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**EXAMINATION OF FAILED DRILL BIT
FROM GEYSERS FIELD**

Topical Report

By
William C. Leslie

February 16, 1976

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Ann Arbor, Michigan

U. S. DEPARTMENT OF ENERGY
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February 16, 1976

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ABSTRACT

A Reed Tool Company 73JA drill bit used in the Geysers geothermal field failed primarily because of severe frictional wear of the nose bearing. There is no indication that well temperature by itself caused failure of any part of the bit. However, the high well temperature together with the friction heat generated produced a temperature which lead to softening and premature wear failure of the nose bearing.

INTRODUCTION

At a meeting at Terra Tek, Inc., Salt Lake City, Utah, December 11, 1975, I was given some component parts of a Reed Tool Company bit, Type 73JA, which had been removed from service in the Geysers geothermal field, Sonoma County, California. The service conditions and bit wear measurements are attached as Tables I and II. I was asked to examine these parts in an attempt to determine the principal cause of failure in the bit. The results of this examination are reported here.

PROCEDURES

The cone, lug and roller bearing were sectioned, ground, polished and etched. The sections cut are indicated on Figure 1, which, although it is a drawing of a different type of bit, will serve as a reference. Diamond pyramid (Vickers) hardness

measurements were made as indicated later. Microhardness traverses was made across the nose bearing, 7 to 7A, Figure 1, and across the carburized case in the roller race of the cone, 1 in Figure 1.

Electron microprobe analyses were obtained from the hard facing on the nose bearing, 6, and from the stainless steel inserts of the cone.

Specimens cut from the lug roller race, 4A in Figure 1, were tempered for one hour at temperatures in the range 500 to 1,100°F. The hardness of the case was redetermined after each tempering treatment.

RESULTS AND DISCUSSION

Table III shows the results of carburized case depth measurements and measurements of hard facing thickness on the nose bearing. The most prominent feature is the almost complete erosion of the hard facing on the high-pressure side of the nose bearing (friction pin). The thickness of the carburized case in the ball and roller races is reduced by wear, in agreement with the wear measurements in Table II. The outer surface of the cone has suffered little wear, as indicated by the thick case remaining.

The Reed Rool Company has informed me (February 13, 1976) that they no longer carburize the nose bearing where hard facing is applied.

Table IV lists the hardness of the parts examined. Four parts show a decrease in hardness. In the nose bearing (friction pin) in the area of heaviest wear and in the bushing the decrease

is substantial. The hardness of the carburized case in the nose bearing dropped from 681DPH (59Rc) to 514DPH (50Rc). The hardness of the carburized bushing, which I assume to be Type 430 stainless steel, dropped from about 720DPH (61Rc) to 433DPH (44Rc).

The drop in hardness in the carburized nose bearing of the lug is highly localized, being confined to the heavily worn area. Our tempering studies indicate that this region reached a temperature between 1,000 and 1,100°F. The stainless steel bushing, which rotates around the nose bearing, was softened throughout. The high temperature probably resulted from the combined effects of the friction energy release rate and the high well temperature of about 465°F. Thus, a lower well temperature, other factors being constant, could have resulted in lower peak temperature and an increased nose bearing life because of less annealing of the bearing surfaces at the lower temperatures. In addition, the harder surfaces result in a smaller friction energy release rate, which would further reduce the peak temperature in the bearing. These suggestions agree with the observation that the same drill bit operated in lower temperature oil well or mining environments lasts several times longer than the bit studied here.

The electron probe microanalysis of the hard facing remaining on the nose bearing indicated that the hard facing was an iron-base alloy containing C, Si, Cr, Mn and Mo. The microstructure showed dendrites of primary carbide, surrounded by ferrite and pearlite. The analysis and structure are consistent with a

Group I alloy, perhaps having the following composition:

C	0.50%
Mn	.25
Si	.40
Cr	3.35
Mo	1.25

Although this type is the most widely used hard-facing alloy, it is not the most wear resistant. An alloy from Group 4A (Co-base) or Group 4B (Ni-base) would have been a better choice for this severe application.

Improvement of the hard-facing alloy will not be effective unless the bushing for the nose bearing is also made more wear resistant. In this instance, a tungsten carbide bushing would be an improvement over the carburized Type 430 stainless steel.

This may be the proper place to emphasize the advantages of diamond pyramid hardness (Vickers) measurements over Rockwell hardness measurements at high hardness levels. Although these two measures are of about equal sensitivity at intermediate hardness, at high hardness the Rc changes from 60 to 70 (17%), but DPH changes from 695 to 1076 (55%). The latter is more representative of the hardness change.

Two microhardness traverses were made, with the results shown in Tables V and VI. The data in Table V emphasize the localized heating of the nose bearing. The side suffering heavy wear was markedly softened whereas the opposite side, about one inch removed, remained essentially unchanged in hardness.

The microhardness traverse of the cone roller race shows a comparatively low hardness near the surface (Table VI). This softening at the surface is common in carburized parts because of either decarburization or the presence of retained austenite. However, in this instance the wear on the roller race (Table II) was sufficient to remove any decarburized layer. Therefore, the softening must be attributed to heating, the effects of which did not penetrate beyond about 0.2 mm from the surface.

The results of our tempering study are given in Table VII. From these data we conclude that one side of the nose bearing (friction pin) reached a temperature of about 1,000°F. The surfaces of the ball and roller bearing races evidently reached a temperature of about 800°F.

The analysis of the tungsten carbide inserts in the cone indicated that they contained about 14% cobalt, which would place them in Group 3. This appears to have been a suitable choice.

CONCLUSIONS

1. This Reed 73JA drill bit failed primarily because of severe frictional wear at the nose bearing.
2. The nose bearing area of the bit experienced a peak temperature of about 1,000°F. The temperature can be attributed to the combined effects of the friction energy release rate and the high well temperature of about 465°F.

3. The surfaces of the ball and roller bearing races reached a peak temperature of about 800°F.

4. With these exceptions, no part of the drill bit seems to have been exposed to temperatures greatly in excess of the tempering temperature of the carburized steel parts.

TABLE I. GEYSERS DRILL BIT RECORDS

MAKE	TYPE	DEPTH OUT	FEET DRILLED	HOURS	WEIGHT (1000 LBS)	VERT. DEVIA. (DEG)	TEETH WEAR (1/8)	BEARING WEAR (1/8)	GAGE LOSS (IN)	TEMP.
SMITH	5JA	5782	250	11.5	22	18	2	3	I	285°F
REED	YF3JA	3877	282	15.8	15/20	18	3	5	1/16	240°F
REED	73JA	5139	257	14.3	20/30	17	2	6	1/16	340°F
*REED	73JA	5754	262	14.0	30	15	2	6	3/8	330°F
SEC.	H8J	4380	210	18.0	15/20	20	2	3	5/8	325°F
SMITH	V2HJ	1611	78	8.5	15/20	7	8	8	1/2	160°F
HUGHES	A44	3595	252	19.8	20	17	3	4	1/4	190°F
REED	73JA	5070	296	17.5	27	16	3	5	1/16	300°F

All 60-70 RPM, except Smith V2HJ, which was 400 RPM

All 8 3/4" Bits, except Smith V2HJ, which was 12 1/4".

TABLE II. BIT WEAR MEASUREMENTS (IN)

BIT	AV. BALL DIA. WEAR	AV. ROLLER DIA. WEAR	BEARING RACE DIA. DIFFERENCE		
			FRICTION PIN	BALL RACE	ROLLER RACE
*REED 73J	.010 ^(a)	.003	.078 ^(b)	.042	.026 ^(b)
REED 73J	.004 ^(c)	.001	.038	.022	.012
SMITH 5JA	.012	.012	.011	.012	.030
SMITH F3	0	--	.001	0	0

(a) As much as .013 out of round.

(b) Wear is slanted.

(c) As much as .005 out of round.

TABLE III
Case Depth Measurements

Specimen	Description	Max. (mm)	Min. (mm)
1	cone, roller race	1.30	
1	cone, outer surface	2.00	
1A	cone, ball race	1.40	
1A	cone, outer surface	2.30	
4	lug, ball race	1.48	0.12
4	lug, roller race	0.94	
7	nose bearing, hard facing	1.64	0.01
7	nose bearing, case at central hole	1.40	
7	nose bearing, case under hard facing	1.60	

TABLE IV
Hardness of Components

Specimen	Description	Case		Distance from Surface	Core	
		DPH	Rc		DPH	Rc
1	cone roller race	616	56	0.31mm	330	34
1A	cone ball race	606	55	.35	322	33
1B	cone, outer surface	625	56	.25	322	33
2	bushing	433	44		234	20
4	lug ball race	660	58	.28	274	26
4A	lug roller race	657	58	.30	274	26
5	roller	642	57	.25	606	55
6	nose bearing hard facing	1018	69			
7	nose bearing, heavy wear	417	42		297	30
7A	nose bearing, light wear, outer case	681	59			
7A	nose bearing, light wear, inner case	514	50		322	33

TABLE V

Microhardness Traverse, Nose Bearing (Friction Pin),
from Heavy Wear Side to Light Wear Side

Distance from Steel Surface (mm)	Hardness		Distance from Steel Surface (mm)	Hardness	
	DPH	Rc		DPH	Rc
0.10	424	43	14.60	485	48
.30	440	44	14.80	485	48
.50	442	45	20.00	485	48
.70	440	44	21.00	366	37
.90	426	43	21.50	335	34
1.10	415	42	22.00	305	30
1.30	413	42	23.00	308	31
1.50	411	42	24.00	354	36
1.70	390	40	24.50	455	46
1.90	342	35	25.00	525	51
2.10	312	32	25.20	578	54
2.30	297	30	25.40	578	54
2.50	307	31	25.60	634	57
2.70	303	30	25.80	645	58
3.00	300	30	26.00	680	59
4.00	300	30	26.20	690	60
5.00	372	38	26.40	690	60
5.20	376	38	Steel surface at 26.52 Outer surface of hard facing at 28.12		
5.40	415	42			
5.60	437	44			
5.80	450	45			
6.00	450	45			
6.20	450	45			
Central hole from 6.50 to 14.40mm					

TABLE VI
Microhardness Traverse, Cone Roller Race,
from Carburized Surface

Distance from Carburized Surface mm	Hardness	
	DPH	Rc
0.11	495	49
.31	616	56
.51	600	55
.71	592	55
.91	588	54
1.11	558	53
1.31	570	52
1.51	547	50
1.71	524	49
1.91	504	48
2.11	490	47
2.31	465	45
2.51	437	43
2.71	412	41
2.91	402	40
3.11	396	40
Hardness of core	330	32

TABLE VII

Hardness of Carburized Case after Tempering.
Lug Roller Race

Tempering Temperature °F	Hardness	
	DPH	Rc
as received	660	58.5
500°F	677	59
600	630	56
700	559	53
800	560	53
900	473	47
1000	426	43
1100	353	36

FIG 1