PROCEEDINGS, Twenty-First Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, January 22-24, 1996
SGP-TR-151

NEW MECHANISMS OF ROCK-BIT WEAR IN GEOTHERMAL WELLS

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ABSTRACT

This paper presents recent results of an investigation on failure mode and wear of rock-bits used to drill geothermal wells located in the area of Larderello (Italy). A new wear mechanism, conceived from drilling records and dull bit evaluation analysis, has been identified and a particular configuration of rock-bit has been developed and tested in order to reduce drilling costs. The role of high Bottom Hole Temperature (BHT) on rock-bit performances seems not yet very well understood: so far, only drillability and formation abrasiveness are generally considered to account for poor drilling performances. In this paper, the detrimental effects of high BHT on sealing and reservoir system of Friction Bearing Rock-bits (FBR) have been investigated, and a new bearing wear pattern for FBR's run in high BHT holes has been identified and further verified via laboratory inspections on dull bits. A novel interpretation of flat worn cutting structure has been derived from the above wear pattern, suggesting the design of a particular bit configuration. Test bits, designed in the light of the above criteria, have been prepared and field tested successfully. The paper reports the results of these tests, which yielded a new rock-bit application, today considered as a standard practice in Italian geothermal fields. This application suggests that the correct evaluation of rock-bit wear can help to improve the overall drilling performances and to minimize drilling problems through a better interpretation of the relationships amongst rock-bits, formation properties and downhole temperature.

INTRODUCTION

It is well known that a critical aspect of geothermal drilling is the extreme rock-bit cutting structure wear associated with poor penetration rates and short times on bottom. Abrasiveness, mechanical and petro-physical properties of the drilled formations, together with high BHT, can induce unacceptable rock-bit performances, in terms of cost per foot. Short life on bottom, strong cutting structure wear and undergauge are typical of rock-bits run through hard, abrasive and hot formations connected with geothermal reservoirs, hot dry rocks systems or deep and hot holes for the petroleum industry. Moreover, abrasive formations can cause serious undergauge and wear problems on bottomhole assembly, stabilizers and drill string [Cromling, 1973, Carden *et al.*, 1985, Kelsey, 1987].

This paper reports rock-bit problems shown in the 8-1/2" section of some wells drilled through the geothermal reservoir of Larderello field, Italy (Fig. 1), exploited for superheated steam production used for power generation. Fig. 2 shows the typical casing profile and a lithological cross section of the wells, characterized by a long 8-1/2" section drilled through a deep reservoir, located in a metamorphic fractured formation constituted by micaschists and gneiss. The section starts at an average depth of 2500 m, and is drilled to a total depth of about 3500 m (or occasionally deeper), being drilling operations marked by extreme conditions (e.g., abrasive formations, high BHT, circulation losses, directional holes, etc.). Reservoir temperature is estimated in the range of 230÷250 °C, but local anomalies can raise it up to 400 °C [Bertini *et al.*, 1980]. Accordingly to standard oilfield drilling practices, the 8-1/2" hole is drilled with Friction Bearing Rock-bits (IADC codes from 517 to 837), and mud circulation. FBR's performances are sometimes quite poor: short life on bottom, heavy cutting structure wear, undergauge and early bearing

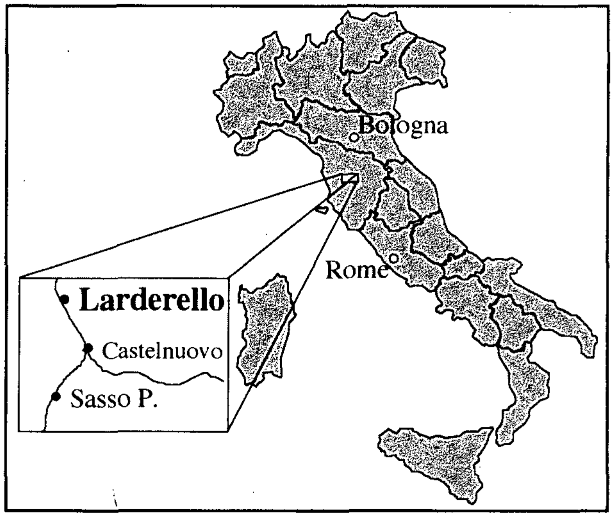

Fig. 1. Location of Larderello Field, Italy.

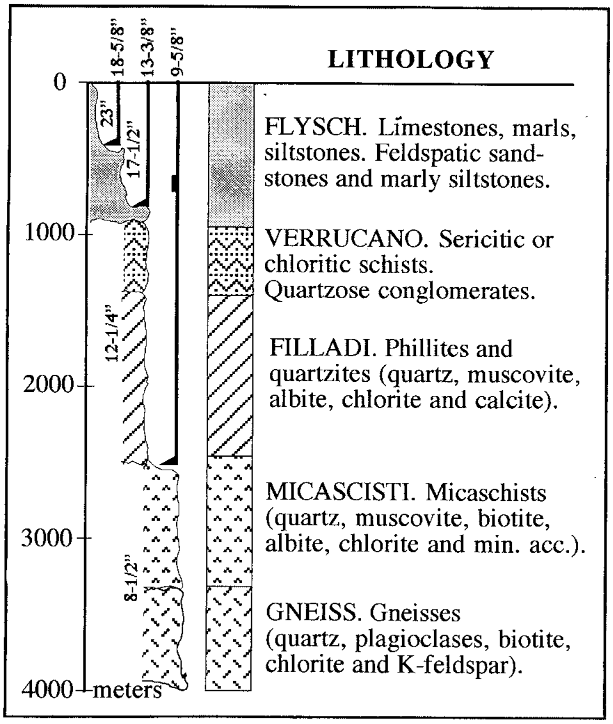

Fig. 2. Lithological cross section and casing profile of a well in Larderello geothermal area.

failure with cones letdown are common issues in this section. Numerous efforts have been made to overcome these problems: some results have been obtained adopting FBR's designed with very hard cutting structures and diamond reinforced cutters on gage [Salesky *et al.*, 1987, Laursen *et al.*, 1988, Macini, 1993].

The role played by high BHT on rock-bit wear seems not yet very well understood: generally, poor performances are attributed only to formation abrasiveness. Wear analysis performed on partially worn-out bits proved that some failure modes can be related to BHT, sometimes attaining equilibrium temperatures, during roundtrips, of 350 °C and over [Manetti, 1973, Bertini *et al.*, 1980, Grant *et al.*, 1983]. FBR's sealing and lubrication system cannot withstand temperatures exceeding 180 °C, due to standard elastomers utilized as seals, energizers or pressure equilibrating diaphragms: the consequent misrunning of the sealing system has been indicated as the first step of FBR premature failure, inducing accelerated cutting structure wear and strong undergauge.

DULL BIT EVALUATION

Wear evaluation has been achieved in two stages: a) rig site inspection, mainly concerning bit body and cutting structure wear; b) laboratory evaluation, performed on disassembled bits, aimed to lubrication system and bearing surfaces failure interpretation. Field experience indicates that FBR's wear modes in high BHT wells show some common peculiarity, schematized as follow:

Cutting structure

Cutting structures are characterized by extreme insert wear (or breakage) and strong undergauge. Inserts are flat worn, occasionally down to the cone shell, and wear flat rate increases from nose to gage rows (Fig. 3). Gage area is generally rounded, with occasional broken inserts; strong undergauge can affect bit shoulder as well (Fig. 4).

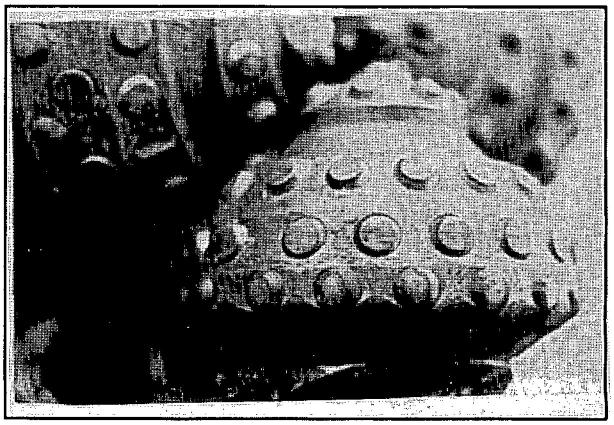

Fig. 3. Typical flat wear on inserts of a 8-1/2" bit, IADC code 737 (after 9.5 m and 3.5 hours).

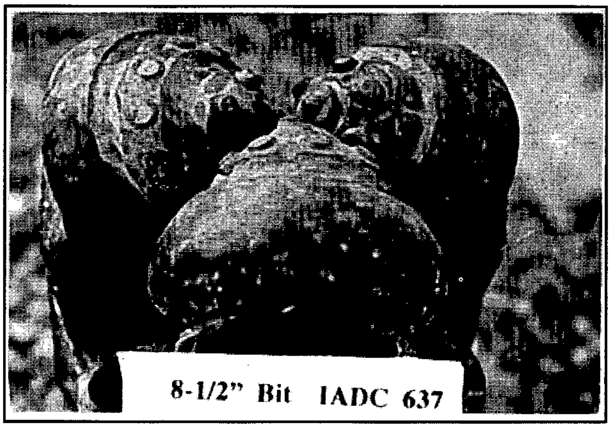

Fig. 4. Extreme cutting structure wear and undergage on 8-1/2" FBR's (after 6 m and 4 hours).

Lubrication system

Major damages concern elastomers forming rotary seals and pressure equalizing diaphragms. Normally, temperatures above 160÷180 °C cause the thermal degradation of most of the elastomers, which turns into brittle and hard compounds, exposed to quick wear. Under these conditions, bearing seal is not effective and a proper bearing lubrication is questionable, if not impossible.

Bearing surfaces

After rotary seal failure, friction bearing surfaces loose the designed hydrodynamic lubrication, and the decreased bearing capacity reduces the lubrication film, allowing for the bearing surfaces to come into contact (see Appendix). It is likely to suppose that the first step of bearing wear initiates on the «soft» cone surface: laboratory inspections, performed on rock-bits run in high BHT holes and pulled at the early stage of bearing wear, confirm that the precision turned inlay metal looks damaged, torn away or worn down to the cone steel. The presence of residual spots of antifriction metal makes the friction surface extremely rough. Fig. 5 and 6 show the friction surface of a cone and its leg respectively. This bearing, field evaluated «Effective», reported thermally degraded rotary seal: there are clear signs of bearing damages (surface roughness).

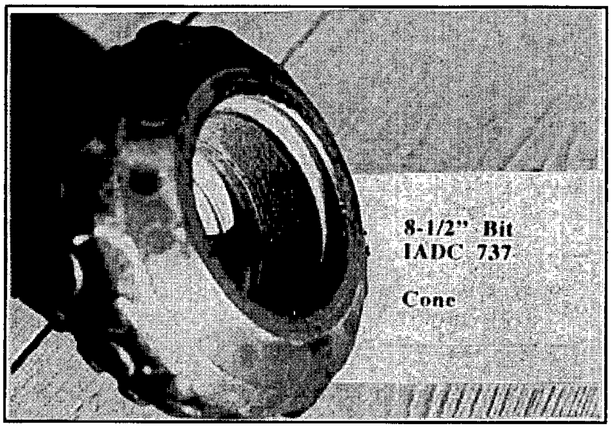

Fig.5. Inner cone rough surface generated on a 8-1/2" FBR after 3.5 hours in a high BHT hole.

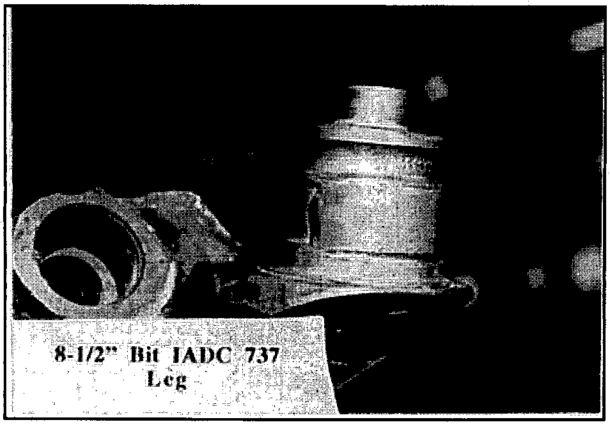

Fig. 6. The leg (Journal) fitting the cone (Bearing) of the above figure (after 9.5 m and 3.5 hours).

In the light of the above, mechanics of friction bearing, dull bit evaluation and investigation of downhole conditions allowed to clearly identify premature wear phenomena occurring on FBR's run in high BHT wells [Macini, 1994]. It has been observed that premature wear occurs mainly in hole sections showing no circulation losses, where it is reasonable to suppose that drilling fluid temperature, during roundtrips, increases more than in sections with circulation losses [Grant *et al.*, 1983]. It is likely to suppose that a sharp FBR, while tripping in, undergoes a temperature rise that can be detrimental to rotary seals: in cases where the bit contacts high BHT for several hours, accordingly to trip time, it tags bottom and starts drilling with lubrication system already thermally degraded. High BHT contributes as well to reduce lubricant viscosity, further decreasing bearing capacity (see Appendix). Such conditions can make easier the set up of semifluid or boundary lubrication regime, particularly when adopting high WOB and low rpm [Hawkes, 1984]. As a consequence, local seizing and galling can take place on bearing surfaces, inducing accelerated wear inside the cone, generating a rough surface to ride on the journal. Cone/Journal friction coefficient increases quickly, forcing to reduce the speed of rotation of the cone. At this stage, it is likely to suppose the set-up of a condition of *Slowed Down Cone Rotation* (SDCR): cone rotation is no more dictated by bottom hole pattern, but it is slowed down by the high friction and local seizing on bearing surfaces. Therefore, the cutting structure is forced to skid and scrape against the formation, rather than driven to hit and crush it. Such a mechanism explains the particular wear flat on the inserts and the slow penetration rate. It has been noticed that the amount of wear flat increases from nose to gage row: generally, gage rows are worn flat up to the cone shell, while nose rows do not show any particular wear. This confirms the hypothesis of SDCR: in fact, work rate per insert row, function of cutter displacement and correlated to its wear rate, increases with the distance from the bit centre (i.e., from nose to gage), accordingly to tangential velocity.

ROCK-BIT APPLICATION

FBR's are not designed to run in absence of a greasy lubrication, causing all the above problems; so, it is recommendable to use bearings designed to run dry, i.e., capable to rotate independently from borehole conditions. A possible solution is the application of Open Bearing Rock-bits (OBR), which are designed with unsealed antifriction roller bearings. OBR's are conceived to drill also in the extreme condition of absence of a greasy lubricant (e.g., air drilling applications): the drilling fluid is allowed to circulate inside the bearing, serving as lubricant and cooler. A roller bearing doesn't need any particular hydrodynamic lubrication to function properly, and is less prone to seizing, helping to reduce the phenomenon of SDCR. The only drawback is roller and bearing surfaces wear, which must not exceed the point to have the leg separated from the cone. Some special 8-1/2" OBR's were tested in sections showing high BHT and no circulation losses, after FBR's runs showing poor performances, premature wear and flat worn cutting structure. Tests were performed with IADC 732 air bits, modified on rig site for mud drilling, welding a plug inside the air inlets [Macini *et al.*, 1994].

RESULTS AND DISCUSSION

Almost all test runs performed in several wells of the area yielded very good and promising results. OBR's allowed to drill longer intervals per bit run with a penetration rate above average, if compared to FBR's. This was possible thanks to the longer life on bottom shown by OBR's in this particular application, due to the minor cutting structure and bearing wear derived from the minimization of SDCR. The 8-1/2" section was thus optimized by substantially reducing trip times and number of bits per section.

Table 1 reports FBR's and OBR's comparative performances recorded in some high BHT wells of Larderello area, showing run number, bit type, depth out, interval drilled, hours on bottom and penetration rate, respectively. All runs are referred to the 8-1/2" section drilled with mud circulation. For a useful comparison, it has been reported only the more representative runs, the ones performed through the same formations group (metamorphites of the reservoir) and with minor changes in WOB and rpm (approximately, 6÷8 tons, 80÷90 rpm). Data analysis substantially confirms the good results of OBR's application discussed above and plotted by Diagrams 1, 2, 3 and 4, reported at the end of the paper.

Diagram 1 shows the interval drilled and hours on bottom recorded in Well #1, the first test well for OBR's application. Runs 56, 57 and 58 refer to a series of very poor FBR's run, while runs 59 and 60 show the test of OBR's. Being the formation expected unchanged, it was decided to use the same drilling parameters, hydraulics and cutting structure design of the previous runs (FBR's are IADC 737 or 637, while OBR's are 732). The test resulted in a longer life on bottom and an increased ROP. Runs 61 and 62 show a double check made with FBR, resulting again in poor performances, comparable to runs 57 and 58. Run 63 and the following confirm the successful application of OBR's. Another check to prove that rock-bit performances can be affected by high BHT is given by the comparison of run 65 (OBR) and 66 (FBR). Here, the bits show the same performances: this can be justified by the fact that in the last part of run 65 the mud circulation was completely lost, causing a significant decrease of BHT, allowing for a correct application of FBR's. Relatively to the interval showing high temperature and no circulation losses, OBR's, compared to FBR's, averaged a six-fold increase in drilled interval, triplicated hours on bottom, and doubled the penetration rate (see Tab. 1).

Diagram 2 plots the interval drilled and hours on bottom recorded in Well #2. After the application of OBR's, both interval drilled and penetration rate were doubled, while hours on bottom increased by 30%. Diagram 3 shows interval drilled and hours on bottom recorded in Well #3: metres and ROP doubled, while hours increased by 20%.
Diagram 4 reports hours on bottom and interval drilled of Well #4: ROP didn't improve, but benefits derived by a 50% increase of interval drilled and hours on bottom; moreover, this well displays the same situation of Well #1: lost circulation started after run 28, yielding good FBR's performances.

Finally, it is stimulating to compare the wear rate and wear mode of FBR and OBR. In Well #1, accordingly to IADC roller bit dull grading system [McGehee *et al.*, 1992], bit 58 was graded 8, 8, WT, A, F, 4, FW, PR, (IADC 737, after 4 m and 2 hours), while bit 59 was graded 0, 1, NO, A, 4, I, NO, HR, (IADC 732, after 51 m and 10.5 hours). There is evidence that on FBR the major role in governing cutting structure wear is played by SDCR and not by formation abrasiveness. This phenomenon is illustrated in Fig. 7, showing bit 59 of well #1 (OBR): insert wear is a minor concern and wear flat is no more present, having eliminated the phenomenon of SDCR.

Fig. 7. OBR run in the critical section of Well 1: cutting structure and bearings are in good shape.

In the light of these results, it is possible to derive additional qualitative information about formation drillability and, therefore, expected penetration rates [Warren, 1987, Gault, 1987], optimization of bearing life [Kelly, 1990, Fear *et al.*, 1992], and rock-bit wear [Fay, 1993]. Heavy wear on rock-bits utilized in geothermal fields is traditionally considered as a direct consequence of formation abrasiveness and poor formation drillability. On the contrary, these results show that formation drillability is very good, formation abrasiveness has only limited effects on cutting structure wear, and bearing wear is mainly influenced by design and BHT. Moreover, the drilling rate increase, resulting from having changed the bearing type, indicates that drillability and other bit parameters used in drilling models are strictly dependent on bit conditions and bit mechanics.

CONCLUSIONS

Drilling rate is one of the main factors affecting drilling costs, and rock-bit wear is one of the main factors affecting the drilling rate. So, the key factor to minimize drilling costs is understanding the interactions between formation and rock-bit, that is the identification of cutting structure and bearing wear patterns, accordingly to particular drilling situations [Fay, 1993, Willis *et al.*, 1990].

FBR's run in high BHT holes can negatively influence the overall drilling performances. A new FBR wear pattern has been recognized in these holes, further verified by means of laboratory inspections and performance analysis. It has been investigated the effects of high temperature on sealing and reservoir system of FBR's, and it has been derived an original interpretation of cutting structure premature wear, early bearing failure and undergauge traditionally recorded in high BHT holes. In particular, a phenomenon called SDCR has been identified as the main cause for the above problems. The application of OBR's was proven effective to reduce premature cutting structure wear, leading to a significant increase of life on bottom and penetration rate. Optimization of drilling performances was obtained by globally decreasing both trip times and number of bits utilized, and by increasing penetration rates. This particular OBR's application was tested in several wells and, today, it has turned into a standardized practice in Italian geothermal fields. The above analized drilling conditions are likely to be found also in deep holes for petroleum exploration, where application of FBR's is even more common.

ACKNOWLEDGEMENTS

I would like to acknowledge the management of ENEL S.p.A. (Pisa, Italy) for the permission to publish all drilling records herein included. Special thanks go to Prof. G. Brighenti and E. Mesini, University of Bologna, for the critical review of the manuscript. Smith International Inc. is also acknowledged for technical contributions and dull bits laboratory inspections. Research supported by CNR Grant N. 95.00326.CT05

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APPENDIX: Principles of FBR bearings

Friction (or journal) bearings adopted on rock-bits consist of two cylindrical surfaces free to rotate one with respect to the other and separated by an oil film: the journal (leg) is stationary and the bearing (cone) rotates. Fig. 8 schematizes a journal bearing with perfect lubrication.

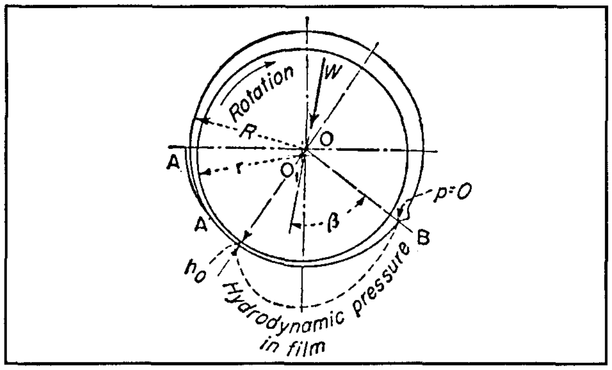

Fig. 8 Journal bearing with fluid lubrication.

Classically, three configurations of lubrication type have been recognized, depending on the running parameters and lubricant efficiency :

1) *Boundary lubrication*, which takes place when the bearing is barely greasy or when the bearing is well lubricated, but the speed of rotation is very low. This condition occurs also in any bearing when the journal is starting from rest, if the bearing is not equipped with an oil lift, or when a complete failure of lubrication happens.

2) *Semifluid lubrication*, which exists between the journal and the bearing when the conditions are not such as to form a load-carrying fluid film to separate the friction surfaces. Semifluid lubrication takes places at comparatively low speed, with intermittent motion, heavy load, insufficient lubricant supply to the bearing, or bearing misalignment.

3) *Fluid* or *complete lubrication*, which is the most desired condition. The journal and bearing surfaces are completely separated by a fluid film, which provides the lowest friction losses and prevents wear. A certain amount of lubricant must be fed to the oil film, in order to compensate for end leakage and to maintain its carrying capacity. Fluid lubrication in a plain cylindrical bearing depends on the viscosity of the lubricant and on its adhesion to the surfaces of the journal and the bearing. The radial clearance provided in the bearing forms, automatically, a wedge-shaped film between the journal and the bearing. The oil is entrained by the journal into the film and a hydrodynamic pressure is created, that is sufficient to float the journal and carry the load applied to it. The minimum film thickness h_0 determines the closest approach of the journal and bearing surfaces with complete lubrication. The maximum allowable approach depends on the degree of finish of these surfaces and on the rigidity of the journal and bearing structures. The operating characteristic K of a friction bearing is described by the following:

$$K = \frac{P}{\mu N}\left(\frac{R-r}{r}\right)^2 \frac{l}{c}$$

where:

R = bearing radius [in]
r = journal radius [in]
l = bearing length [in]
W = load on bearing [lb]
$P = W/2rl$ [psi]
μ = oil viscosity [psi sec]
N = bearing rpm [sec^{-1}]
$s = R-r$ = clearance [in]
h_0 = film thickness [in]
$e = h_0/s$
c = coefficient for side leakage of oil

Tabulated one can find the ratio *e* (minimum film thickness to radial clearance) Vs. the operating characteristic K as a function of β, that is the angle between the direction of the load W and the entering edge of the load-carrying oil film. Usual values estimated for rock bits are $75° < \beta < 90°$. The coefficient *c* corrects for side leakage: in fact there is a loss of carrying capacity caused by the drop in the hydrodynamic pressure *p* in the oil film from the midsection of the bearing towards its end; $p = 0$ at the ends. The value of *c* depends on the length to diameter ratio of the bearing (*l/d*) and on *e*. Generally, rock-bit bearings have a small *l/d* ratio, that causes a decrease in load carrying capacity.

A decrease of rotational speed and/or oil viscosity and an increase of the applied load or bearing misalignment will cause a decrease of the film thickness. As long as hydrodynamic conditions exist to create a lubricating film between the two rotating surfaces, the life of a journal bearing is virtually limitless. When the film breaks down, due to high loads, low speed or low viscosity, the bearing surfaces come into contact and boundary or semifluid lubrication takes place. The degree to which the bearing surfaces come into contact varies mainly with the surface roughness: bearing materials are machined so that damages from asperity interactions can be minimized (precision turning). In fluid lubrication, the heat generated inside of the bearing is a function of lubricant viscosity, applied load and relative speed between cone and journal: the heat produced varies with the square of the speed [Hawkes, 1984]. Heat generated in bits smaller than 10" due to fluid lubrication is considered insignificant, but it must be taken in account when designing bits larger than 10". In semifluid lubrication the heat generated is a function of applied load and metallurgical properties of the cone and journal surfaces. Rough surfaces will generate more heat than smooth ones. In bits smaller than 10", semifluid lubrication accounts for most of the heat generated. In bits larger than 10" both fluid and semifluid lubrication accounts for the heat generated. As the lubricating film gets thinner, causing more asperity interactions, heat generated by semifluid lubrication will be more than that generated by fluid one, and will eventually be the cause for bearing failure.

WELL #1: Monteverdi 5B

Bit #	IADC code	Depth out [m]	Interval drld [m]	Hours btm[h]	ROP [m/h]
51	837	3237	16	6.0	2.7
52	837	3265	28	11.0	2.5
53	837	3280	15	8.5	1.7
54	737	3292	12	5.0	2.4
55	737	3299	7	2.5	2.8
56	737	3308	9	4.5	2.0
57	737	3315	7	4.0	1.7
58	737	3319	4	2.0	2.0
59	**732**	3370	**51**	**10.5**	**4.9**
60	**732**	3431	**61**	**12.5**	**4.9**
61	617	3435	4	1.0	4.0
62	837	3443	8	2.5	3.2
63	**732**	3485	**42**	**8.5**	**4.9**
64	**732**	3564	**79**	**18.0**	**4.4**
65	**732**	3657	**93**	**17.0**	**5.5**
67	**732**	3836	**75**	**15.5**	**4.8**
Avg	FBR	--	*11.0*	*4.7*	*2.5*
Avg	**OBR**	--	***66.8***	***13.6***	***4.9***

WELL #2: Colla 2C

Bit #	IADC code	Depth out [m]	Interval drld [m]	Hours btm[h]	ROP [m/h]
22	517	2483	20	4.0	5.0
23	537	2557	74	20.0	3.7
24	537	2659	102	25.5	4.0
25	**612**	2824	**165**	**20.5**	**8.0**
26	**612**	2993	**169**	**23.0**	**7.3**
27	**612**	3178	**185**	**21.5**	**8.6**
28	**612**	3348	**170**	**21.0**	**8.1**
29	**612**	3500	**152**	**23.0**	**6.6**
30	**612**	3703	**203**	**22.5**	**9.0**
31	**612**	3882	**179**	**21.0**	**8.5**
32	**622**	4055	**173**	**17.0**	**10.2**
33	**622**	4216	**161**	**18.5**	**8.7**
Avg	FBR	--	*65.3*	*16.5*	*4.2*
Avg	**OBR**	--	***173.0***	***20.9***	***8.3***

WELL #3: Colline 5

Bit #	IADC code	Depth out [m]	Interval drld [m]	Hours btm[h]	ROP [m/h]
15	537	899	35	12.0	2.9
16	617	909	10	6.0	1.7
17	537	1066	157	19.0	8.3
18	**612**	1219	**153**	**19.5**	**7.8**
19	**612**	1408	**189**	**20.5**	**9.2**
20	**612**	1513	**105**	**11.0**	**9.5**
21	**612**	1647	**134**	**15.5**	**8.6**
22	**612**	1703	**56**	**5.5**	**10.2**
23	**612**	1846	**143**	**15.0**	**9.5**
Avg	FBR	--	*67.3*	*12.3*	*4.3*
Avg	**OBR**	--	***130.0***	***14.5***	***9.1***

WELL #4: Radicondoli 26C

Bit #	IADC code	Depth out [m]	Interval drld [m]	Hours btm[h]	ROP [m/h]
21	537	2997	65	12.0	5.4
22	537	3054	57	11.0	5.2
23	537	3118	64	10.5	6.1
24	**612**	3211	**93**	**14.5**	**6.4**
25	**612**	3285	**74**	**15.5**	**4.8**
26	**612**	3400	**115**	**17.0**	**6.8**
27	**612**	3491	**91**	**18.5**	**4.9**
28	**732**	3602	**111**	**22.0**	**5.0**
Avg	FBR	--	*62.0*	*11.1*	*5.6*
Avg	**OBR**	--	***96.8***	***17.5***	***5.6***

WELL #5: Colla 2A

Bit #	IADC code	Depth out [m]	Interval drld [m]	Hours btm[h]	ROP [m/h]
20	537	2621	130	39.0	3.3
21	537	2676	55	17.0	3.2
22	**612**	2930	**254**	**35.0**	**7.3**
23	**612**	3005	**75**	**13.0**	**5.8**
24	**612**	3256	**251**	**45.0**	**5.6**
25	**612**	3336	**80**	**21.0**	**3.8**
26	537	3412	76	17.0	4.5
27	**612**	3529	**117**	**20.0**	**5.9**
28	537	3614	85	22.0	3.9
29	**612**	3843	**229**	**28.0**	**8.2**
Avg	FBR	--	*86.5*	*23.8*	*3.7*
Avg	**OBR**	--	***167.7***	***27.0***	***6.1***

WELL #6: Miniera 4B

Bit #	IADC code	Depth out [m]	Interval drld [m]	Hours btm[h]	ROP [m/h]
50	537	2506	78	11.0	7.1
51	537	2563	57	21.0	2.7
52	537	2619	56	20.5	2.7
53	537	2675	56	16.5	3.4
54	**612**	2750	**75**	**21.0**	**3.6**
55	**612**	2848	**98**	**24.0**	**4.1**
56	**732**	2923	**75**	**27.0**	**2.8**
Avg	FBR	--	*61.8*	*17.3*	*4.0*
Avg	**OBR**	--	***82.7***	***24.0***	***3.5***

WELL #7: Monteverdi 5ST

Bit #	IADC code	Depth out [m]	Interval drld [m]	Hours btm[h]	ROP [m/h]
22	517	2462	43	13.0	3.3
23	517	2508	46	12.0	3.8
24	537	2524	16	6.0	2.7
25	**732**	2674	**150**	**34.0**	**4.4**
26	**732**	2819	**145**	**40.0**	**3.6**
27	**732**	2914	**95**	**30.0**	**3.2**
28	**732**	3046	**132**	**39.0**	**3.4**
Avg	FBR	--	*35.0*	*10.3*	*3.3*
Avg	**OBR**	--	***130.5***	***35.8***	***3.7***

Table 1: FBR's and OBR's performances recorded in Larderello area. All runs are referred to the 8-1/2" section. Depth and drilled intervals are reported in meters. Bold indicates OBR's. Avg is the arithmetic mean of the current records.

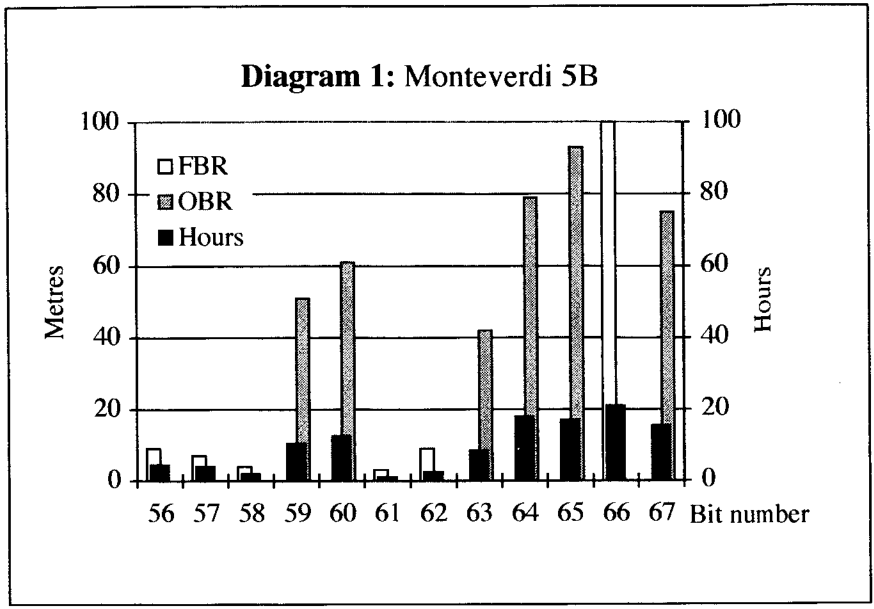
Diagram 1: Monteverdi 5B

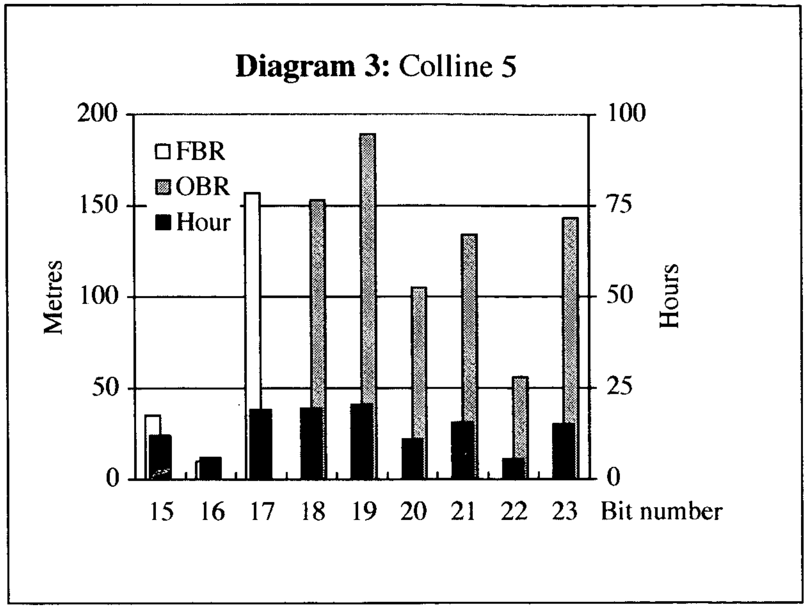
Diagram 3: Colline 5

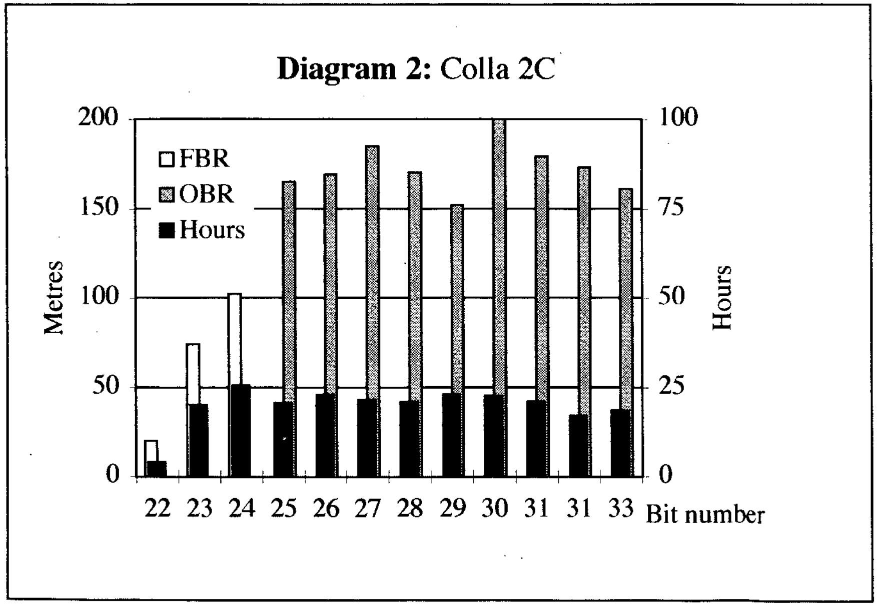
Diagram 2: Colla 2C

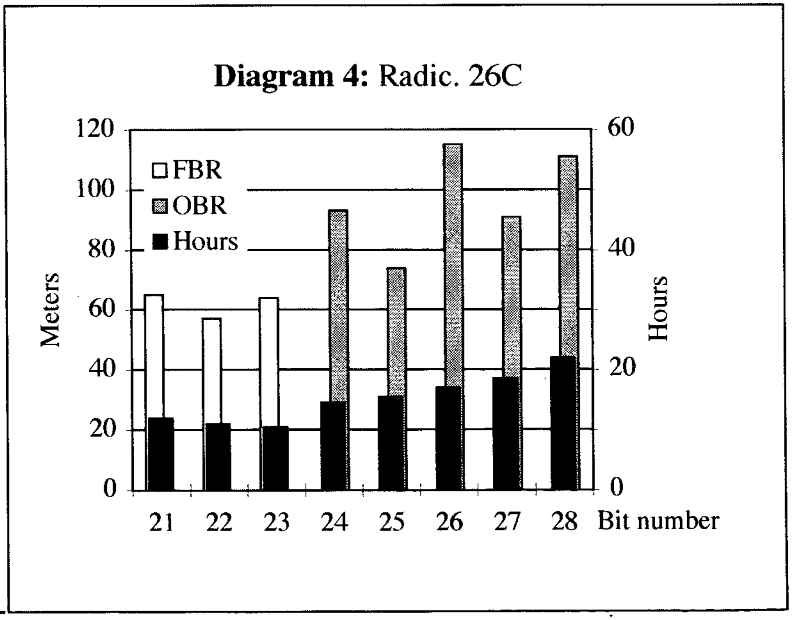
Diagram 4: Radic. 26C