Pumping Well Failure Analysis Using Electronic Data Processing Techniques

E. D. JUNKIN, JR.
Getty Oil Company

This paper has been prepared in recognition of a growing interest in the subject techniques. However, discussion of these techniques, of necessity, must be prefaced by defining the real and final objective, how is it to be accomplished, when and where are necessary programs to be initiated, and who is responsible for the successful implementation and execution of these programs.

The ultimate goal is effective equipment failure control to reduce costs or, in other words, effective cost control. Initially, equipment failures must be isolated, defined and their economic impact established in such a manner that an appropriate proposal for control can be prepared for management approval. Experience has shown, as should be the case in line authority, that successful failure control programs must be initiated and continued with the full support of management. Recognizing and defining equipment failures and their costs is a matter of simple uniform reporting procedures. Analysis of this data provides timely recognition of problem conditions and where either initial or revised control measures are needed. The latter must be a continuing procedure if an optimum failure control program is to be maintained. Local supervisory personnel thus have the necessary information to develop and direct required programs and to evaluate the results. With initial responsibility designated to management and supervisory personnel, the day-to-day execution of specified procedures is the responsibility of operating personnel. Obviously, operating personnel must be properly trained if they are to effectively discharge this responsibility. Both inter-company and industry-sponsored work shops and short courses are achieving this objective.

In 1960 the production manager in Getty Oil Company's North American Exploration and Production Division (then the Southern Division of Tidewater Oil Co.) charged the division engineering staff with the responsibility of developing and directing a division-wide corrosion-equipment failure control program. This decision was based largely on the recognized success of several smaller programs which had been conducted on a local basis. The final objective and considerations necessary to the accomplishment of that objective, as described above, were in view at that time. The development of an initial plan was a relatively simple matter compared to the several years of concentrated effort in field operations required to achieve a successful program.

The key to success is commitment—on both the part of management and the people who recognize and define equipment failures, record these observations, evaluate the problem and proceed to implement the necessary control method(s). As results were realized, interest and support of the program grew and continue to grow today. Obviously, cost control is vitally important to management, and operating personnel who are directly responsible for such cost control are always receptive to an effective means of accomplishing that objective. Today, effective equipment failure control programs are a working, integral phase of Getty Oil Company's field operations. In this sense they are analogous to safety programs—effective prevention requires continuous surveillance and effort.

The plan of field implementation must remain flexible so that alternate procedures may be executed and evaluated. Trial-and-error methods in field operations can become unreasonably expensive and therefore must be tempered with good judgment. In selecting control methods, economics are considered; i.e., the cost of a given equipment failure occurrence may be less than the cost of an adequate control method and is thus better left alone, unless control is required for reasons of safety or for continuity of operations. It has been necessary to recognize other conditions which contribute to equipment failure, other than metal loss resulting from corrosion. Wear and other adverse mechanical conditions which produce excessive loads on equipment must be corrected. Design and material selection are in themselves important factors in reducing equipment failures.

A paper titled "Production Cost Control—A People Problem" was presented during the April 1970 Seventeenth Annual Meeting of the Southwestern Petroleum Short Course by Mr. C. F. Dwyer. Mr. Dwyer prefaced his discussion of cost control procedures with a short discussion of the philosophy of cost control which he concluded by stating, "Normally, good people—once they know the problem—and believe a solution possible—will not sit still until it is corrected. Everyone wants to achieve; the system merely shows the way and people provide the action". Successful equipment failure programs are dependent on motivating people to act. This begins with working with the people involved to establish that a problem exists and to define those characteristics which will make it possible to recognize that problem should it reoccur. This system continues to establish the importance of failure data and cost records and their analysis as well as to establish confidence in control methods. Ultimately a sustained program of recognition, definition, control and evaluation is established.

The initial plan for a division-wide corrosion-equipment failure control program, developed in 1960, included a provision for obtaining the necessary data on the occurrences, causes and costs of equipment failures. Manual methods used in earlier local programs were inadequate. A system was needed which employed a fast, simple and inexpensive method for recording data in the field. Furthermore the system must provide a means of data storage and retrieval to permit analyzing and reproducing this data in a permanent form for use by operating personnel. It was found that electronic data processing techniques could be used to routinely process and analyze massive amounts of data quickly and at a nominal cost. Figures 1 through 10 illustrate input forms and various types of machine printouts to depict the evolution from the original formats and procedures to those being used today.

Figure 1 is the original data input form—'Equipment Failure Report'. The form consists of four major parts: (1) location and date, (2) failure data and depth of subsurface failures, (3) cost information and (4) remarks. The form was designed to fully utilize the eighty character spaces on a data punch card. Numbers in parentheses identify the space on the punch card in which each piece of information goes. The electronic data processing machine is programmed to 'read' the punched cards, analyze the data and print out a permanent record. Location is defined by the use of the appropriate numeric characters to provide Division, District, Area codes, Lease Title No., Well No. and Date. Failure data is shown by circling the appropriate number in each data column and the depth of failure is numerically recorded. Cost data is recorded, as shown, to the nearest dollar. 'Remarks' shown in the designated spaces are permanently recorded; 'Other Remarks' are not. The form provided a fast, simple means of recording required failure data on the job. Its use was originated on January 1, 1961, and was discontinued on December 31, 1969, in favor of a revised form which is to be discussed later.

Figure 2 is an example of the original printout format. Printouts were issued monthly and distributed to operating personnel. Cumulative data printouts were issued and distributed at the close of each quarter concluding with an annual summary of that year's reported data. Under this original format, data was not carried forward into the following year's summaries. The Failure Report Summary in Fig. 2 shows cumulative data for the first quarter. Note first the arrow locating the printout of input data shown in Fig. 1. Data was first sorted by sub-area, as shown in the upper left-hand corner, to group together the leases supervised by each foreman. Data for each lease was grouped together by well number. Individual well data was grouped together by failing equipment in chronological order. The printout was quickly scanned to locate repeat or high frequency failures which were optimum situations for implementing measures to improve failure control. A total cost was shown for each lease and the total sub-area cost was shown and summarized to reflect the distribution of failures and failure costs for specific types of equipment. Total costs were similarly shown and summarized for each Area, District, and the Division. This printout format was initiated in January 1961 and was discontinued with completion of the 1969 Annual Summary in favor of a revised format which is to be discussed later.

Figure 3 is typical of Special Summary printouts which were compiled for different types of failure analysis. One page of printout is used to illustrate the analysis of three years of pump failure data on a group of 150 wells which was retrieved from the data files, sorted and printed out to show the distribution of these costs with respect to the failing pump part. Note that all barrel failures are grouped together as are plunger failures and valve ball and seat failures. This particular analysis revealed the following distribution of costs: PLN—54.1 per cent, BRL—32.1 per cent, VBS—10.6 per cent and OTH—3.2 per cent.

Figure 4 is a graphical presentation of the data analysis obtained in another Special Summary. The distribution of total subsurface failure costs reported in the Division for a three-year period is shown. This analysis revealed that subsurface failure costs represented 76.5 per cent of the total reported failure costs. The remaining 23.5 per cent, surface failures, was also analyzed for cost distribution.

Figure 5 illustrates a summary printout of three years of pumping oil well failures. This summary included all wells in the Division. A typical well summary is shown designating repeat type failures and showing total costs per year. Summary of lease totals for this three-year period shows a distribution of those costs by failing equipment as well as repeat failures in each of those categories. Annual totals are augmented by showing the actual number of wells which failed each year and the cost per failed well per year. A similar analysis of total costs was made for each Area, District and the Division.

Figure 6 illustrates the Sub-Surface Equipment Failure Report which has been in use since January 1, 1970. A similar form is used to report surface equipment failures. Information shown to locate and date the failure is basically the same as before. Present techniques do not require Division, District and Area coding and this available space on the form is now used to designate the producing reservoir to permit this subgrouping of failures when desired. Certain failure and cost data, previously recorded, was found to be of no appreciable value. The primary advantage in this new form is the space available to record and identify those maintenance costs which occurred incidental to the failure cost. Previously these costs were either not shown or were included in the total cost, but not identified. With the present form, for example, rod and/or pump maintenance performed in conjunction with repairing a tubing failure can be reported and the costs so identified. Current techniques permit the use of a second punch card which allows expanding the number of 'Remarks' spaces available.

Figure 7 is typical of the current Sub-Surface Equipment Failure Summary. Note first the arrow locating the printout of the input data illustrated in Figure 6. Rod maintenance costs are shown as reported and will be included in the analysis of total rod costs. Reported incidents of maintenance are not included in counting the total number of failures. The format of the printout is basically the same as before except now monthly and cumulative lease totals are recorded. Repeat failures occurring on the same equipment are identified in the 'Control' column by designating the number of days since the last failure. This type of designation is emphatic and quickly draws attention to a problem condition. Furthermore each monthly printout now shows cumulative failure and maintenance data reported for the past twelve months. For example, when the January 1971 summary was printed, data for that month was added and data for the month of January 1970 was deleted. This readily available twelve-month performance history is of great value to operating personnel for on-the-job evaluation of control methods and for making timely decisions with respect to equipment inspection and/or replacement. This summary printout format was adopted in January 1970.

Figure 8 illustrates the first monthly and quarterly data analysis developed in conjunction with the revised summary printout discussed previously. The number of failures, failure cost and maintenance costs are shown for each type of equipment. The number and cost of repeat failures and total costs are also shown. The analyses shown are for a Sector (previously Sub-Area). Similar analyses are printed out for each Area, District and the Division.

Figures 9 and 10 show revised formats of subsurface equipment failure analyses recently adopted to replace those shown in Fig. 8. The data presented is the same, only the format has been changed. Note that both monthly and quarterly analyses are presented to provide a continuous record of performance which can be quickly reviewed. This enhances the value of data analyses to supervisors whose primary interest is in overall status and the total individual performance of the operating segments under his supervision. Furthermore the revised format reduced the number of summary printout pages by a factor of eight.

Figures 11 and 12 show graphically the failure history and other pertinent information on a group of wells in West Texas and a group of wells in Illinois.

The data on the West Texas wells shown in Figure 11 illustrates an effective, stabilized control program on 140 wells with an average failure cost of \$145/well/yr through the year 1966. In 1967 the original operation was expanded to include an additional 450 wells and failure costs increased to an average of \$320/well/yr. Obviously, equipment failure control on these wells was not effective. The plot of data for ensuing years shows that improved control has been established, and continues to improve. This has been accomplished over a period of time when per well production of water and oil has steadily increased, giving further credit to the effectiveness of control measures which have reduced failure costs to an average of \$175/well/yr. The increase in treating costs under these conditions is typical; however, with control established, these costs are being reduced by optimizing treating methods.

The plot of failure data on a group of wells in Illinois, shown in Figure 12, presents much the same record of improved equipment failure control as above. Failure costs on approximately 350 pumping wells in Illinois had risen to an average of \$365/well/yr. Improved control methods reduced these costs to \$220/well/yr. The increase in costs shown in 1970 is primarily attributed to a group of approximately 50 wells which experienced rapid, large increases in production as a result of waterflood operations.

Further, it is interesting to note the increases (26.5 per cent cumulative) in material prices and labor costs which have occurred over the ten-year period for which failure data is shown in the last two figures. The dollar impact of these increases on \$/well/yr costs gives further credit to the results of failure control programs.

An equally successful companion program is being used to record, analyze and print out failure data on surface equipment. Cost performance studies on specific types of surface equipment, e.g., compressors, are significant as end uses of this program.

Current EDP input and printout formats, as illustrated in Figures 6 through 10, have been well received and are recognized by operating personnel as being significant improvements in data reporting and analysis. The twelve months failure history shown on the printout provides operating personnel with sufficient data to readily evaluate control methods and to make necessary changes without delay. Monthly and Quarterly Summaries give additional, more detailed information to facilitate evaluation of the total program.

Annual Equipment Failure reports have been discontinued in favor of quarterly reviews conducted by local supervisors. These are not for general review, but rather to examine specific problems, establish revisions in control methods as required and to evaluate the current status of failure control. These reviews are addressed to the objective—reduction of excessive equipment failure costs where they exist.

Continued reduction in repeat or other high failure costs is being achieved and further reductions are to be realized. The outlook is good because management and operating personnel alike are committed to maintaining established performance and, furthermore, improving that performance as it may become possible to do so.

In the final analysis, the specific endeavors of companies, as well as people, are aimed at achieving one ultimate goal—money; and "that is the name of the game". If it is not already, it will ultimately be evident that the winning strategy must include an effective equipment failure control program—it's "a matter of dollars and sense".

TW 807-F

NOTE: Circle appropriate number in each column.

EQUIPMENT FAILURE REPORT

LEASE OR PROPERTY *B. Cox*

DIV. (1) 3 DIST. (2) 2 AREA (3) 1 TITLE NO. (4)–(10) 1 2 3 4 5 6 7 WELL NO. (11)–(14) 7 DATE DAY (15)(16) 21 MO (17)(18) 1 YR (19)(20) 64

SURFACE OR SUBSURFACE

FAILING EQUIPMENT (21—22)	SERVICE (28—29)	TYPE OF FAILURE (30—31)	LOCATION OF FAILURE (32—33)	CAUSE OF FAILURE (34—35)	METHOD OF REPAIR (36—37)
01 VAL Valve	01 FO Flowing Oil	01 HOL Hole	01 BDY Body	01 WER Wear	01 ACD Acidize
02 FLN Flowline	02 FG Flowing Gas	02 BRK Break	02 PIN Pin	02 ABR Abrasion	02 RPL Replaced
03 TRD Treater Dehydrator	03 GL Gas Lift	03 STK Stuck	03 CLP Coupling	03 INT Internal Corrosion	03 RPA Repaired
04 TNK Tank	04 RPB Rod Pump (Beam)	04 SPT Split	04 THD Thread	04 EXT External Corrosion	04 ROC Reamed or Cut
05 BHR Boiler or Heater	05 RPH Rod Pump (Hydr.)	05 PLG Plugged	05 UPS Upset	05 SND Sand	05 SOH Steamed or Heated
06 MET Meter	06 HP Hydraulic Pump (Kobe)	06 UNS Unscrewed	06 PLN Plunger	06 SCL Scale	06 CTD Coated
07 ROD Sucker Rod	07 WI Water Injection	07 LEK Leak	07 BRL Barrel	07 PAR Paraffin	07 BOW Bailed or Washed
08 TBG Tubing	08 GI Gas Injection	08 CRK Crack	08 VBS Valve, Ball or Seat	08 ILL Improper or Lack of Lubrication	08 OTR Other
09 PMP Pump, Subsurface	09 WS Water Source	09 DEF Deformed	09 IMP Impeller	09 MUD Mud	
10 CSG Casing	10 PLT Plant Service	10 OTR Other	10 WTR Water Section	10 IPA Improper Application	
11 GLE Gas Lift Equipment	11 OTR Other		11 OIL Oil Section	11 OTR Other	
12 PKR Packer	22 DZP Dual Zone Rod Pump		12 GAS Gas Section		
13 ANC Anchor			13 OTR Other		
14 RPM Redo Pump			27 PKO Packoff		
15 OTR Other			28 VLC Valve Cage		

POWER

FAILING EQUIPMENT	SERVICE	TYPE OF FAILURE	LOCATION OF FAILURE	CAUSE OF FAILURE	METHOD OF REPAIR
16 EGG Engine, Gas	12 PUD Pumping Unit Drive	11 BRK Break	14 HSY Hydraulic System	12 ILV Improper or Lack of Lubrication	09 MIR Minor Repair
17 EGL Engine, Gasoline	13 COD Compressor Drive	12 STK Stuck	15 BRG Bearing	13 COR Corrosion	10 MRE Major Overhaul
18 EGD Engine, Diesel	14 GED Generator Drive	13 PLG Plugged	16 GBX Gear Box	14 HAT Excessive Heat	11 RPE Replaced
19 EMO Electric Motor	15 SPD Surface Pump Drive	14 LEK Leak	17 CLH Clutch	15 WER Wear	12 OTM Other
20 PUB Pumping Unit - Beam	16 BOD Boat Drive	15 CRK Crack	18 RDT Radiator	16 ABR Abrasion	
21 PUH Pumping Unit - Hydr.	17 NGS Natural Gas Compr.	16 UNS Unscrewed	19 CYL Cylinders	17 IPA Improper Application	
22 CMP Compressor	18 WAT Water Pumping	17 OTM Other	20 VLS Valves	18 ROM Routine Maintenance	
23 SPM Pump - Surface	19 OIL Oil Pumping		21 RGS Rings	19 OTM Other	
24 OTM Other	20 OWM Oil-Water Mix		22 BLT Belts		
	21 OTM Other		23 STM Starter Motor		
			24 ESY Electrical System		
			25 MGO Magneto		
			26 OTM Other		

DEPTH OF FAILURE (23—27) 2150

REMARKS (59—78) PULL TBG RPL BARREL

COST OF FAILURE	
CO. LABOR & EQUIPMENT (38—42)	25
MATERIAL (43—47)	125
OUTSIDE SERVICE (48—52)	250
TOTAL (53—58)	400

OTHER REMARKS *Pulled Rods ~ found cups cut*
Pulled tubing and found Barrel corroded
Replaced Barrel and repaired pump.

SIGNED

FIGURE 1

PAGE 1 FIRST QUARTER DATE 1964

FAILURE REPORT SUMMARY

FORM TW-874-B

DIVISION	DISTRICT	AREA	LEASE DESCRIPTION	WELL NO.	DATE DAY	MO	YR	FAIL. EQPT	DEPTH OF FAILURE	PROD. CODE	TYPE FAIL.	LOC. OF FAIL.	CAUSE OF FAIL.	METH. OF RPR	COMP. LABOR	MAT'L.	OUTSIDE SERVICE	TOTAL	REMARKS
			SUB AREA 1																
3	1	1	COX, B.																
3	1	1		7	21	01	64	PMP	2150	RPB	LEK	BRL	INT	RPL	25	125	250	400	PULL TBG RPL BARREL
																		400	
3	1	1	WRIGHT, L.																
3	1	1			21	01	64	SPM		OWM	LEK	BDY	INT	RPL	75	275		350	
3	1	1			3	02	64	TRD		PLT	LEK	GAS	INT	RPA	225	375	75	675	INST CATHODIC PROT
3	1	1		3	15	02	64	TBG	900	GL	HOL	BDY	INT	RPA		60	225	285	REPLACED 4 JTS
3	1	1		3	23	03	64	FLN		RPB	LEK	CLP	EXT	RPA	3			3	
3	1	1		5	12	02	63	ROD	1725	RPB	BRK	CLP	EXT	RPA		24	145	169	RPL 2 RODS
3	1	1		5	10	01	64	ROD	1625	RPB	BRK	BDY	EXT	RPA		12	120	132	
3	1	1		5	21	01	64	ROD	975	RPB	BRK	BDY	EXT	RPA		12	125	137	
3	1	1		5	5	03	64	ROD	1100	RPB	BRK	BDY	EXT	RPL	25	504	325	854	SURVEYED RODS RPL 42
3	1	1		5	15	03	64	EGG		PUD	OTM	OTM	OTM	MIR	25	45		70	ROUTINE-CHG PLUGS
3	1	1		10	21	02	64	ROD	725	RPB	BRK	BDY	EXT	RPA		12	95	107	
3	1	1		12	1	03	64	FLN		GL	HOL	BDY	EXT	RPA	3			3	
3	1	1		15	29	01	64	FLN		RPB	HOL	BDY	EXT	RPA		100	50	150	
3	1	1		15	11	02	64	TBG	500	RPB	HOL	BDY	WER	RPA		50	225	275	2 JTS TBG
3	1	1		15	19	03	64	ROD	250	RPB	BRK	CLP	EXT	RPA		12	75	87	
																		3297	
3	1	1	SIMPSON, P.																
3	1	1		20	2	01	64	FLN		GL	HOL	BDY	EXT	RPA	3			3	
3	1	1		20	5	01	64	FLN		GL	HOL	BDY	EXT	RPA	3			3	
3	1	1		20	10	01	64	FLN		GL	HOL	BDY	INT	RPA	3			3	
3	1	1		20	12	01	64	FLN		GL	HOL	BDY	EXT	RPL		125	75	200	RPL 200 FT - RAISED
																		209	

ROD NO.	ROD COST	TUBING NO.	TUBING COST	PUMP NO.	PUMP COST	FLOWLINES NO.	FLOWLINES COST	TOTAL
6	1486	2	560	1	400	7	365	3906

FIGURE 2

PAGE 1 — SPECIAL — DATE 1965

FORM TW 874-B

FAILURE REPORT SUMMARY

DIVISION	DISTRICT	AREA	LEASE DESCRIPTION	WELL NO	DATE DAY	DATE MO	DATE YR	FAIL EQPT	DEPTH OF FAILURE	PROD CODE	TYPE FAIL	LOC OF FAIL	CAUSE OF FAIL	METH OF RPR	COST OF FAILURE COMP LABOR	MAT'L	OUTSIDE SERVICE	TOTAL	REMARKS
3	6	1	JONES, R.																
3	6	1		2	12	03	64	PMP	3000	RPB	LEK	BRL	ABR	RPA	52	119		171	
																		171	
3	6	1	SMITH, W.																
3	6	1		2	9	01	64	PMP	3000	RPB	LEK	BRL	ABR	RPA	64	21		85	
3	6	1		3	9	11	64	PMP	3000	RPB	LEK	BRL	ABR	RPA	64	19		83	
3	6	1		4	13	01	64	PMP	3000	RPB	LEK	BRL	ABR	RPA	64	21		85	
3	6	1		5	26	02	64	PMP	3000	RPB	LEK	BRL	WER	RPA	64	21		85	
3	6	1		5	25	02	65	PMP	3000	RPB	LEK	BRL	WER	RPA	64	37		101	
3	6	1		6	11	11	64	PMP	3000	RPB	LEK	BRL	ABR	RPA	64	19		83	
3	6	1		7	7	12	64	PMP	3000	RPB	LEK	BRL	ABR	RPA	64	26		90	
3	6	1		8	24	09	65	PMP		RPB	LEK	BRL	WER	RPA		196	80	276	
																		888	
3	6	1	JONES, R.																
3	6	1		1	10	03	64	PMP	3000	RPB	LEK	PLN	ABR	RPA	64	17		81	
																		81	
3	6	1	SMITH, W.																
3	6	1		7	11	12	64	PMP	3000	RPB	STK	PLN	SND	RPA	256	79		335	
																		335	
3	6	1	JONES, R.																
3	6	1		2	3	03	65	PMP	3050	RPB	LEK	VBS	WER	RPA	64	62		126	
3	6	1		2	28	09	65	PMP		RPB	LEK	VBS	WER	RPA	64	42		106	
																		232	
3	6	1	SMITH, W.																
3	6	1		1	25	02	64	PMP	3000	RPB	LEK	VBS	ABR	RPA	64	50		114	
3	6	1		2	28	04	65	PMP		RPB	LEK	VBS	EXT	RPA	64	45		109	
3	6	1		4	25	08	64	PMP	3000	RPB	LEK	VBS	WER	RPA	64	46		110	
3	6	1		4	23	07	65	PMP		RPB	LEK	VBS	WER	RPA	52	46		98	
3	6	1		8	6	04	65	PMP		RPB	LEK	VBS	WER	RPA	64	44		108	
																		539	

ROD NO	ROD COST	TUBING NO	TUBING COST	PUMP NO	PUMP COST	FLOWLINES NO	FLOWLINES COST	TOTAL

FIGURE 3

DISTRIBUTION OF SUB-SURFACE EQUIPMENT FAILURE COSTS

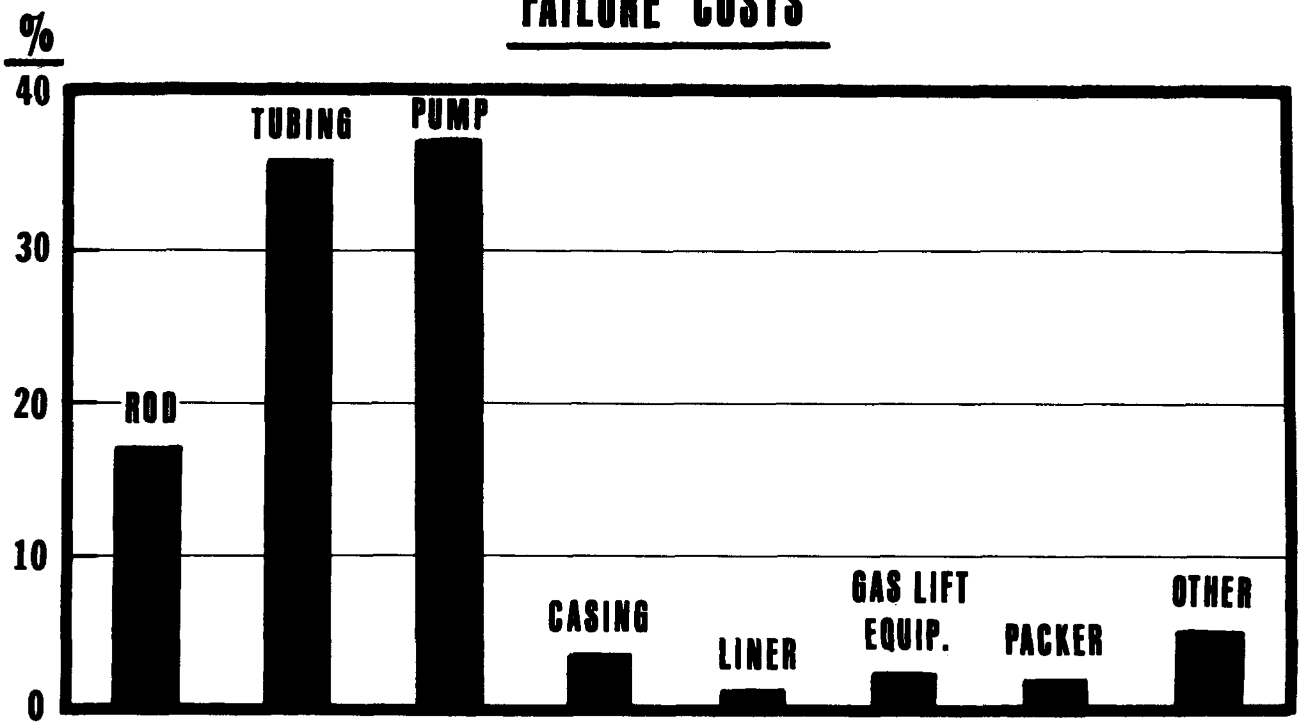

FIGURE 4

PAGE 650

DOWN-HOLE FAILURES-PUMPING WELLS
YEARS 1967, 1968, 1969

SPECIAL
02/05/71

		WELL	DATE	FCP ------FAILURE DATA------	------------COST------------			REMARKS
1 3 4 BROWN, LIZZIE 120 AC								
1 3 4		0021	30 07 69	ROD 01450 RPB BRK BDY EXT RPA	10	74	84	
1 3 4	RPT ROD	0021	01 08 69	ROD 02250 RPB BRK BDY EXT RPA	10	147	157	
1 3 4	RPT ROD	0021	30 11 69	ROD 00150 RPB BRK BDY EXT HPA	10	105	115	
1 3 4	RPT ROD	0021	16 12 69	ROD 02475 RPB UNS PIN WER RPA	35	116	151	
1 3 4		0021	03 08 69	TBG 02200 RPB SPT BDY WER RPA	35	211	246	
1 3 4	RPT TBG	0021	19 11 69	TBG 01240 RPB LEK THD OTR CTR	16	321	337	
1 3 4		0021	03 11 69	PMP 02600 RPB STK VES SNC CTR	13	168	181	

1967
1968
1969 1271
3 YR WELL TOT 1271 $ 424/YR/WELL

1 3 4 BROWN, LIZZIE 120 AC LEASE TOTAL

	ROD NO	ROD COST	TUBING NO	TUBING COST	PUMP NO	PUMP COST	TOTAL NO	TOTAL COST				
TOTAL FAILURES												
	26	3737	8	1848	22	6976	56	12561	1967	12561	9 WELLS	$ 1396/Y/W
	15	2611	3	1315	13	5553	31	9479	1968	9479	8 WELLS	$ 1185/Y/W
	12	1666	3	995	1	181	16	2862	1969	2862	5 WELLS	$ 572/Y/W
	53	8024	14	4158	36	12710	103	24902	3 YEAR TOTAL	24902	11 WELLS	$ 755/Y/W
REPEAT FAILURES												
	21	2973	4	906	14	3745	39	7624	1967		5 WELLS	
	9	1050	1	257	6	2067	16	3374	1968		5 WELLS	
	7	1214	1	331			8	1551	1969		3 WELLS	
	37	5237	6	1500	20	5812	63	12549	3 YEAR TOTAL		9 WELLS	

FIGURE 5

TW-407-0

SUB-SURFACE EQUIPMENT FAILURE REPORT

LEASE OR PROPERTY *Lease Name*

NOTE: Circle appropriate number in each column

RESERVOIR CODE [ ][ ] (1) (2) TITLE NO. [ ][ ][3][6][0] [0][0] (3) (4) (5) (6) (7) (8) (9) (10) WELL NO. [ ][ ][2][1] (11) (12) (13) (14) DATE MO. [1] (15) (16) DAY [26] (17) (18) YR. [70] (19) (20)

FAILURE DATA

FAILING EQUIPMENT (21-22)	SERVICE (23-24)	LOCATION OF FAILURE (25-26)	CAUSE OF FAILURE (27-28)	DEPTH OF FAILURE (29-33)
(01) ROD Sucker Rod	01 FG Flowing Gas	01 BDY Body	01 CF Corrosion Fatigue	2650
02 TBG Tubing	02 FO Flowing Oil	02 UPS Upset	02 INT Internal Corrosion	
03 PMP Pump, Rod	03 GL Gas Lift	(03) PIN Pin	03 EXT External Corrosion	
04 GLV Gas Lift Valve	(04) PO Pumping Oil	04 CLP Coubling	04 EMB Embrittlement	
05 HPM Hydraulic Pump	05 GI Gas Injection	05 BRL Barrel	05 TYD Tensile Yield	
06 SPM Subm. Cent. Pump	06 WI Water Injection	06 PLG Plunger	06 WER Wear	**COST OF FAILURE**
07 PKR Packer	07 WS Water Source	07 PT Pull Tube or Rod	(07) UNS Unscrewed	
08 ANC Anchor		08 VLC Valve Cage	08 IMU Improper make-up	
09 CSG Casing		09 BS Ball & Seat	09 SCL Scale	LABOR & EQUIP. (34-38) 126
10 OTH Other (w/Remarks)		10 MND Mandrel	10 SND Sand	MATERIALS (39-43) 20
		11 OTH Other (w/Remarks)	11 MUD Mud	
			12 OTH Other (w/Remarks)	

PREVENTIVE MAINTENANCE	PREVENTIVE MAINTENANCE	PREVENTIVE MAINTENANCE
EQUIPMENT (44-45)	**EQUIPMENT (56-57)**	**EQUIPMENT (68-69)**
(01) ROD Sucker Rod; 05 HPM Hydraulic Pump	01 ROD Sucker Rod; 05 HPM Hydraulic Pump	01 ROD Sucker Rod; 05 HPM Hydraulic Pump
02 TBG Tubing; 06 SPM Subm. Cent. Pump	02 TBG Tubing; 06 SPM Subm. Cent. Pump	02 TBG Tubing; 06 SPM Subm. Cent. Pump
03 PMP Pump Rod; 07 PKR Packer	03 PMP Pump Rod; 07 PKR Packer	03 PMP Pump Rod; 07 PKR Packer
04 GLV Gas Lift Valve; 08 ANC Anchor	04 GLV Gas Lift Valve; 08 ANC Anchor	04 GLV Gas Lift Valve; 08 ANC Anchor
MAINTENANCE (46-47)	**MAINTENANCE (58-59)**	**MAINTENANCE (70-71)**
01 RMN Routine Mainten.; 05 UPG Upgrade	01 RMN Routine Mainten.; 05 UPG Upgrade	01 RMN Routine Mainten.; 05 UPG Upgrade
(02) VIN Visual Inspec.; 06 HYT Hydraulic Test	02 VIN Visual Inspec.; 06 HYT Hydraulic Test	02 VIN Visual Inspec.; 06 HYT Hydraulic Test
03 EIN Electronic Inspec.	03 EIN Electronic Inspec.	03 EIN Electronic Inspec.
04 OTH Other (w/Remarks)	04 OTH Other (w/Remarks)	04 OTH Other (w/Remarks)
COST	**COST**	**COST**
LABOR & EQUIP. (48-51)	LABOR & EQUIP. (60-63)	LABOR & EQUIP. (72-75)
MATERIALS (52-55) 178	MATERIALS (64-67)	MATERIALS (76-79)

REMARKS (23-78)

2nd CARD

KEY PUNCH NOTE: IF REMARKS SHOWN REPEAT COLS 1-20, ABOVE AND PROCEED → [R][M] (21) (22)

23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

RPL 10 1-IN RODS

51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78

Signed *C.W.L.*

FIGURE 6

```
DATE RUN 01/31/71                               SUB-SURFACE EQUIPMENT FAILURE SUMMARY                          REPORT NO. 960010

DIST AREA SECT      DISTRICT NAME               AREA NAME                    SECTOR NAME                           DATE       PAGE
  1    2    29                                                                                               4TH DEC 1970   58

WELL                   FAILURE          PRV MNT          COST
 NO.   DATE    EQP SRV LOC CSE DEPTH EQP TYP LBR&EQP MAT'L  TOTAL  CONTROL   *****                REMARKS                  *****
----   ----    ----------------------- ------- ----------------------  -------   ---------------------------------------------------

BROWN, LIZZIE '120 ACRE'         360 00      RES. CODE

  10   1 25 70 ROD PO  PIN THU   125                 84      18    102             RPL 1 IN. ROD
  10   5 11 70 ROD PO  PIN UNS  1000                 82      10     92  106 DYS
                                                                   194

  12   2 17 70 SPM PO  OTH WER  2630                490     600   1090
                                                                  1090

  17  11 10 70 SPM PO  OTH OTH  2600                440     800   1240             REDA PUMP MOTOR BURNED OUT RPL PMP MOTOR AND PROTECTOR
                                                                  1240

  18   4 11 70 SPM PO  OTH SCL  2675                335    1339   1674
  18   5 13 70 SPM PO  OTH SCL  2550                319    1200   1519   32 DYS    BARIUM SULFATE
  18  12  7 70 SPM PO  OTH INT  2400                319    1300   1619  208 DYS
                                                                  4812

  20   2 24 70 SPM PO  OTH INT  2650                296     650    946             PMP STUCK
  20   5 13 70 SPM PO  OTH SCL  2650                264     969   1233   78 DYS    BARIUM SULFATE
  20   5 23 70 SPM PO  OTH SCL  2650                569     969   1538   10 DYS    BARIUM SULFATE STUCK PMP
  20   7 14 70 SPM PO  OTH OTH  2650                516     852   1368   52 DYS    MOTOR BURNED OUT - REPLACED
                                                                  5085

  21   1 26 70 ROD PO  PIN UNS  2650                126      20    146             RPL 10 1-IN RODS
                                      ROD VIN               178    178
  21   6 15 70 ROD PO  PIN UNS  1950                 82      10     92  140 DYS
  21   8  5 70 TBG PO  BDY CF      3                281      40    321             DAMAGED JOINT. TUBING. SLIP.
                                                                   737

              LEASE TOTALS  -   COMPLETE
                         JAN-70   FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC
         MONTHLY            426  2036           1674   4382     92   1368    321                 1240   1619
         YEAR TO MO.        426  2462   2462    4136   8518   8610   9978  10299  10299  10299  11539  13158
```

FIGURE 7

```
DATE RUN 01/31/71                          SUB-SURFACE EQUIPMENT FAILURE SUMMARY                       REPORT NO. 960010
                                                     SECTOR ANALYSIS
                                               ****  PERMANENT RECORD  ****

DIST AREA SECT     DISTRICT NAME                AREA NAME                  SECTOR NAME                     DATE       PAGE
  1    2    29                                                                                          DEC 1970      70

              ROD                               TBG                               PMP                     TOTAL - ROD, TBG, PMP
 FAILURES     MAINT     TOTAL        FAILURES    MAINT     TOTAL       FAILURES    MAINT     TOTAL      FAILURES     MAINT    TOTAL
 NO    $        $         $          NO    $       $         $         NO    $       $         $        NO    $        $        $
 9    944                944         1    400               400                                        10   1344             1344

 RPT FAIL                            RPT FAIL                          RPT FAIL                         RPT FAIL
 NO    $                             NO    $                           NO    $                          NO    $
 7    792                                                                                               7     792

              GLV                               HPP                               SPM                               PKR
 FAILURES     MAINT     TOTAL        FAILURES    MAINT     TOTAL       FAILURES    MAINT     TOTAL      FAILURES     MAINT    TOTAL
 NO    $        $         $          NO    $       $         $         NO    $       $         $        NO    $        $        $
                                                                       1    1619              1619

 RPT FAIL                            RPT FAIL                          RPT FAIL                         RPT FAIL
 NO    $                             NO    $                           NO    $                          NO    $
                                                                       1    1619

              ANC                               CSG                               OTH                     TOTAL - ALL CAUSES
 FAILURES     MAINT     TOTAL        FAILURES    MAINT     TOTAL       FAILURES    MAINT     TOTAL      FAILURES     MAINT    TOTAL
 NO    $        $         $          NO    $       $         $         NO    $       $         $        NO    $        $        $
                                                                                                        11   2963             2963

 RPT FAIL                            RPT FAIL                          RPT FAIL                         RPT FAIL
 NO    $                             NO    $                           NO    $                          NO    $
                                                                                                        8    2411
=================================================================================================================================
DIST AREA SECT     DISTRICT NAME                AREA NAME                  SECTOR NAME                     DATE       PAGE
  1    2    29                                                                                       4TH QTR 1970     71

              ROD                               TBG                               PMP                     TOTAL - ROD, TBG, PMP
 FAILURES     MAINT     TOTAL        FAILURES    MAINT     TOTAL       FAILURES    MAINT     TOTAL      FAILURES     MAINT    TOTAL
 NO    $        $         $          NO    $       $         $         NO    $       $         $        NO    $        $        $
 67   9300     368       9668        12   4966              4966       34   11477    734     12211      113  25743    1104    26847

 RPT FAIL                            RPT FAIL                          RPT FAIL                         RPT FAIL
 NO    $                             NO    $                           NO    $                          NO    $
 41   6461                           5    2526                         12   5560                        58   14547

              GLV                               HPP                               SPM                               PKR
 FAILURES     MAINT     TOTAL        FAILURES    MAINT     TOTAL       FAILURES    MAINT     TOTAL      FAILURES     MAINT    TOTAL
 NO    $        $         $          NO    $       $         $         NO    $       $         $        NO    $        $        $
                                                                       18   30531             30531

 RPT FAIL                            RPT FAIL                          RPT FAIL                         RPT FAIL
 NO    $                             NO    $                           NO    $                          NO    $
                                                                       6    9707

              ANC                               CSG                               OTH                     TOTAL - ALL CAUSES
 FAILURES     MAINT     TOTAL        FAILURES    MAINT     TOTAL       FAILURES    MAINT     TOTAL      FAILURES     MAINT    TOTAL
 NO    $        $         $          NO    $       $         $         NO    $       $         $        NO    $        $        $
                                                                                                        131  56274    1104    57378

 RPT FAIL                            RPT FAIL                          RPT FAIL                         RPT FAIL
 NO    $                             NO    $                           NO    $                          NO    $
                                                                                                        64   24254
```

FIGURE 8

DATE RUN 01/31/71

SUB-SURFACE EQUIPMENT FAILURE SUMMARY
MONTHLY SECTOR ANALYSIS

REPORT NO. 960010

DIST AREA SECT 1 2 29   DISTRICT NAME   AREA NAME   SECTOR NAME   DATE DEC 1970   PAGE 70

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ROD-PO	MONTH	NO	2	3	6	7	12	6	1	3	7	1	10	9
		$	426	309	879	828	1880	552	112	478	2166	76	1018	944
	YR TO DATE	NO	2	5	11	18	30	36	37	40	47	48	58	67
		$	426	735	1614	2442	4322	4874	4986	5464	7630	7706	8724	9668
TBG-PO	MONTH	NO	0	2	3	1	1	0	2	2	0	0	0	1
		$	0	549	1607	405	275	0	962	768	0	0	0	400
	YR TO DATE	NO	0	2	5	6	7	7	9	11	11	11	11	12
		$	0	549	2156	2561	2836	2836	3798	4566	4566	4566	1566	4966
PMP,SPM-PO	MONTH	NO	0	8	3	5	8	6	11	3	4	0	1	1
		$	0	6797	1028	3130	8758	3327	7332	4133	1439	0	1776	1619
	YR TO DATE	NO	0	8	11	16	24	30	41	44	48	48	49	50
		$	0	6797	7825	10955	19713	23040	30372	34505	35944	35944	37720	39339
TOTAL R,T,P-PO	MONTH	NO	2	13	12	13	21	12	14	9	11	1	11	11
		$	426	7655	3514	4363	10913	3879	8406	5379	3605	76	2794	2963
		WELLS	2	12	10	11	15	10	11	8	9	1	10	9
	YR TO DATE	NO	2	15	27	40	61	73	87	95	106	107	118	129
		$	426	8081	11595	15958	26871	30750	39156	44535	48140	48216	51010	53973
		WELLS	2	14	21	27	32	37	42	45	46	46	49	50
--REPEAT-- R,T,P-PO	MONTH	NO	0	1	4	5	14	6	6	3	9	1	6	8
		$	0	285	1868	573	6191	1034	4388	829	3462	76	707	2411
		WELLS	0	1	3	5	10	6	5	3	7	1	5	7
	YR TO DATE	NO	0	1	5	10	24	30	36	39	48	49	55	63
		$	0	285	2153	2726	8917	9951	14339	15168	18630	18706	19413	21824
		WELLS	0	1	3	7	16	21	23	23	24	24	24	27
ALL OTHER	MONTH	NO	0	0	0	1	0	0	0	1	0	0	0	0
		$	0	0	0	975	0	0	0	2430	0	0	0	0
	YR TO DATE	NO	0	0	0	1	1	1	1	2	2	2	2	2
		$	0	0	0	975	975	975	975	3405	3405	3405	3405	3405
TOTAL ALL FAIL	MONTH	NO	2	13	12	14	21	12	14	9	11	1	11	11
		$	426	7655	3514	5338	10913	3879	8406	7809	3605	76	2794	2963
	YR TO DATE	NO	2	15	27	41	62	74	88	97	108	109	120	131
		$	426	8081	11595	16933	27846	31725	40131	47940	51545	51621	54415	57378

FIGURE 9

DATE RUN 01/31/71

SUB-SURFACE EQUIPMENT FAILURE SUMMARY
QUARTERLY SECTOR ANALYSIS

REPORT NO. 960010

DIST AREA SECT 1 2 29   DISTRICT NAME   AREA NAME   SECTOR NAME   DATE DEC 1970   PAGE 71

		1ST QR	2ND QR	3RD QR	4TH QR	YR TO DATE
PO WELLS						
ROD	NO	11	25	11	20	67
	FAIL $	1436	3070	2756	2038	9300
	MAIN $	178	190	0	0	368
	TOT $	1614	3260	2756	2038	9668
-RPT	NO	1	18	8	14	41
	$	94	2275	2517	1575	6461
TBG	NO	5	2	4	1	12
	FAIL $	2156	680	1730	400	4966
	MAIN $	0	0	0	0	0
	TOT $	2156	680	1730	400	4966
-RPT	NO	3	0	2	0	5
	$	1519	0	1007	0	2526
PMP & SPM	NO	11	19	18	2	50
	FAIL $	7825	15015	12904	2859	38603
	MAIN $	0	200	0	536	736
	TOT $	7825	15215	12904	3395	39339
-RPT	NO	1	7	8	1	17
	$	540	5523	5155	1619	12837
TOTAL PO -	NO	27	46	33	23	129
	FAIL $	11417	18765	17390	5297	52869
	MAIN $	178	390	0	536	1104
	TOT $	11595	19155	17390	5833	53973
-RPT	NO	5	25	18	15	63
	$	2153	7798	8679	3194	21824
ALL WELLS						
ROD	NO	11	25	11	20	67
	FAIL $	1436	3070	2756	2038	9300
	MAIN $	178	190	0	0	368
	TOT $	1614	3260	2756	2038	9668
TBG	NO	5	2	4	1	12
	FAIL $	2156	680	1730	400	4966
	MAIN $	0	0	0	0	0
	TOT $	2156	680	1730	400	4966

		1ST QR	2ND QR	3RD QR	4TH QR	YR TO DATE
ALL WELLS - CON'T						
PMP	NO	8	12	14	0	34
	FAIL $	2199	3444	5834	0	11477
	MAIN $	0	200	0	536	736
	TOT $	2199	3644	5834	536	12213
SPM	NO	3	8	5	2	18
	FAIL $	5626	12546	9500	2859	30531
	MAIN $	0	0	0	0	0
	TOT $	5626	12546	9500	2859	30531
HPM	NO	0	0	0	0	0
	FAIL $	0	0	0	0	0
	MAIN $	0	0	0	0	0
	TOT $	0	0	0	0	0
GLV	NO	0	0	0	0	0
	FAIL $	0	0	0	0	0
	MAIN $	0	0	0	0	0
	TOT $	0	0	0	0	0
PKR	NO	0	0	0	0	0
	FAIL $	0	0	0	0	0
	MAIN $	0	0	0	0	0
	TOT $	0	0	0	0	0
CSG	NO	0	0	0	0	0
	FAIL $	0	0	0	0	0
	MAIN $	0	0	0	0	0
	TOT $	0	0	0	0	0
OTH	NO	0	0	0	0	0
	FAIL $	0	0	0	0	0
	MAIN $	0	0	0	0	0
	TOT $	0	0	0	0	0
TOTAL ALL	NO	27	47	34	23	131
	FAIL $	11417	19740	19820	5297	56274
	MAIN $	178	390	0	536	1104
	TOT $	11595	20130	19820	5833	57378

FIGURE 10

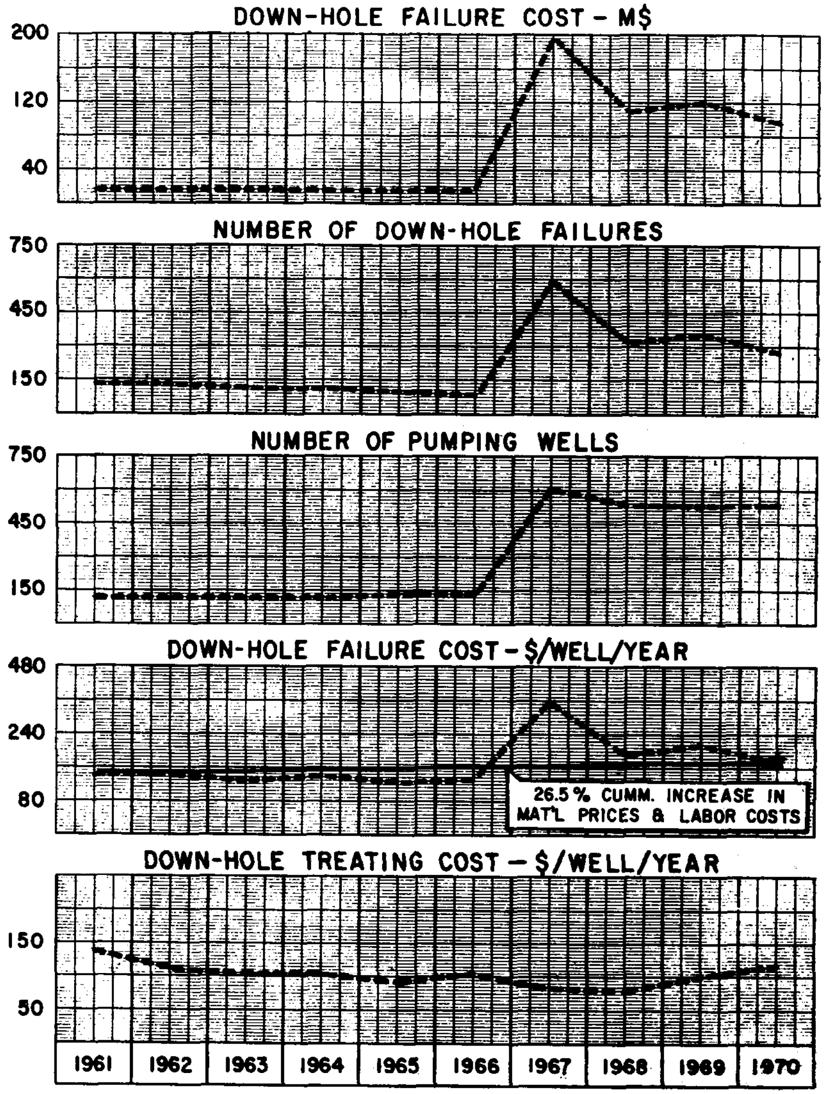

FIGURE 11

PUMPING WELL FAILURE CONTROL — WEST TEXAS

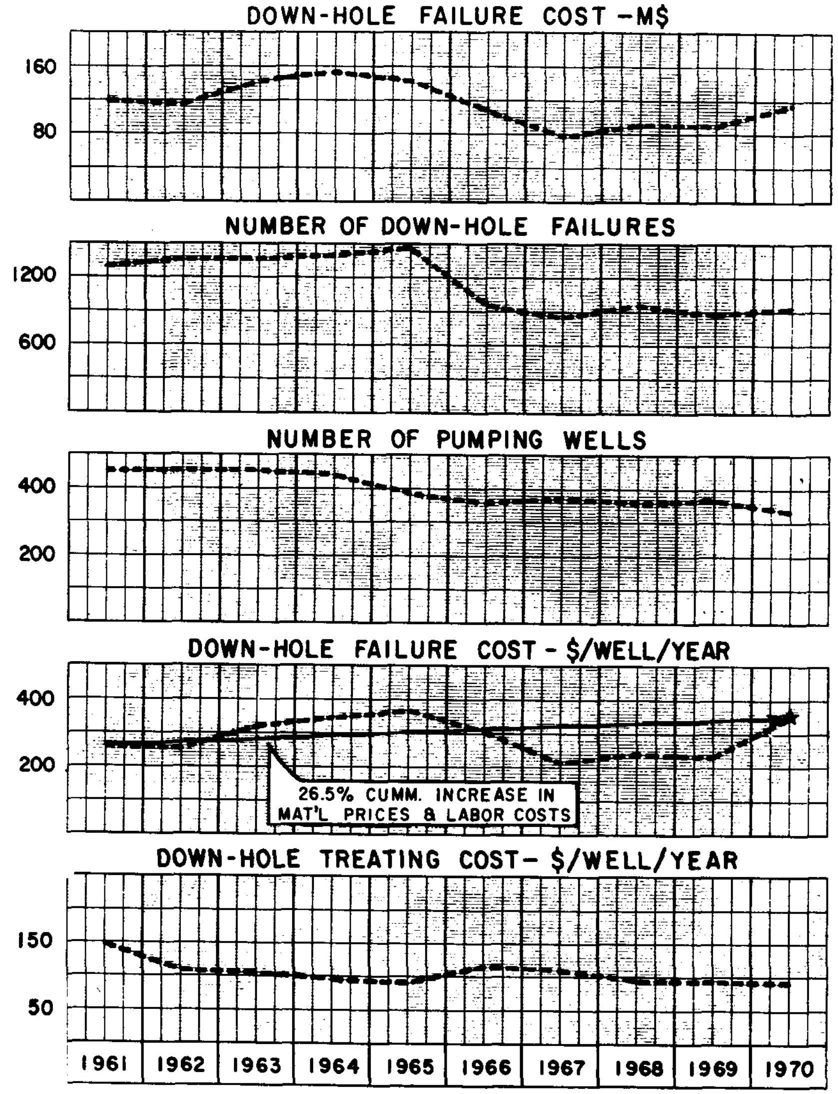

FIGURE 12

PUMPING WELL FAILURE CONTROL — ILLINOIS