	10+	-	10+	70
'C' - Poor	8	Alloy St. - Ni. Plt.	7	-	-	7	23
Not Rated	1	Reg. Steel	Insufficient Data				
	19	Other	Various Alloys				

\+ Life of non-failed parts exceeds failures; service months are an average of both.

Balls and Seats (Tables 6 and 7)

Performance data in the tables reflect either ball or seat service, whichever failed first. The ball and seat are considered as one unit since they are generally replaced as a unit. The service data show that the stellite (cobalt, chrome, tungsten nonferrous alloy) provides outstanding service and is most widely used within the division. In one shallow field, Field No. 2, District B, the monel valve has performed well in a very sour environment. Care should be exercised in the application of monel because it is a relatively soft metal and will deform under heavy loads as encountered in deep wells. Its hardness is about R_c35 as compared to R_c58 for Stellite.

In some fields, a cheaper ball (tool steel or stainless) with a very hard tungsten carbide (R_c72) seat is used. No improved valve performance has been apparent with this combination, primarily because a failure of either part required a service job, and generally, both parts were replaced.

TABLE 6—SUBSURFACE PUMP METALS EVALUATION: TRAVEL VALVE - BALLS AND SEATS

Material Rating	Metal Code	Description	Average Service - Months District "A"	"B"	"C"	Total	Total No. Runs
'A' - Goo	52	Stellite	-	12+	15	13+	1082
'A' - Qualified	15	Monel (1)	-	11+	-	11+	75
'B' - Fair	9	Spec. Alloy- Harden	8+	8+	-	8+	247
	54	Tungsten Carbide	5+	8+	6+	8+	271
'C' - Poor	10	Stainless - 329 & 414	7+	-	-	7+	313
	55	Stainless - 440 C&A	5+	10+	-	6+	307
Not Rated	53	Titanium Carbide	Insufficient Data				

(1) Hardness - 27/35 R_c - Not suited for heavy loads

+ Life of non-failed parts exceeds failures; service months are an average of both.

TABLE 7—SUBSURFACE PUMP METALS EVALUATION: STANDING VALVE - BALLS AND SEATS

Material Rating	Metal Code	Description	Average Service - Months District "A"	"B"	"C"	Total	Total No. Runs
'A' - Good	52	Stellite	-	12+	14	13+	1221
'A' - Qualified	15	Monel (1)	-	11+	-	11+	74
'B' - Fair	9	Spec. Alloy - Harden	-	8+	-	8+	171
'C' - Poor	10	Stainless - 329, 414	7+	-	-	7+	305
	54	Tungsten Carbide	3+	8+	-	7+	243
	55	Stainless - 440 C&A	4+	11+	-	5+	303
Not Rated	53	Titanium Carbide	Insufficient Data				
	2	Reg. Steel - Harden	Insufficient Data				

(1) Hardness - 27/35 R_c - Not suited for heavy loads

+ Life of non-failed parts exceeds failures; service months are an average of both.

Other Fittings—Cages, Couplings, Pull Rod, and Pull Tube (Tables 8 through 11)

Regular steel metallurgy has provided satisfactory service for the other fittings and is used extensively within the division. Naval brass has performed well in Field No. 2, District C, under difficult pumping conditions. This metal has good corrosion-resistant properties but is a softer metal with less strength than regular steel.

Upgrading Pump Parts

Component parts that are candidates for upgrading (less than 12 months average service life) were

TABLE 8—SUBSURFACE PUMP METALS EVALUATION: TRAVEL VALVE - CAGE

Material Rating	Metal Code	Description Cage	Guide	Average Service - Months District "A"	"B"	"C"	Total	Total No. Runs
'A' - Good	32	Reg. St.	Reg. St.	12+	14+	13	13+	654
	33	Reg. St.	Insert	8+	-	16+	11+	405
'A' - Qualified	37	Alloy St.	Insert	-	13+	-	13+	56
	41	Stainless	Insert	-	22+	-	22+	19
	44	Brass	Brass	-	-	12+	12+	244
	45	Brass	Insert	-	-	12+	12+	282
'B' - Fair	34	Reg. St.	Spray	-	-	8+	8+	57
	36	Alloy St.	Alloy St.	8+	11+	10+	10+	299
	40	Stainless	Stainless	7+	10	-	8+	89
	48	Monel	Monel	-	10+	-	10+	131
'C' - Poor	43	Stainless	Rubber	7+	-	-	7+	122

+ Life of non-failed parts exceeds failures; service months are an average of both.

TABLE 9—SUBSURFACE PUMP METALS EVALUATION: STANDING VALVE - CAGE

Material Rating	Metal Code	Description Cage	Guide	Average Service - Months District "A"	"B"	"C"	Total	Total No. Runs
'A' - Good	32	Reg. St.	Reg. St.	10+	14+	13+	13+	879
	33	Reg. St.	Insert	8+	10+	13+	11+	289
	36	Alloy St.	Alloy St.	8+	12+	-	11+	352
'A' - Qualified	37	Alloy St.	Insert	-	16+	-	16+	48
	44	Brass	Brass	-	-	13+	13+	571
	45	Brass	Insert	-	-	14+	14+	314
'B' - Fair	34	Reg. St.	Spray	-	-	8+	8+	43
	38	Alloy St.	Spray	-	10+	-	10+	64
	48	Monel	Monel	-	10+	-	10+	96
'C' - Poor	40	Stainless	Stainless	4+	10+	-	7+	66
	43	Stainless	Rubber	4+	-	-	4+	59
Not Rated	41	Stainless	Insert	Insufficient Data				

+ Life of non-failed parts exceeds failures; service months are an average of both.

TABLE 10—SUBSURFACE PUMP METALS EVALUATION: TOP PLUNGER CAGE OR UPPER PULL TUBE COUPLING

Material Rating	Metal Code	Description	Average Service - Months District "A"	"B"	"C"	Total	Total No. Runs
'A' - Good	1	Reg. Steel	8+	14+	14	13+	1503
'A' - Qualified	6	Alloy St. - Harden	-	11+	-	11+	39
	10	Stainless	-	14+	-	14+	21
	13	Brass	-	-	13	13	56
'B' - Fair	5	Alloy Steel	-	12+	6+	10+	203
	15	Monel	-	9+	-	9+	142
'C' - Poor	2	Reg. Steel	5+	10+	9+	7+	180
Not Rated	14	Al. Br. - Chr. Plt.	Insufficient Data				
	32	Reg. Steel - Reg. Steel	Insufficient Data				

+ Life of non-failed parts exceeds failures; service months are an average of both.

TABLE 11—SUBSURFACE PUMP METALS EVALUATION: PULL ROD OR TUBE

Material Rating	Metal Code	Description	Average Service - Months District "A"	"B"	"C"	Total	Total No. Runs
'A' - Good	1	Reg. Steel	7+	13+	14+	13+	1865
'A' - Qualified		NONE					
'B' - Fair	5	Alloy Steel	-	11+	6+	10+	228
	15	Monel	-	10	-	10	84
'C' - Poor	2	Reg. Steel - Harden	6+	-	6+	6+	137
	6	Alloy Steel - Harden	-	-	6+	6+	31
Not Rated	13	Brass or Al. Br.	Insufficient Data				

+ Life of non-failed parts exceeds failures; service months are an average of both.

summarized by fields (Table 12). All 26 fields had pump parts that were candidates for upgrading, even those with average service equal or exceeding 12 months. In several fields only one part would require attention, but in nine fields all components of the pump had poor service records.

TABLE 12—SUMMARY OF UPGRADE CANDIDATES

I. Fields with Average Pump Service of 12 months or greater

District	Field	Problem Parts
"B"	1	Std. Valve
	3	Std. Valve and Plunger
	4	Barrel
	5	Barrel
	8	Barrel
	15	Barrel and Plunger

II. Fields with Average Pump Service of less than 12 months

District	Field	Problem Parts
"B"	2	All components
	6	Barrel and Plunger
	7	Plunger, Valves, Travel Valve Cage and Top Cage
	9	Valves
	10	Barrel, Valves and Cages
	11	All components
	12	Barrel, Plunger, Std. Valve and Cage, and Top Cage
	13	All components
	14	Std. Valve Cage and Pull Rod

A table like that presented in Table 3 can serve as a guideline in appropriate metals selection for upgrading. To illustrate the table's use, under "Pump Barrel" in Field No. 1, District B, metal code No. 1 had provided 15 months average service as compared to 6 months for metal code No. 6. Thus, greater use of metal code No. 1 should improve barrel service. The "pump barrel" at Field No. 4, District B, had a short service life of about 9 months and only metal code No. 6 had been used. Selection of another metallurgy from Table 4 "Barrels" would be recommended for evaluation. In summary, utilize existing metals that have performed satisfactorily in specific fields. If there are none, select other metals that have performed well from Tables 4 through 11. This approach can reduce the "trial and error" effort and expense in selecting the right combinations of pump parts for service improvement.

PUMP SURVEILLANCE

For proper surveillance and improvement of subsurface part performance, it is planned to review pump data on an annual basis by computer analysis. Generally, metals selection has been at the discretion of the pump company or the shop, with limited input from Exxon. The application of different metals has been made experimentally. Now sufficient data is available to provide suitable guidelines as to proper metals selection in most fields. It is believed that, by combining our pump data with the pump company's information, further improvements in metals selection and, ultimately, in total pump service can be attained.

CONCLUSIONS

1. Average pump-part service of at least 12 months should be an attainable goal, and pumps should be upgraded accordingly.
2. Past performance data provides guidelines for upgrading pumps. General guidelines for pump-part metals selection are as follows:
   a. Barrels: Chrome or nickel plate on a corrosion-resistant base metal.
   b. Plungers: Spray-metal coatings on a reggular steel-base metal and unprotected pins.
   c. Valves: Stellite.
   d. Cages, couplings, pull rods, and pull tubes: Regular steel.
3. A low ratio of average pump run to average part life in a specific field indicates that service jobs other than pump failures dominate well servicing costs.

REFERENCES

1. White, J. R.: "Computer Application in Sucker Rod Pumping Management," Southwestern Petroleum Short Course, 1976.

APPENDIX

Pump Metallurgy Codes

1		Regular Steel-No Hardening
2		Regular Steel-Harden
3		Regular Steel-Chrome Plated
4		Regular Steel-Nickel Plated
5	One Piece Barrel	Alloy Steel
6		Alloy Steel-Harden
7	One Piece Plunger	Alloy Steel-Chrome Plated
8		Alloy Steel-Nickel Plated
9	Pull Rod	Special Alloy-Harden
10		Stainless Steel
11	Top Cage	Stainless Steel-Harden
12		Stainless Steel-Chrome Plated
13	Valves	Brass or Aluminum Bronze
14		Brass or Al Brz-Chrom Plated
15		Monel
16		Monel-Chrome Plated

17		Cobalt Nickel Spray
18		Co-Ni Spray-Cor. Resis Pins
19		Other
20		Cast Iron**Regular Steel
21		Cast Iron**Alloy or Stainless
22		Cast Iron**Brass or Monel
23		Hard Cast Iron**Regular Steel
24	Liner Barrels & Sectional Plungers	Hard Cast Iron**Alloy or Stnls
25		Hard Cast Iron**Brass or Monel
26		Ni-Hard**Regular Steel
27		Ni-Hard**Alloy or Stainless
28		Ni-Hard**Brass or Monel
29		Stnls Steel**Regular Steel
30		Stnls Steel**Alloy or Stnls
31		Stnls Steel**Brass or Monel
32		Regular Steel**Regular Steel
33		Regular Steel**Insert
34		Regular Steel**Spray
35		Regular Steel**Rubber
36		Alloy Steel**Alloy Steel
37		Alloy Steel**Insert
38		Alloy Steel**Spray
39		Alloy Steel**Rubber
40		Stainless Steel**Stnls Steel
41		Stainless Steel**Insert
42	Cages	Stainless Steel**Spray
43		Stainless Steel**Rubber
44		Brass or Al Brz**Br or Al Brz
45		Brass or Al Brz**Insert
46		Brass or Al Brz**Spray
47		Brass or Al Brz**Rubber
48		Monel**Monel
49		Monel**Insert
50		Monel**Spray
51		Monel**Rubber
52		Cobalt-Chrome Steel
53	Valves	Titanium Carbide
54		Tungsten Carbide
55		Spec. - Stainless 440C, 440A