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Integration and Evaluation of a Position Sensor with Continuous Read-out for use with the Environmental Measurement-While-Drilling Gamma Ray Spectrometer System

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INTRODUCTION

The Environmental Measurement-While-Drilling-Gamma Ray Spectrometer (EMWD-GRS) system represents an innovative blend of new and existing technology that provides real-time environmental and drill bit data during drilling operations. The EMWD-GRS technology was demonstrated at Savannah River Site (SRS) F-Area Retention Basin[1].

The EMWD-GRS technology demonstration consisted of continuously monitoring for gamma-radiation-producing contamination while drilling two horizontal boreholes below the backfilled waste retention basin. These boreholes passed near previously sampled locations where concentrations of contaminant levels of cesium had been measured. Contaminant levels continuously recorded by the EMWD-GRS system during drilling were compared to contaminant levels previously determined through quantitative laboratory analysis of soil samples. The demonstration of the EMWD-GRS was a complete success. The results show general agreement between the soil sampling and EMWD-GRS techniques for Cs-137.

It was recognized that the EMWD-GRS tool would better satisfy our customers' needs if the instrument location could be continuously monitored. During the demonstration at SRS, an electromagnetic beacon with a walkover monitor (Subsite®[2]) was used to measure bit location at depth.. To use a beacon locator drilling must be stopped, thus it is normally only used when a new section of pipe was added. The location of contamination could only be estimated based on the position of the EMED-GRS package and the distance between locator beacon readings. A continuous location system that would allow us to know the location of each spectrum as it is obtained is needed.

The EMWD-GRS system has been improved by the integration of an orientation sensor package for position sensing (PS) (EMWD-GRS/PS). This added feature gives the capability of

calculating position, which is tied directly to EMWD-GRS sensor data obtained while drilling. The EMWD-GRS/PS system is described and the results of the field tests are presented.

APPARATUS and PROCEDURES

Apparatus

The EMWD-GRS/PS system is a complete instrumentation package capable of acquiring a variety of environmental data[3] while collecting orientation information for the calculation of bit location. By tying bit location with environmental measurements, a complete log of subterranean conditions can be mapped. Figure 1 shows a block layout of our drilling instrumentation downhole.

Coil	Telemetry System	Orientation Sensors	3 Axis Accel.	Multi-Channel Analyzer	High Voltage Supply	Crystal Gamma Detector

Figure 1. Block layout of the Sandia EMWD-GRS/PS tool. The crystal gamma detector was placed forward, closest to the drill bit. The coil is in the rears to accommodate communication back to the surface.

The orientation sensor package was built by Applied Physics Systems, Mountain View CA, Model 544. This is a microprocessor controlled system utilizing a three axis fluxgate magnetometer for azimuth and three axis accelerometers for inclination. The 544 microprocessor uses the magnetometer and accelerometers for calculation of roll, pitch, and heading. The package is approximately four inches long and 0.75 inch square and easily integrates into the existing EMWD-GRS system

The model 544 comes with RS-232 or TTL interfaces. For our applications, the TTL interface was the natural choice. The EMWD-GRS/PS telemetry board is setup to read orientation values from the 544 every 1.5 seconds. This data is then transmitted to the surface and stored with other measurement data verses time on a portable PC. Data coming from the 544 was already in the final form, heading, pitch and roll. The 544's microprocessor also provides the calculated values for magnetic and gravitational fields. These two additional calculated values provided the system with some measure of data quality. Valid accelerometer and magnetometer readings always provide constant values for magnetic and gravitational fields.

When these values were not valid, primarily do to drilling rotation, the heading, pitch and roll readings were ignored. By taking orientation readings every 1.5 seconds, a large number of readings were acquired whether the drilling was progressing or stopped for any reason, i.e. adding additional drill rods and/or change in steering trajectory. The most accurate readings are acquired when drilling has paused .

The specifications for the components included in the modified EMWD-GRS/PS system are shown in Table 1.

Table 1. Specifications of Modified EMWD-GRS/PS System

Transmission Data Rate	2400 Baud, 8 analog and 8 digital channels
Battery Pack	32v, approx. 12 hrs. of continuous operation
Multi-Channel Analyzer	256 Channels 0.150 to 1.6 MeV range Complete spectrum every 20 seconds
Gamma Detector	1x4 in. Sodium Iodide, NaI(TI), Crystal with matching Photo-Multiplier Tube, PMT
High Voltage Supply	24v step up to 900-1600v for PMT biasing
Angular Orientation Sensor, Model 544	+/- 0.5 Degrees Inclination +/- 0.5 Degrees Azimuth Complete set of orientation readings every 1.5 seconds

Procedures

Heading is an azimuth reading giving direction in degrees where North is 360 degrees and South is 180 degrees. Pitch provides inclination. Using these two values, a vector can be plotted verses displacement as the bit is pushed through the ground.

Displacement was obtained by using rod length which follows current industry practice. In the future, a computer based measurement using a string potentiometer to track movement of the drill bit will provide continuous displacement and improved bit location tracking.

Data acquisition for pipe farm test, TA III, Sandia National Laboratories

Prior to drilling at Perry, the orientation sensor package, which was integrated into the EMWD-GRS system, was tested at the pipe farm in Technical Area III at Sandia National Laboratories. The pipe farm consists of several PVC pipes placed into the ground using horizontal boring equipment, drilling daylight-to-daylight. Using a simple rope and conventional logging truck, the orientation sensor package was pulled through the PVC pipe. The instrumentation was pulled through at a rate of 2.4 ft/min to simulate a slow drilling process. Both depth and azimuth were obtained.

Data acquisition for horizontal drilling test, Charles Machine Works, Inc. , Perry, OK

In a cooperative effort with Charles Machine Works Inc., the EMWD-GRS/PS system was tested during drilling at Perry, OK. The bore was completed using a Ditch Witch ® JetTrac 2511. A daylight-to-daylight bore of approximately 150 ft. at an average depth of 6 ft. was performed. The Subsite Beacon® was place behind the drill bit in front of the EMWD-GRS/PS instrumentation package. This allowed for the tracking the drill bit by the orientation sensor and the conventional walk-over system.

Once again, the coil unspooled without complications and all data channels were collected continuously while drilling. The downhole instrumentation sent data uphole without error to the computer in real-time. At the time of the test, orientation information was saved to disk but not displayed on the screen real time. Only after returning to Sandia was this data extracted and used to calculate the results displayed in Figures 4 and 5 in the Data and Results section.

DATA and RESULTS

Pipe Farm Test

Figure 2 presents the depth data from the pipe farm test. Only surface survey data of the end points were available. The orientation sensor data resulted in an accumulated error of 1.2 ft. in distance and depth. A 1/100 ft. error is nominal for the industry. Our end points data agree with the surface survey within this error. Figure 3 shows the azimuth data from the pipe farm

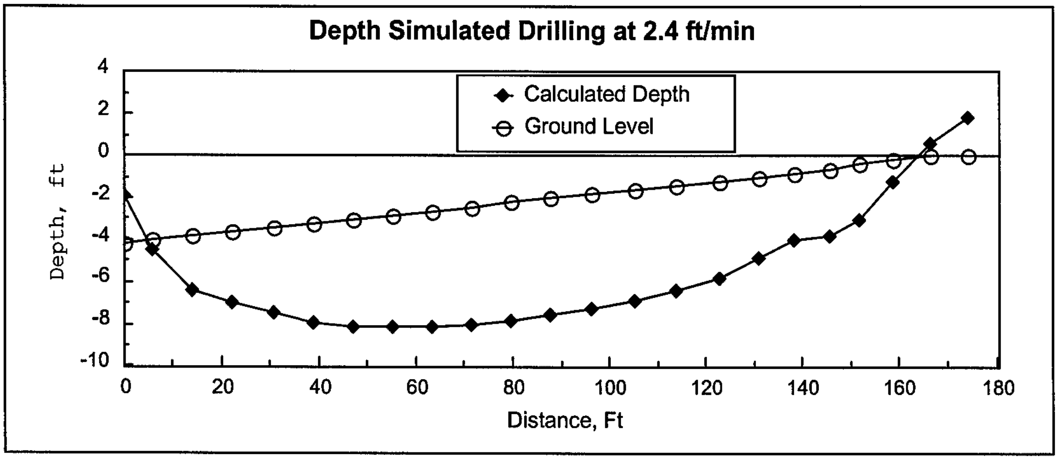

Figure 2. Depth Calculations From Inclination Data At Sandia Pipe Farm Test. One of every 100 points was plotted to make labeling easier .

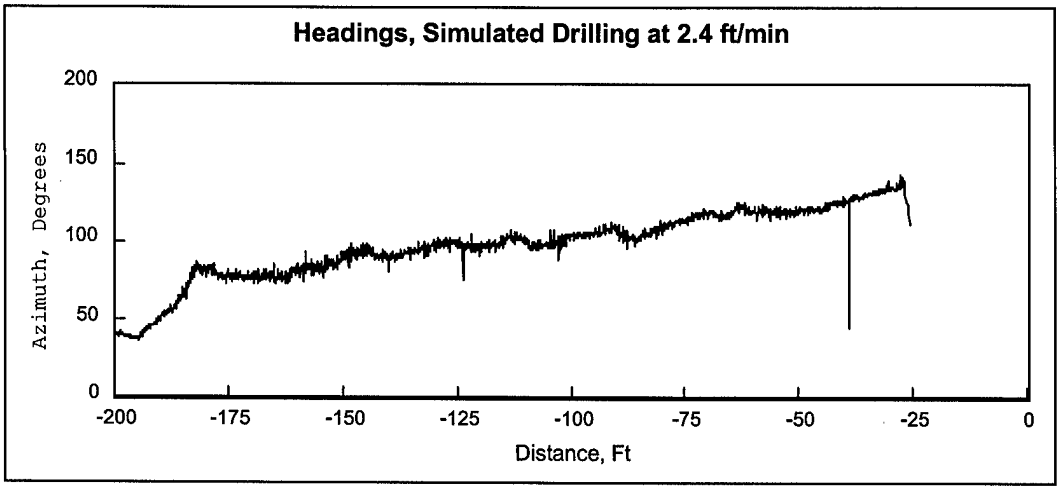

Figure 3. Azimuth Data From Sandia Pipe Farm Test. Here every point is plotted.

test. In this figure, all 2200 data points are shown. The azimuth direction shown here agrees with compass readings.

Horizontal Drilling Test

The EMWD-GRS/PS depth data and the beacon depth data shown in Figure 4. The depth calculated from pitch is in good agreement with the depth data provided by the beacon. The depth measurements agree to within 10%. Given the uncertainty of any walk-over system, it is difficult to assign error to the depth calculation.

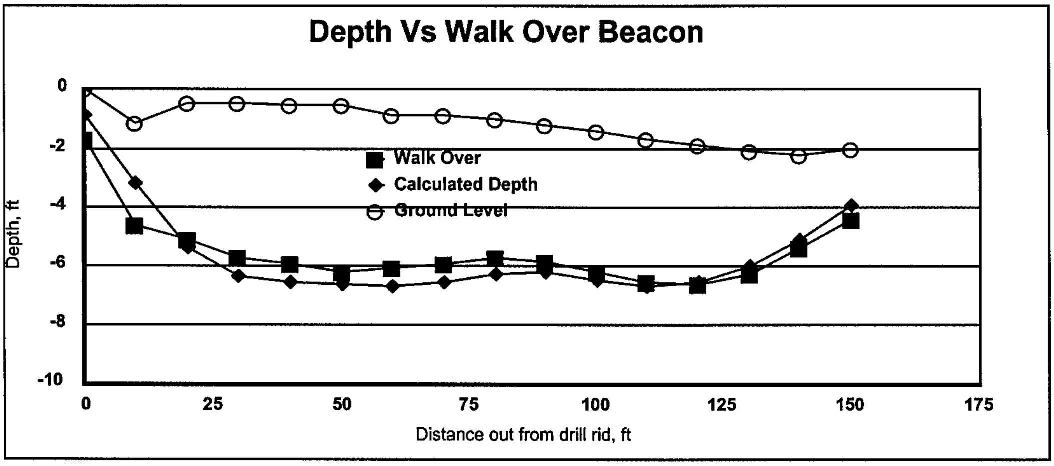

Figure 4. Depth Data From Perry

Magnetometer readings provide azimuth based on the direction of the earth's magnetic fields. This measurement will be in error the if earth's magnetic field is distorted by large magnetic bodies in close proximity to the sensor. For this reason, the EMWD-GRS/PS is placed within non-magnetic, stainless steel housings. However, the drill rig is magnet and will effect the measurement until the package has been drilled into the ground 20-40ft. Also, care must be exercised to insure other common site equipment, such as trucks and backhoes, are not parked near where the drilling is occurring or will occur. For the Perry test, the first three azimuth reading were ignored, because of these factors.

In general, the azimuth readings, compared in Figure 5 to a surface survey, gave reasonable indications of direction except for the final two readings Their accuracy is questionable when compared to the surface survey. Future drilling may require additional stopping to check for azimuth reading wobble. This will help insure that the readings are not influenced by stray magnetic fields.

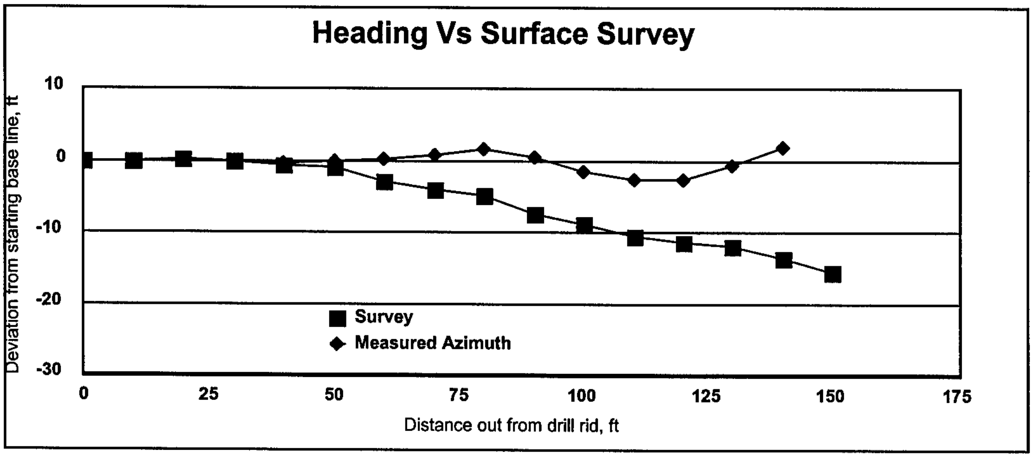

Figure 5. Azimuth Data From Perry

LESSONS LEARNED

As a result of the drilling experience, we learned

- Care must be taken to avoid distorting the earth's magnetic field in the vicinity of the drilling operation where possible. For example: Move large support equipment such as back-hoes and/or vehicles away from drilling trajectory.
- One measure of magnetic interference is to rotate the bit while stationary, "Wobble Test". Periodic wobble tests should be conducted. As the bit rotates, the magnetic heading should wobble less than the manufactures specification.
- Best practice is to use a normal compass reading to measure the starting base line direction of the drill bit until the bit has moved 20-40 ft away.
- The calculation of the azimuth is based in part on the inclination readings. Thus, error can compound. The model 544 orientation sensor uses a small inclination sensor to fit within 0.75 inch package. By using larger packaging and larger inclination sensors, accuracy for both inclination and azimuth will improve. Based on future requirements and sufficient funding, greater accuracy orientation sensors from Applied Physics Systems will be evaluated.

CONCLUSIONS

An orientation sensor package has been integrated with the EMWD-GRS system successfully, without significant modifications. The EMWD-GRS system is unmatched in industry for such applications. There were no problems taking the orientation sensor package data along with the gamma spectrometer data, because of it's data transmission rate of 2400 Baud and 8 Analog/8 digital data channels. Preliminary results from the first drilling test, though encouraging, indicate a need for improved procedures when using this system. We hope to refine the drilling procedures during subsequent drilling tests.

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2. Subsite® is a subsidiary of Charles Machine Works, Inc.
3. Lockwood, G. J., R. A. Normann, L. K. Bishop, R. J. Florin and C. V. Williams, Environmental Measurement -While-Drilling System for Real-Tome Field Screening of Contaminants, NO-DIG '95, Toronto, Canada, April 30-May 3, 1995.

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