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Measurement-While-Drilling (MWD) Development for Air Drilling

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DISCLAIMER

MEASUREMENT-WHILE-DRILLING (MWD) DEVELOPMENT FOR AIR DRILLING

CONTRACT INFORMATION

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Period of Performance:	Sept. 30, 1988 to December 31, 1993

SCHEDULE AND MILESTONES

PHASE IV Program Schedule (FY 1994)

	O	N	D	J	F	M	A	M	J	J	A	S
Field Tests		_	_									
System Rehabilitation		_	_	_								
Final Report				____								

OBJECTIVES

This program is being conducted under cost-sharing contract No. DE-AC21-88MC25105 with the U.S. Department of Energy, Morgantown Energy Technology Center (METC).

The program is entitled "MEASUREMENT-WHILE-DRILLING (MWD) DEVELOPMENT FOR AIR DRILLING," and is being performed by Geoscience Electronics Corporation, (GEC), in Westlake Village, California.

The objective of this program is to tool-harden and make commercially available an existing wireless MWD tool to reliably operate in an air, air-mist, or air-foam environment during Appalachian Basin oil and gas directional drilling operations in conjunction with downhole motors and/or (other) bottom-hole assemblies. The application of this technology is required for drilling high angle (holes) and horizontal well drilling in low-pressure, water sensitive, tight gas formations that require air, air-mist, and foam drilling fluids.

The basic approach to accomplishing this objective was to modify GEC's existing electromagnetic (e-m) "CABLELESS"™ MWD tool to improve its reliability in air drilling by increasing its tolerance to higher vibration and shock levels (hardening). Another important aim of the program is to provide for continuing availability of the resultant tool for use on DOE-sponsored, and other, air-drilling programs.

The hardened MWD tool is required to meet the following minimum requirements:

- o System MTBF, 50-hours.
- o Maximum depth (TVD) of 10,000 feet.
- o Battery life in excess of the tool MTBF.
- o Operational in rotary drilling and downhole motor scenarios.
- o Operate in hole diameters from 6-1/4 to 10-5/8 inch.
- o Data transmission rate of 1 bit/second, minimum.
- o Operating temperature 125°C, maximum.
- o Directional data provided on azimuth, inclination, and tool face.
- o Operate in typical air flow rates of 1,500 to 3,000 CFM, and mist or foam rates from 10 to 30 barrels per hour.

A system implementation concept is shown in Figure 1.

BACKGROUND INFORMATION

Two-way communications, between sensors and other devices at the bottom of, or along, bore holes and the surface, have traditionally been performed by wirelines and stored-data technology. Telemetry (up-link) and command (down-link) functions have more recently been performed by use of real-time, mud-based methods.

As more and more horizontal, slant-horizontal, arc, and other high-angle boreholes are drilled (some with air), the need for non-wireline and non-mud-based communications becomes more important because of the difficulty of inserting tools and logs in the absence of a large gravitational force component, and the inability of mud-based systems to operate in air or for that matter in the absence of flow. The oilfield logging industry has developed tubing-conveyed-logging tools, but these too lack the flexibility required, because they still require a wireline. Even with side-entry subs, these tools are too costly or difficult to use in some cases.

Air-drilling of directional wells is on the rise for a number of reasons, and wireline steering tools and mud-based MWD tools are proving to be less than effective.

In recent years, new wireless electromagnetic-based real-time borehole communications techniques have been developed with capabilities for supporting relatively-low data rates (compared with wire line) adequate for some applications. These are in commercial use in Measurement-While-Drilling (MWD) systems. Others are finding

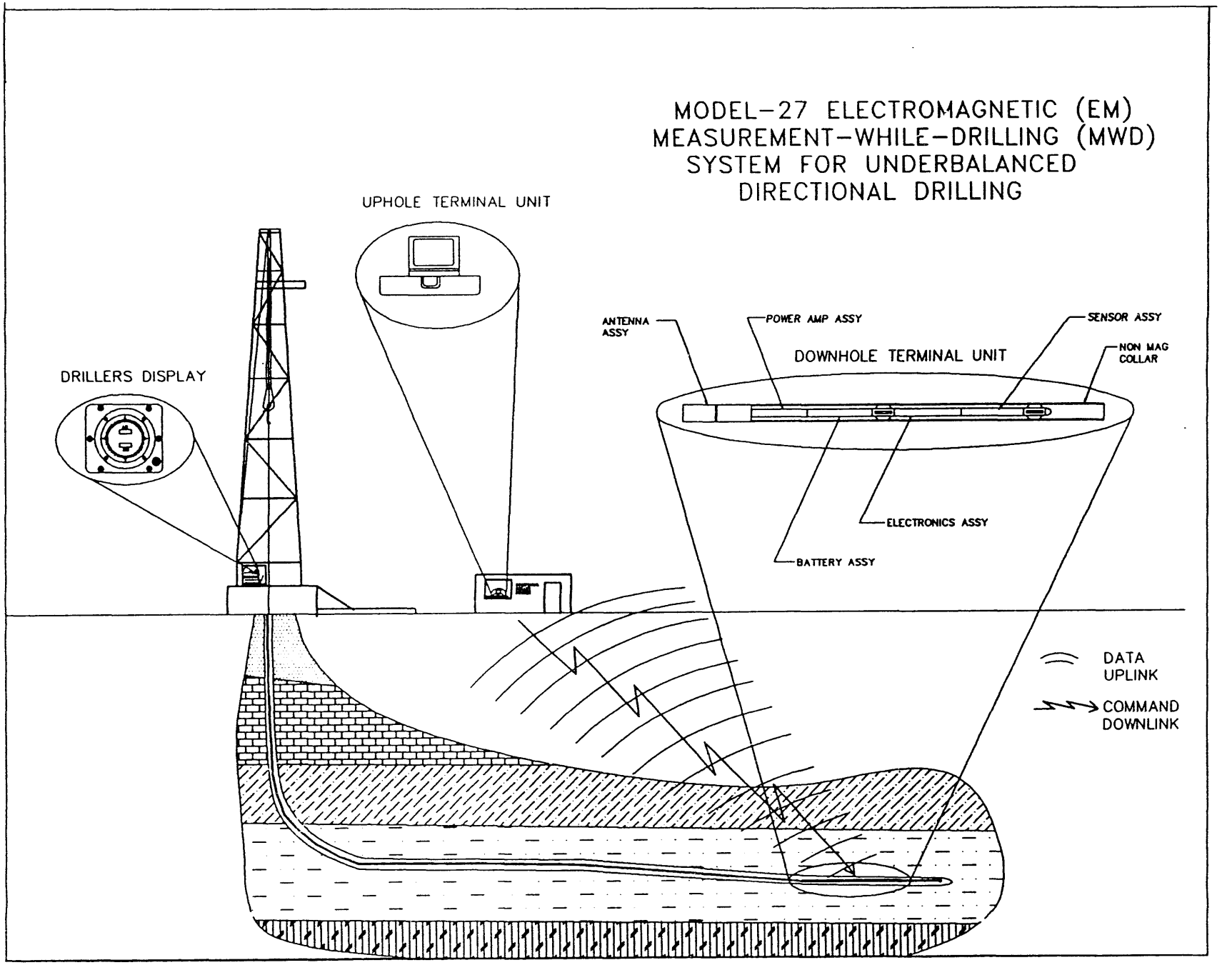

FIGURE 1. System Implementation Concept

their way into non-drilling use in connection with oil and gas reservoir evaluation and completion work. While most of the work has been done in larger boreholes, some systems are being built into drill-strings as small as 2.5 inches (6.35 cm) OD.

Wireless electromagnetic borehole communications technology holds out hope for providing reliable, two-way, high-data-rate data and command links in wellbores; regardless of hole size and angle, mud or air, flow and no-flow, cased or open hole.

Historically, the modern borehole communications concept was first realized using an electromagnetic method, the wireline. The wireline presented cable-handling problems in drilling. However, it did better in many cases than competitive methods of the time. When mud-pulse-telemetry Measurement-While Drilling (MWD) was introduced, it seemed reasonable to trade away the unused high data rate of the wireline for the convenience of the "wire-less" mud-pulse tool.

Progress in the drilling industry has slowly put pressure on the MWD-services industry to improve reliability.

In the last few years, the need for reliable, low cost, directional drilling services in air drilling scenarios has become widely recognized. Attempts at using directional drilling systems that were designed to operate in mud have resulted in less than satisfactory performance when operated in air. The severe shock and vibration environment of air operation compared to mud operation immediately extracted a heavy toll in reduced reliability.

Mud pulse MWD tools, in general, perform marginally, at best, when operated on air and are not at all viable.

Even though some wireline steering tools have been made to operate reliably in air, the logistics limitations and cost of operating with a wireline are frequently unacceptable.

PRESENT PROGRAM STATUS (Phase IV)

The Phase IV effort was authorized on September 30, 1991, and consisted of the following task plan:

TASK 4-1 -- DESIGN REVIEW

Evaluated the status of the Model 27 MWD System design and convened a meeting with COTR and consultants to review and recommend design changes and other system improvements.

TASK 4-2 -- REPAIR/REPLACE EXISTING MODEL 27 EQUIPMENT

This task covered primarily the rehab of the Model 27 after Field Test #5. The work resulted in having two complete Model 27 strings available.

TASK 4-3 -- TRANSDUCER RE-DESIGN, FAB OF TWO UNITS, TEST OF ONE

This task took into account the guidance from the Task 4-1 Design Review, and involved an expert consultant in details of the design. Laboratory testing of one prototype was conducted in early May, after which the second unit

was completed. This task also included the re-certification of the 7-1/2-inch transducers, if required under Task 4-5.

TASK 4-4 -- RE-DESIGN AND FABRICATION OF TWO ADVANCED UPHOLE TERMINAL UNITS

This work was primarily concerned with adapting GEC's design of its new PC-based AUTU to work with the Model 27, provide for field re-programming, and on-site data management capabilities. Special attention was paid to the need for flexibility of programs, and consistency of formats with other MWD systems.

The Barrier Safety Box (lightning protection) recommended by the Design Review was designed and fabricated under this task.

TASK 4-5 -- CONDUCT UP TO FOUR FIELD TESTS

GEC's Appalachian Consultant and GEC personnel canvased available operators to make arrangements for field tests. This also included being alert to the possibility of finding a wellbore that could serve as a dedicated test facility for some or all of the field tests.

TASK 4-6 -- DESIGN AND IMPLEMENT SYSTEM IMPROVEMENTS

This task primarily was concerned with the replacement of Interconnect Harnesses and the O-Ring Sealing that were cited in the Design Review Minutes. Additionally it included work required to perform elevated-temperature environmental testing of the existing downhole units.

TASK 4-7 -- DESIGN AND BUILD A DRILLER'S DISPLAY UNIT

In accordance with the guidance contained in the Design Review Minutes, one Driller's Display was designed and fabricated using a rugged commercial unit as the basis.

TASK 4-8 -- FINAL REPORT

This task covers preparation of the Final Report in conformance with the Contractual requirements

FIELD TEST #6

Field Test Number 6 (FT #6), using Geoscience's Model 27 MWD system, was performed in Fuel Resources' well, J. F. Turner #5, in Barbour County, WV between 11 October and 15 October, 1992.

The primary purpose of FT #6 was to: a) evaluate the reliability of the revised and reworked Model 27 Systems, b) further evaluate the effectivity of the system changes made to accommodate the dry-air-drilling of very dry formations, and c) evaluate the performance of software revisions suggested at the Phase IV Preliminary Design Review, held in January, 1992.

Model 27 Downhole Subsystem SN-02, using a 5-axis directional sensor unit, was installed in the drill string on Sunday, October 11 at an MD of 1262. It was removed on October 15, from TD at 5220 feet, at 14:30 for a total in-holtime of 99.0 hours. During that time, there were 88.9 rotating -hours accumulated. No failures occurred during the 99.0 hours in hole, however, the downhole bat-

teries were exhausted after 77.8 hours of operation and the system ceased sending surveys.

Survey information was acquired from an MD of 1262 to 4495 feet (battery exhaustion). A preliminary analysis of the survey data showed a Latitude and Departure of 30 feet north and 128 feet west, respectively, at a depth of 4495 feet.

Occasional signal-reception problems occurred. These manifested as check-sum errors caused by electrical noise corrupting the received data or as weak or absent signals, suggesting a high contact resistance between the BHA and the formation. Multiple surveys (1 to 5) were taken immediately after a new joint was connected and the bit placed on bottom with 10-20K-lbf-load on the bit, without rotation. If the survey was not successfully received (check-sum error), then it was commanded be sent again, when it was generally successfully received. Often, the survey was commanded and successfully received after drilling had re-commenced. However, the gravity data was erroneous, due to the centripetal acceleration caused by the rotating drillstring.

The multiple surveys exercised the system extensively, and a maximum number of transmissions were made. This also consumed battery power which resulted in the batteries being exhausted prematurely. Further, the downhole transmitter was operated at higher than needed power at times, further exacerbating the battery problem. Under normal operations, multiple surveys would be infrequent and the lowest transmitter power would be used.

The test is deemed quite successful overall. High-signal-level transmissions and good survey data were received under ideal downhole conditions. System changes to be made, will assure reliable survey data from deep holes under all conditions.

Model 27 Reliability

The reliability of the revised and reworked Model 27 Systems seemingly has improved radically since FT #5 in December, 1980. Prior to Field Test #6, the longest MTTF (Mean-Time-To-Failure) was just over 20 hours. In FT #6, over 78 hours of drilling time was accumulated without a failure. After battery exhaustion, the unit did not fail. Upon retrieval and replacement of batteries, it was determined to be working. Hence one could argue that the MTTF was 88.9 hours. Although it would be presumptuous to imply an MTBF from this one sample, it does indicate a substantial reliability improvement. We attribute this both to the system modifications accomplished in the past two years, plus the intensive laboratory stress testing accomplished during the period June-August, 1992.

Dry-Air-Drilling of Dry Formations

The effectivity of the system changes made to accommodate the dry-air-drilling of very dry formations was further evaluated in Field Test #6. The setting was perfect, in that the formations represent the driest, and nothing was added to the drilling air. By having the driller place the bit on bottom with about 10-20 kpsi on the bit, GEC was able to receive transmissions at virtually

every joint. In some cases however, we needed to repeat the process up to five times to receive a useful survey transmission. In most cases, after drilling recommenced, transmissions were received quite reliably, although the gravitational-based data (from accelerometers) was generally useless. GEC believes that the mechanism involved is that in dry-air-drilling of dry formations, the small amount of water present in the rock matrix is blown away by the air flow prior to setting the bit on bottom, while after drilling begins again, new surfaces are constantly opened containing some pore water. The conducting media required between the lower electrode and the formation (normally provided by the mud in mud drilling) is almost entirely provided by the bit contact with the pore water in the uncut formation, in the case of dry-air drilling of dry formations.

GEC did not experience equipment failures, and hence we were able to evaluate the effectiveness of the system modifications made to accommodate the dry-hole, dry-air conditions.

Software Performance

The performance of software revisions suggested at the Phase IV Preliminary Design Review, held in January, 1992, was evaluated. The ability to perform revisions in the survey parameters without losing any prior data, and the provisions for downloading the data to disc were both successfully demonstrated. In addition, plotting of Latitude and Departure versus depth was demonstrated. The inclination data from which the wellbore trajectory is computed, agreed closely with the single-shot data available.

Conclusions

This test was about as perfect as possible, with the exception of the husbanding of the battery life. GEC experienced difficulty early on, in receiving signals due to poor BHA/formation-contact, and made the decision to operate at high power and low frequency (low data rate), all of which ate up the batteries at a high rate. Additionally, in many cases it took up to five surveys at each joint, whereas one should have been adequate. GEC expects the future to be able to accommodate any bit run up to 7000 or more feet without experiencing battery exhaustion.

When downhole contact between the BHA and formation was optimum, as it was during rotation, high signal levels were experienced. Survey data acquired at the connections, when the BHA was totally at rest, is excellent. GEC intends modifying the system to optimize operations consistent with these disparate factors.

A Mean-Time-To-Failure (MTTF) of 89.9 hours appears reasonable from the data. It is not possible to infer an MTBF figure from this test. It is quite obvious, however, that the system reliability performance has been significantly improved since FT #5 was performed almost two years earlier.

Based on the above results, GEC concludes that it is certainly feasible to attain 100 hours MTBF, for the Model 27, in any and all situations, and hence to provide a reliable MWD for air-drilling.

FIELD TEST NO. 7

The subject test on the Geoscience Electronics Corporation's Model 27 Air-Drilling MWD system, was performed in 3-C Oil Co's Robin's Trust well, in Pratt County, Kansas, between 1 June and 8 June, 1993.

GEC was told that the Model 27 tool would be in the drillstring on Wednesday evening, June 2, and hence the GEC personnel arrived at the site the evening of June 1, and set up.

As of Saturday, June 5, the tool had not gone downhole, due to several operator-related delays in preparing for re-entry after cementing the casing.

Upon site arrival, it was discovered that all of the Downhole Instrumentation Units had arrived with smashed cases. After setting up the equipment, it was found that Sensor Unit 02 had two inoperative accelerometers. This new unit had just been completed by Tensor, and this was its first field deployment. A claim for damages was immediately filed with the freight forwarder, and the defective unit was returned to Tensor for repair.

Model 27 Downhole Subsystem SN-01, using a Tensor 6-axis directional sensor unit, was installed in the drill string at 1300 on June 6. It was removed at 1900, on June 7, for a total in-hole time of 30 hours. During that time, there were 5.33 rotating hours (2.5 sliding, 2.83 rotating) accumulated, behind an air-powered mud motor. Zero failures occurred during the downhole operation.

Survey information was received starting at a depth of 4832 feet and continuing to a depth of 4877 feet. A preliminary analysis of the survey data indicates good correlation with comparative data available at the site.

Generally, the received signals from depth were quite adequate to have completed the bore. Some problems in downlinking occurred, which were traced to poor electrical contact between the drillstring and the BOP (casing).

On June 6, a circuit breaker feeding power to the trailer, blew. This had also happened earlier, and inspection at the time indicated a severe problem in the lighting plant. The representative of Eagle Drilling promised to have it repaired. Power was restored after the event on the 6th, but 220 volts was inadvertently fed to our 115-volt line. Several failures resulted, including the main UTU, and video display. The test proceeded, using the backup UTU.

The decision to terminate the test, short of wellbore completion, was reached jointly in consultation with the operator. It was concluded that the Model 27 MWD was not operationally adequate, and the operator could do better with a commercial steering tool or mud-pulse MWD. The operator expressed willingness to allow GEC to stay on as a piggy-back. From GEC's viewpoint, this meant losing the $50K partial indemnification for LIH, and the revenues. Also, GEC may again have found the Model 27 to be in mud, and involved in an operation with lots of hole sticking, and slow drill-

ing, resulting in poor cost-effi ciency in conducting tests.

In light of all of the above, the threat of an unrecoverable loss-in-hole, the diminished capability due to all the transit and site mishaps, and the commitment to go to Canada for underbalanced drilling tests in late June, it was decided to terminate early.

Conclusions

The preliminary conclusions drawn from this test are:

- GEC is not in a position to fully support a commercial, later, revenue service activity due to lack of hot spares. In particular the lack of backup sensor units is a severe limitation.

- While GEC did correctly estimate the uplink field strength, there was trouble with the downlink due to an effect, not observed in prior tests. Hence GEC concludes that learning continues, especially those that seem to be site-and equipment-specific.

- No downhole failures occurred to the Model 27 equipment, even though the tool was in a build curve, behind a high-torque motor on air, and experienced a 4.5°-change-in-12-feet dogleg while rotating.

3-C Oil welcomed participation in their next Kansas well, but insists on more adequate backups. GEC needs to start a building program to to include at least one additional sensor unit.

Recommendations

The problem of receiving signals while at rest, with about 10-20 kpsi on the bit, compared with the situation while drilling has been examined. GEC has decided on a system software modification that will circumvent this problem. One additional operating mode will be provided, as follows:

- Upon a special downlink command, the Downhole Unit while at rest, will read the sensors and store the data.

- At a predetermined interval the Downhole Unit will transmit a survey message using the stored data.

In this way, the system will be capable of reading the directional sensors while the BHA is quiescent, and the survey point will be almost at the same location as a single shot would be. The transmission of the data will take place while drilling, wherein the best results have been attained.

The occurrence of wells-of-opportunity, suitable for performance of meaningful tests, are diminished. Hence GEC needs to make the most of any opportunities.

FUTURE WORK

The Contract is set to expire on 12/31/93, and unless extended, will mark the end of the air drilling tests. The System has been undergoing field testing in other underbalanced drilling scenarios, mostly in Canada, and in particular, SE Saskatchewan.

Field Tests #8 and #9 are planned for November/December. A site for FT #8 has been found, but not as yet confirmed, as of this writing.

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