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TITLE: REDRILLING OF WELL EE-3 AT THE LOS ALAMOS NATIONAL LABORATORY HDR PROJECT

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# REDRILLING OF WELL EE-3 AT THE LOS ALAMOS NATIONAL LABORATORY HDR PROJECT

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## ABSTRACT

The successful sidetracking of well EE-3 and the drilling of well EE-3A proved that with detailed planning and by adjusting techniques based on previous experience at Fenton Hill, drilling can be accomplished with reduced risk. The primary drilling problems associated with drilling of hot, crystalline basement rock, are (a) abrasiveness between the downhole tools and the formations and (b) a crooked wellbore path. These were essentially eliminated by a specially designed drilling fluid and careful pre-planning of the directional drilling operations. These improvements have taken much of the risk out of drilling at the Fenton Hill Hot Dry Rock (HDR) Geothermal Test Site.

The sidetracking of EE-3 and drilling of EE-3A were undertaken to complete the hydraulic connection between boreholes. Drilling through fractured regions indicated by the dense zones of microseismic activity increased the probability of success. EE-3 was sidetracked at 9,373' and redrilled to a depth of 13,182' (Figure 1).

## INTRODUCTION

The Los Alamos National Laboratory Hot Dry Rock project at Fenton Hill, New Mexico is described in Reference 1. Initially two deep wells, GT-2 and EE-1 were drilled and a HDR reservoir created. This system was extensively tested (Reference 2). Later, a larger, hotter system was planned and a pair of wells, EE-2 and EE-3 were directionally drilled to total depths of 15,289' and 13,933' respectively (References 3,4, and 5). Well EE-3 was above well EE-2 by a vertical separation of 1,200' in the same plan with wellbores inclined at 35° from vertical (Figure 2). Considerable problems with both sidetracking and drilling had plagued previous drilling operations in both the GT-2/EE-1 and the EE-2/EE-3 well pairs.

Drilling problems encountered were associated with five aspects of the granitic formations, namely; hardness, abrasiveness, temperature, hot gases, and deviation.

The hardness of the formations led to difficulty with sidetracking by using the standard techniques with downhole motors and bent subs. Another problem associated with the formation hardness is that abrupt doglegs created during drilling can not be "smoothed out" by standard rotary drilling methods. Doglegs created in softer formations can be rounded to gradual doglegs by the use of "string reamers". These abrupt doglegs increased drill string fatigue and wear problems. This led to numerous fishing operations in the previously drilled boreholes.

The formation abrasiveness caused severe wear on downhole drilling tools, wirelines and wireline tools. Roller reamers and bits with tungsten carbide inserts were rapidly damaged due to the formation abrasiveness. Diametrical bit wear resulted in time consuming reaming operations of under gauge hole. This usually resulted in premature failure of the bit used for reaming. Severe wear of the drill string due to the combination of abrasiveness and high side loading, because of the directional nature of the wells, contributed to the problems of downhole equipment failure and the need for frequent equipment inspections.

The temperature increased the corrosiveness of the drilling fluid reducing the fatigue life of the drill string, resulting in several "twist off's". The temperature also contributed to drill pipe protector failure which increased casing wear from drill pipe tool joints. Downhole motors containing elastomers were limited in usage because the high temperature destroyed the elastomers.

Reservoir creation activities by hydraulically fracturing between EE-2 and EE-3 began in April, 1982. Several hydraulic fracturing operations attempted to connect the two wellbores. In December, 1984 a massive hydraulic fracturing experiment was conducted by pumping 5.6 million gallons into EE-2 (References 6 and 7). The injection zone was 60' of openhole between the 9 5/8" casing shoe at 11,578' and a sand/barite plug at 11,648'. The massive hydraulic fracture created was mapped as a large seismic cloud but did not intersect well EE-3.

The attempts to create a HDR reservoir by hydraulically fracturing between two wells (EE-2, EE-3) already drilled were unsuccessful. It was decided to sidetrack EE-3 and re-direct the wellbore into pre-selected clusters of micro-seismic events which were recorded during the MHF. The drilling would be planned to address the experienced problems to assure a successful deep sidetracking and redrilling operation.

## PLANNING

A comprehensive redrilling plan for sidetracking, directional drilling, testing and completing was developed. This plan was developed by the LANL personnel and sub-contractors on the HDR project. The plan was then reviewed by geothermal industry personnel and comments were incorporated into the final planning.

The initial step in the development of the redrilling plan was the target selection. Target selection was made with three goals in mind: (1) the penetration of as much of microseismic region created during the MHF as possible. (2) the drilling along a well trajectory that could be easily modified to allow re-direction of the wellbore into other seismic zones if fracture connections to EE-2 could not be made after 600' of initial target region drilling and (3) minimization directional motor drilling and severity of the wellbore curvature.

The target selection resulted in sidetracking at about 9,300' turning the hole to the South from N77E to S36E and dropping hole angle from 22 1/4° to about 11°. The dogleg severity would be limited to 2°/100' maximum while turning and sidetracking and 1°/100' while dropping angle only (Figure 3).

Sidetracking in granite rocks of 28,000 to 40,000 psi comprehensive strength had been attempted several times (and accomplished twice) using cement plugs and downhole motors with bent subs above the motor. Difficulties arose in cement placement and achieving cement compressive strength sufficient to side load the bit to get a "ledge" started into the granite borehole wall. It was planned to make an attempt to sidetrack off the ledge of a previously underreamed section at around 9,290' using a downhole motor and bent sub without placing a cement plug in the milled section. This was given a limited chance of success, but had the desirable features of possibly lower dogleg severity at the sidetrack and elimination of potential problems associated with the use of a whipstock. In case the sidetrack would not be made using the downhole motor and bent sub, two specially built 2°/100' whipstocks were procured.

The drilling fluid was designed to reduce drag, corrosion, torque, abrasion, and to improve hole cleaning. The mud would be a lightweight, low solids, fresh water sepiolite, and bentonite system treated with lignite and caustic. Triglycerides would be used to overcome torque and drag problems. The mud properties of primary importance were lubricity, pH, solids, weight and yield point (Table IV). The corrosion control program was an integral part of the drilling fluid program. Careful monitoring of pH and corrosion coupons provided guidance for treatments to the system.

Eliminating downhole drill string failures and minimizing wear on the 9 5/8" casing were prime considerations for the drill string design, handling procedures and inspection program. The drill string was designed for 100,000 lbs over pull in air with an 80,000 lb bottomhole assembly. The drill string handling program included: (a) odd-even break on tool joints while tripping to prevent galling and seizure of threads and shoulders on connections, (b) use of non-hardbanded tool joints in casing, and (c) the use of pipe spinners to make-up and break tool joints to reduce wear on the 9 5/8" casing. Rotary slips were to be set softly. Special geothermal grade thread lubricants would be used on all rotary tool joints. In addition, two complete strings of drill pipe and drill collars would be on-site so that drilling could be continued during inspection. Drill pipe pup joints were used to change tool joint position while milling, reaming and drilling.

The drill pipe would undergo a full-length inspection after no more than 200 hours of rotation. Blacklight or magnetic particle inspection of all tool joints in the bottomhole assembly would be performed at intervals not to exceed 100 rotating hours. The option of inspecting drill pipe and bottomhole assemblies prior to the 200 and 100 hour range was retained in the event severe doglegs, fishing, and or milling operations exceeded the normal working range of downhole components.

## OPERATIONS

Sidetracking Operations. A section was milled in the 9 5/8" casing from 9,285' to 9,353' (68' (Figure 4)). A series of Dyna-Drills and bent subs were run without achieving a sidetrack. An additional 19' of 9 5/8" casing was section milled down to 9,372'. After section milling a cement plug was set through the section and drilled out. A gauge run with the pack-stop assembly was made to insure locating properly on the bottom stub of 9 5/8" casing. The pack stock and whipstock was run (Figure 3), oriented with a steering tool and hydraulically set. The face of the whipstock was 45°R of N70E, this allowed for a small build-in inclination which was necessary to avoid re-entering the EE-3X abandoned borehole directly below the kick off point (KOP). A limber assembly with a tungsten carbide cutter bit was used to drill off the whipstock. The assembly consisted of: 8 1/2" bit, bit sub, 2 joints of 4 1/2" drill pipe, 6-6 1/2" drill collars, 21 joints of 5" heavy weight drill pipe. After drilling off the whipstock for 30' to a depth of 9,410', the hole was reamed to remove any ledges that may have formed during kick off operations. A positive displacement motor and 1° bent sub were then utilized to drill to about 9,450'. The inclination was 22 1/4° at 9,450' with an azimuth of N74°E.

At a depth of 9,457' the rig used to sidetrack had reached its depth capabilities and a large drill rig was brought in to drill the remainder of the hole.

Redrilling Operations. After sidetracking off the whipstock, two motor runs were made using a 1° and 2° bent sub to establish the hole on the desired trajectory. Three corrective runs were made at 10,655', 11,015' and 11,315'. The hole angle and direction were primarily controlled by slight variations of the bottom hole assemblies (Table 1).

The directional program was very successful in dropping angle and turning the hole to the right. The bottom hole assemblies were of the following basic types:

1. Slow Dropping Assembly
   8 1/2" bit
   6 point full gauge reamer
   Short drill collar
   3 point full gauge reamer
   Monel drill collar
   3 point full gauge reamer
   5 - 6 1/4" drill collars
   24 joints 5" heavy weight drill pipe

2. Fast Dropping Assembly
   8 1/2" bit
   3 point under gauge reamer
   Float sub
   Monel drill collar
   6 point full gauge reamer
   Steel drill collar
   3 point full gauge reamer
   5 - 6 1/4" drill collars
   24 joints 5" heavy weight drill pipe.

3. Hold and Drill Assembly
   8 1/2" bit
   Float sub
   8 1/2" full gauge spiral (full wrap stabilizer) (IBS)
   Short drill collar
   3 point full gauge reamer
   X-over
   Steel drill collar
   8 1/2" full gauge spiral (full wrap) stabilizer (IBS)
   4 - 6 1/4" drill collars
   24 joints 5" heavy weight drill pipe.

By making small adjustments in weight on bit, rotary RPM, and pump pressure the well bore trajectory target guidelines established in the drilling plan were maintained throughout the redrill.

The 8 1/2" roller cone bit record is shown in Table II. The drilling rates varied from an average low of 9.0' to 16' per hour during normal drilling operations. Average penetration rate for the 3,700' of drilling was 12' per hour. Gauge wear caused no problems and only minimum reaming was required. The use of full gauge tungsten carbide pads installed on bit shanks contributed to the drilling of a full gauge hole.

The drilling fluid program was simple, inexpensive, and greatly reduced the torque, drag and wear problems associated with prior drilling experience using water as a circulating medium. The drilling fluid lost its rheological and lubricity properties after long periods of stagnation at geothermal bottom-hole temperatures. A phase change from sepiolite to smectite was detected using x-ray diffraction analysis. This degradation was associated with significant increases in drillstring drag, torque and drill string wear. The system would then be replenished by increasing the concentration of bentonite and decreasing the use of lignite.

The drilled cuttings were removed efficiently from the wellbore. The cuttings were generally about 1/16" to 1/8" in size. Sample quality was good to excellent throughout the redrill operation. No significant amounts of large size cuttings were recovered in previous drilling using water as a circulating medium.

Coring Operations. The first coring operation was conducted at a depth of 9,450' to 9,457' using an experimental Christensen Navi-Drill Core System with an 8 1/2" diamond and polcrystalline diamond impregnated core bit (Table 2). A total core recovery of 4' 2" or 60% of interval cored was achieved. The second core run utilizing a PDC cutter core system, also an experimental system for hot crystalline rock, cored from 10,875' to 10,880'. Recovery was 2' 7 1/2" of core or 55% of total footage cored. Subsequent runs #2 and #3 were made using a tri-cone X3TC7 hybrid core system. Coring rates of penetration and recovery were substantially improved over previous runs. The hybrid core bit runs of 15' and 30' recovered 87% and 80% respectively in 15' and 30' barrel lengths.

## CONCLUSION

The EE-3A redrill operations success can be attributed to several factors that, when combined, led to a safe and productive effort. The dedication of management to insure proper redrill planning and adequate personal, played a vital role. The ability of the management team, scientists, engineers and technicians to work effectively proved to be a valuable resource as the redrill project progressed.

Penetration rates for drilling the deviated hole average approximately 100' per day while staying within the proposed trajectory guidelines (Figure 5). The torque, drag and abrasion were reduced significantly with the use of the sepiolite mud system and sample quality was good to excellent throughout the redrill which was also attributed to the drilling fluid.

The placement of reamers and stabilizers in the bottom hole assemblies performed satisfactorily in maintaining target trajectory throughout most of the redrill. Motor drilling to maintain target trajectory was used 4 times to initiate the required turns. A total of 517' of the 3,732' was motor drilled, roughly 14%, which resulted in substantial cost savings. The ability to drill crystalline rock effectively in a sidetracked borehole and maintain trajectory was accomplished on the redrill.

ACKNOWLEDGMENT

The work was sponsored by the US Department of Energy and supported by the governments of the Federal Republic of Germany and Japan. Special thanks for their support and dedication to achieve a successful redrill.

Reference to a company or product name does not imply approval, recommendation or endorsement of the product or service by the University of California (Los Alamos National Laboratory) or the US Department of Energy to the exclusion of others that may be suitable.

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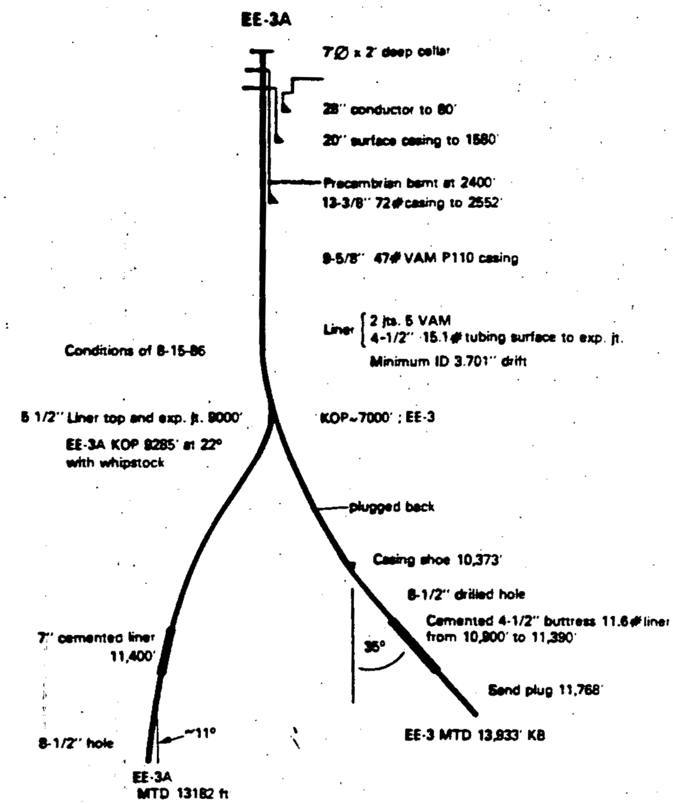


FIGURE 1. Diagram View of EE-3A Wellbore.

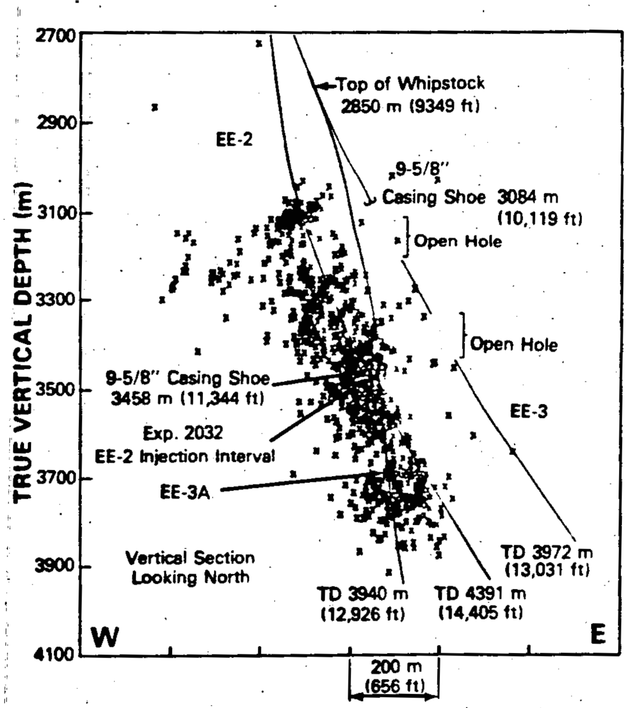


FIGURE 2. Elevation View of Microseismic Events and Boreholes EE-2, EE-3, EE-3A.

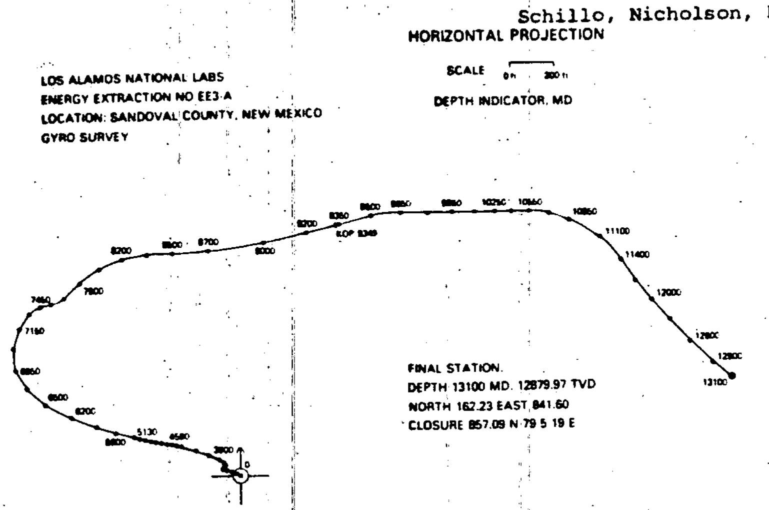


FIGURE 3. Gyro Survey of EE-3A Borehole.

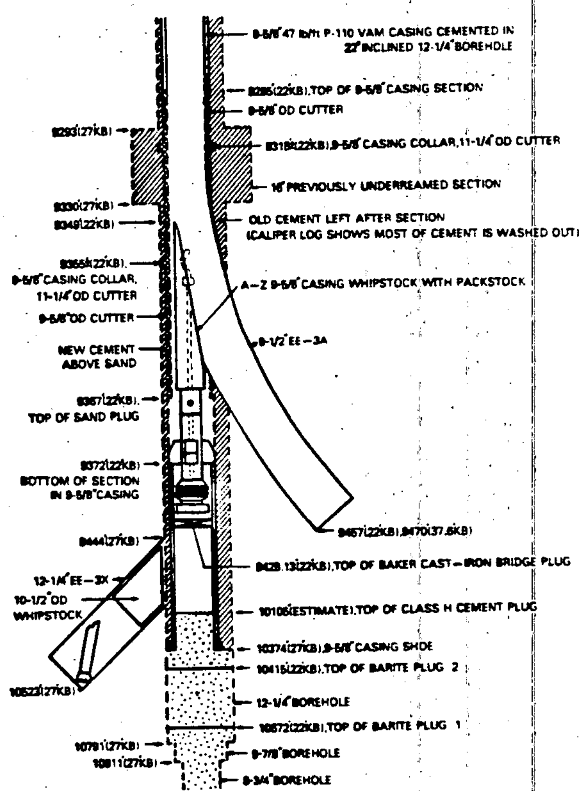


FIGURE 4. Whipstock Assembly and Section Mill.

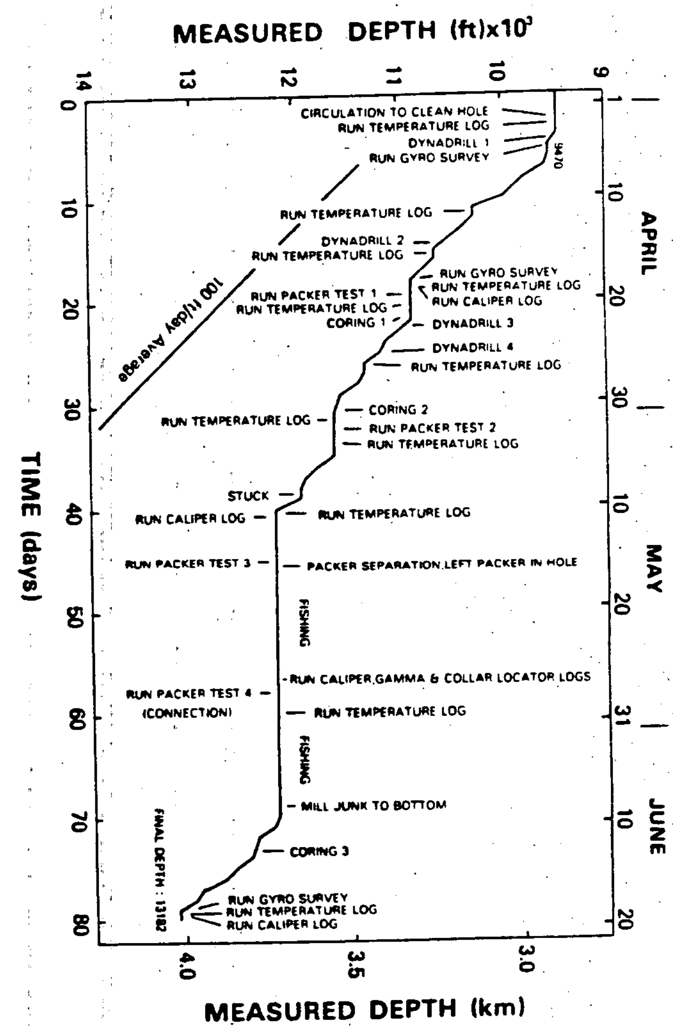


FIGURE 5. Drilling Time Curve with Major Events.

## TABLE I

BHA USED TO ROTARY DRILL EE-3A

| RUN No. | DEPTH OUT (ft) | INTERVAL DRILLED (ft) | ASSEMBLY (Rotary Drilling) | REMARKS |
|---|---|---|---|---|
| 1 | 9377 | 28 | Bit (0.70), bit sub with float (2.98), baffle ring, 2 jts 4-1/2" DP (62.95), 6-6-1/2" DCs (186.03), 21 jts HWDP (639.22) | First drill by whipstock (BRINKERHOFF SIGNAL). Build assembly. |
| 2 | 9408 | 31 | Bit (0.70), bit sub (2.98), 8-1/2" IBS (3.63), 2 jts 4-1/2" DP (62.95), 6-6-1/2" DCs (186.03), 21 jts HWDP (639.22) | Ream and drill. Build assembly. |
| 3 | 9391 | 0 | Bit (0.70), X-0, float sub (2.98), 8-1/2" IBS (3.63), 6-9/16" pony collar (4.95), 8-1/2" IBS (4.19), 6-5/8" DC (30.34), 8-1/2" IBS (4.82), 5-6-1/2" spiral DCs (155.69), 21 jts HWDP (639.22) | Ream. Stuck. Build assembly. |
| 4 | 9410 | 2 | Bit (0.70), float sub (1.63), 6-3/4" 3 pt RR with K (7.02), baffle plate, 6-1/2" pony collar (5.08), 3 pt RR with K (5.12), bit sub (2.98), 6-5/8" DC (30.34), 6-7/8" IBS (4.82), 4-6-5/8" DCs (124.47), 21 jts 4-1/2" HWDP (639.22). | Ream and drill. Build assembly |
| 5 | 9450 | 0 | Bit (0.70), baffle plate, 6-3/16" 3 pt RR (5.83), 6-1/2" pony collar (5.08), 6-5/16" 3 pt RR (5.12), bit sub (2.98), 6-5/8" DC (30.34), 6-5/16" IBS (4.19), 4-6-5/8" DCs (124.47), 21 jts HWDP (639.22) | Ream and ream. |
| 6 (3) | 9601 | 53 | Bit (0.85), 8-3/8" 3 pt RR (4.80), float sub (1.50), 6-1/4" monel DC (32.54), 6 pt RR with K & Q (9.15), 6-1/8" DC (29.95), 3 pt RR (6.35), 5-6-1/4" DCs (139.15), X-0 (1.89), 24 jts HWDP (753.15) | First drill by BIG CHIEF. Ream Drill. Drop assembly. |
| 7 (4) | 9836 | 235 | Bit (0.85), 3 pt RR (4.80), float sub (1.50), 6-1/4" monel DC (32.54), 6 pt RR (9.15), 6-1/8" DC (29.95), 3 pt RR (6.35), 5-6-1/4" DCs (139.15), X-0 (1.89), 24 jts HWDP (753.15) | Drop assembly. |
| 8 (5) | 9913 | 77 | Bit (0.85), 8-3/8" 3 pt RR with Q (4.80), 6-1/4" monel DC (32.54), 6 pt RR with K & Q (9.15), 6-1/8" DC (29.95), 3 pt RR with Q (6.35), 5-6-1/4" DCs (139.15), 3 pt RR (5.90), 24 jts HWDP (753.15) | Drop assembly. |
| 9 (6) | 10273 | 362 | Bit (0.85), 3 pt RR with Q (4.80), 6-1/4" monel DC (32.54), 6 pt RR with Q & K (9.15), 6-1/8" DC (29.95), 3 pt RR (6.35), 5-6-1/4" DCs (139.15), 3 pt RR with K (5.90), 24 jts 5" HWDP (753.15) | Drop assembly. |
| 10 (7) | 10540 | 265 | Bit (0.85), 6 pt RR (7.90), 6-1/4" pony DC (5.08), 6-1/4" monel DC (32.54), 6 pt RR with Q (10.90), 6-1/4" DC (28.10), 3 pt RR with K (7.70), 5-6-1/4" DCs (141.00), X-0 (1.89), 24 jts HWDP (753.15) | Drop assembly |
| 11 (9) | 10875 | 220 | Bit (0.85), 6 pt RR (7.90), 6-1/4" monel DC (32.54), 6 pt RR (10.90), 6-1/4" DC (28.10), 3 pt RR (7.10), 5-6-1/4" DCs (141.00), X-0 (1.89), 24 jts HWDP (753.15) | Drop assembly |
| 12 (11) | 11126 | 111 | Bit (0.85), 3 pt RR (5.12), 6-1/4" short DC (5.06), 6-1/4" monel DC (32.48), 6 pt RR with K (9.15),6-1/4" DC (29.95), 3 pt RR (6.35), 5-6-1/4" DCs (140.90), X-0 (1.89), 24 jts 5" HWDP (753.15) | Ream and drill. Drop assembly. |
| 13 (13) | 11593 | 278 | Bit (0.85), 3 pt RR with K (4.78), 6-1/4" short DC (5.12), 3 pt RR (5.06), float sub (1.45), 6-1/4" monel DC (32.48), 6 pt RR (9.15), 6-6-1/4" DCs (170.86), X-0 (1.89), 24 jts HWDP (753.15) | Ream and drill. Drop assembly. |
| 14 (14) | 11600 | 7 | Bit (0.85), junk sub (2.97), 6 pt RR (7.89), float sub (1.45), 6-1/4" monel DC (32.48), 6 pt RR (10.90), 6-6-1/4" DCs (170.85), X-0 (1.89), 24 jts HWDP (753.15) | Ream and drill. Drop assembly. |
| 15 (15) | 11786 | 171 | Bit (0.85), 8-1/2" 6 pt RR with K (7.90), 8-1/2" 4-blade stab (4.05), 6-1/4" short DC (5.05), 8-1/2" RWP stab (7.48), 6-1/2" monel DC (32.48), 8-1/2" 3 pt RR with K (5.48), 9-6-1/4" DCs (255.66), 24 jts FWDP (753.15) | Ream, open 7-7/8" hole and drill. Drop assembly. |
| 16 (16) | 11954 | 168 | Bit (0.85), 8-1/2" 6 pt RR (9.18), 8-1/2" 4-blade stab with float (4.05), 6-1/4" short DC (5.05), 8-1/2" RWP stab (7.48), 6-1/4" monel DC (32.48), 8-1/2" 3 pt RR (5.27), 6-6-1/4" DCs (170.40), 24 jts FWDP (753.15) | Ream and drill. Drop assembly. |
| 17 (17) | 11956 | 2 | Bit (0.85), junk sub (2.97), 8-1/2" 4-blade stab with float (4.05), 8-1/2" 6 pt RR (9.18), 6-1/4" short DC (5.05), 8-1/2" RWP stab (7.48), 6-1/4" monel DC (32.48), 8-1/2" 3 pt RR (5.27), 6-6-1/4" DCs (170.40), 24 jts FWDP (753.15) | Ream and drill. Stuck. Drop assembly |
| 18 (RR17) | 12203 | 247 | Bit (0.85), junk sub (2.95), 6 pt RR (9.18), 6-1/4" short DC (5.05), 3 pt RR (5.10), 6-1/4" monel DC (32.48), 3 pt RR (7.73), 6-6-1/4" DCs (170.40), X-0 (1.89), 24 jts FWDP (753.15) | Ream and drill. Drop assembly. |
| 19 (18) | 12402 | 199 | Bit (0.85), bit sub with float (2.95), 3 pt RR with K (5.38), 6-1/2" short DC (4.88), 3 pt RR with K (6.35), 6-1/4" monel DC (31.70), 6 pt RR with K (9.16), 6-6-1/4" DCs (170.40), X-0 (1.70), 24 jts FWDP (753.28) | |
| 20 (19) | 12439 | 37 | 7-7/8" bit (0.85), 7-7/8" 3 pt RR (4.91), bit sub (2.95), 6-1/4" short DC (4.88), 7-7/8" 3 pt RR (6.24), 6-1/4" monel DC (31.70), 8-1/2" 6 pt RR (9.16), 6-6-1/4" DCs (170.40), X-0 (1.70), 24 jts FWDP (753.28) | Pilot hole for core. |
| 21 (20) | 12716 | 247 | Bit (0.75), float sub (2.96), 3 pt RR (6.34), 6-1/4" short DC (4.96), 3 pt RR (5.40), 6-1/4" monel DC (31.70), 6 pt RR (9.15), 6-6-1/4" DCs (168.72), X-0 (1.70), 24 jts HWDP (753.28) | Open 7-7/8" hole and drill. Drop assembly. |
| 22 (21) | 13008 | 292 | Bit (0.75), float sub (2.96), 3 pt RR (6.34), 6-1/4" short DC (4.96), 3 pt RR (5.40), 6-1/4" monel DC (31.70), 6 pt RR (9.15), 6-6-1/4" DCs (168.72), X-0 (1.70), 24 jts HWDP (753.28) | Ream and drill. Drop assembly. |
| 23 (22) | 13182 | 174 | Bit (0.75), float sub (2.96), 3 pt RR with K (6.34), 6-1/4" short DC (4.96), 3 pt RR with Q (6.71), 6-1/4" monel DC (31.70), 6 pt RR (9.15), 4-6-1/4" DCs (114.01), X-0 (1.70), 24 jts HWDP (753.28) | Ream and drill. Drop assembly. |

Note: All bits used are 8-1/2" diameter except #20.
DP = drill pipe; IBS = integral blade stabilizer; pt RR = point roller reamer; K = carbide cutters;
Q = Steel cutters; stab = stabilizer; RWP = replaceable wear pad.
The numbers in parenthesis correspond to bit numbers in APPENDIX C.

TABLE II

DETAILED EE-3A BIT RECORD

**List of Abbreviations**

| | |
|---|---|
| HTC | Hughes Tool Co. |
| STC | Smith Tool Co. |
| NSRB | Non-Sealed Roller Bearing |
| SJB | Sealed Journal Bearing |
| CB | Core Bit |
| HWDP | Heavy Weight Drill Pipe |
| FWDP | Flex Weight Drill Pipe |
| DC | Drill Collar |

| BIT NUMBER | SIZE | MAKE | TYPE | JETS | DEPTH OUT | FEET DRILLED | ROTATING HOURS | FT/HR | BIT WEIGHT 1000 # | POUNDS PER DIA IN. | RPM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RR#1 | 8 1/2" | STC | F3G | 14-14-14 | 9470 | | | | | | |
| 2 | 8 1/2" | HTC | HH77 | 16-16-16 | 9548 | 78 | 5.5 | 14.18 | 18-20 | 2118-2353 | DynaDrill |
| 3 | 8 1/2" | STC | 7GA | 10-10-10 | 9601 | 53 | 6.5 | 8.15 | 40-45 | 4706-5294 | 50 |
| 4 | 8 1/2" | HTC | HH77 | 12-12-12 | 9836 | 235 | 23.5 | 10. | 35-40 | 4118-4706 | 50 |
| 5 | 8 1/2" | STC | 7GA | 14-14-12 | 9913 | 77 | 7.25 | 9.94 | 35 | 4118 | 50 |
| 6 | 8 1/2" | HTC | HH77 | 14-14-12 | 10275 | 362 | 27.25 | 13.28 | 40-45 | 4706-5294 | 50 |
| 7 | 8 1/2" | HTC | J55R | 16-16-16 | 10540 | 265 | 25.5 | 10.39 | 40 | 4706 | 45-50 |
| 8 | 8 1/2" | STC | 7GA | 15-15-15 | 10655 | 115 | 7 | 16.43 | 20-25 | 2353-2941 | DynaDrill |
| 9 | 8 1/2" | STC | 7GA | 12-12-12 | 10875 | 220 | 14.75 | 14.92 | 40-42 | 4706-4941 | 45-50 |
| CB#1 | 8 1/2" | DOWD CO. | CTS4HR | | 10880 | 5 | 5.5 | 0.91 | 20 | | 55 |
| 10 | 8 1/2" | STC | 7GA | 14-14-14 | 11015 | 135 | 8.75 | 15.43 | 20-25 | 2353-2941 | DynaDrill |
| 11 | 8 1/2" | STC | 7GA | 12-12-12 | 11126 | 111 | 12.5 | 8.88 | 40 | 4706 | 65 |
| 12 | 8 1/2" | STC | 7GA | 12-12-12 | 11315 | 189 | 10 | 18.9 | 40-45 | 4706-5294 | DynaDrill |
| 13 | 8 1/2" | STC | 7GA | 12-12-12 | 11593 | 278 | 31 | 9. | 40-45 | 4706-5294 | 60 |
| 14 | 8 1/2" | STC | 7GA | 12-12-12 | 11600 | 7 | 1 | 7. | 22 | 2588 | 60 |
| CB#2 | 7 7/8" | STC | X3TC7 | | 11615 | 15 | 4 | 3.75 | 8-12 | | 45 |
| 15 | 8 1/2" | STC | 7GA | 14-14-14 | 11786 | 171 | 10.75 | 15.91 | 45 | 5294 | 60 |
| 16 | 8 1/2" | STC | 7GA | 14-14-14 | 11954 | 168 | 14.75 | 11.39 | 45 | 5294 | 60 |
| 17 | 8 1/2" | STC | F7 | 15-15-15 | 11956 | 2 | 0.5 | 4. | 20-30 | 2353-3529 | 50-60 |
| RR#17 | 8 1/2" | STC | F7 | 15-15-15 | 12203 | 247 | 23.25 | 10.62 | 35 | 4118 | 60 |
| RR#17 | 8 1/2" | STC | F7 | | | | | | | | |
| 18 | 8 1/2" | STC | 7GA | 14-14-14 | 12402 | 199 | 22.5 | 8.84 | 45 | 5294 | 55 |
| 19 | 7 7/8" | HTC | J77 | 14-14-14 | 12439 | 37 | 2.75 | 13.45 | 39 | 4588 | 80 |
| CB#3 | 8 7/8" | STC | X3TC7 | | 12469 | 30 | 5.75 | 5.22 | 12-14 | | 40 |
| 20 | 8 1/2" | STC | 7GA | 14-14-14 | 12716 | 247 | 20.75 | 11.9 | 45 | 5294 | 60-65 |
| 21 | 8 1/2" | STC | 7GA | 14-14-14 | 13008 | 292 | 19.75 | 14.78 | 46 | 5412 | 55-60 |
| 22 | 8 1/2" | STC | 7GA | 14-14-14 | 13182 | 174 | | | 40 | 4706 | 55-60 |

| BIT NUMBER | PUMP RATE (GPM) | PUMP PRESSURE (PSI) | $HHP/in^2$ | BEARING TYPE | MUD WEIGHT (PPG) | PLASTIC VISCOSITY (cP) | BIT CONDITION | DEVIATION |
|---|---|---|---|---|---|---|---|---|
| RR#1 | | | | | | | | |
| 2 | 340 | 1100 | 3.85 | NSRB | 6.7 | 14 | 4-4-I | 21.09°N82E |
| 3 | 374 | 2500 | 9.61 | " | 8.7 | 17 | 4-6-I | 18.5°N90E |
| 4 | 390 | 1750 | 7.02 | " | 8.6 | 15 | 7-6-I | 16.5°N89F |
| 5 | 390 | 1350 | 5.41 | " | 8.7 | 9 | | |
| 6 | 390 | 1350 | 5.41 | " | 8.6 | 15 | 8-8-1/4 | 11°N90E |
| 7 | 390 | 1167 | 4.68 | SJB | 8.6 | 8 | 8-6-1/16 | 13°N87E |
| 8 | 344 | 1100 | 3.89 | NSRP | 8.7 | 5 | 7-6-I | 13.25°S72E |
| 9 | 390 | 1500 | 6.02 | " | 8.6 | 11 | 5-5-I | 15°S71E |
| CB#1 | 395 | 1150 | | CB | 8.5 | 10 | 2-2-I | |
| 10 | 393 | 1500 | 6.06 | NSRB | 8.5 | 14 | 7-7-I | 13.75°S53F |
| 11 | 390 | 1445 | 5.79 | " | 8.7 | 8 | 3-3-I | |
| 12 | 390 | 1445 | 5.79 | " | 8.6 | 17 | 6-7-1/16 | 9.5°S30E |
| 13 | 390 | 1445 | 5.79 | " | 8.6 | 9 | 8-8-1/2 | 9°S32E |
| 14 | 377 | 1779 | 6.9 | " | 8.8 | 22 | | |
| CB#2 | 292 | 720 | | CB | 8.8 | 22 | | 8.5°S36E |
| 15 | 390 | 1450 | 5.81 | NSRB | 8.6 | 9 | 6-7-1/8 | 8.75°S37E |
| 16 | 383 | 1255 | 4.94 | " | 8.7 | 12 | 5-5-I | 8.25°S42E |
| 17 | 373 | 1200 | 4.6 | SJB | 8.6 | 12 | | |
| RR#17 | 307 | 1000 | 3.16 | " | 8.5 | 12 | 7-4-1/8 | 9°S44E |
| RR#17 | | | | | | | | |
| 18 | 372 | 1350 | 5.16 | NSRB | 8.5 | 3 | 6-6-I | 10°S40E |
| 19 | 372 | 1300 | 5.79 | SJB | 8.7 | 12 | 2-2-I | |
| CB#3 | | 750 | | CB | 8.7 | 14 | | |
| 20 | 357 | 1507 | 5.53 | NSRB | 8.7 | 16 | 8-8-1/16 | 10°S42.5E |
| 21 | 357 | 1476 | 5.42 | " | 8.8 | 14 | 7-8-I | 11.5°S46.5E |
| 22 | 357 | 1376 | 5.05 | " | 8.7 | 24 | | 12.33°S53.9F |

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3