ENVIRONMENTAL MEASUREMENT WHILE DRILLING SENSOR DELIVERY SYSTEM

TECHNOLOGY DESCRIPTION

The Environmental Measurement While Drilling (EMWD) sensor delivery system represents an innovative blending of new and existing technologies for obtaining real-time data during drilling. The objective of this project is to distinguish contaminated from non-contaminated areas in real time while drilling beneath a hazardous waste site. The downhole sensors are located behind the drill bit and linked by a high-speed data transmission system to a computer at the surface. As drilling is conducted, real-time data are collected on the nature and extent of contamination, thus enabling on-the-spot decisions regarding drilling and sampling strategies. The system provides real-time data on environmental conditions, drill bit location, and system health.

The EMWD system has been adapted with the integration of a gamma ray spectrometer (GRS) and an angular orientation sensor (3-axis magnetometer). The GRS consists of a sodium-iodide, thallium-activated crystal coupled to a photomultiplier tube (PMT). The GRS output feeds to a multichannel analyzer (MCA). The 256-channel gamma spectrum (0.1-1.6 MeV) data are transmitted to the surface via a signal conditioning and transmitter board. A full gamma spectrum is transmitted to the surface every 20 seconds. The drill bit location is determined by tracking the bit heading (azimuth), tool face (role), and inclination (tilt). Each of these readings is made every 2 seconds. Sampling speed from the analog channels can reach 100 kHz. The telemetry system is firmware programmable to easily support many different data formats and additional data channels. The data transmission format (digital frequency modulation (FM) bi-phase, 4,800 baud) provides excellent noise rejection for jumping the wireless connection between the rotating drill pipe and the stationary receiver. A Sandia National Laboratories (SNL)-designed receiver removes the FM carrier and buffers serial data to be used by a personal computer. A rechargeable battery pack supplies downhole instrumentation power for more than 18 hours of drilling. The battery pack remains uphole for easy maintenance and/or recharging.

The system also monitors the uphole battery voltage as measured downhole, and the temperatures associated with the detector and instrumentation. System health is the measurement of downhole battery voltage and temperature along with the more sophisticated measurements of magnetic interference and vibration. The EMWD design includes data assurance techniques to increase safety by reducing the probability of giving a safe indication when an unsafe condition exists.

Preliminary field tests were successfully completed at SNL, the radioactive calibration facility in Grants, New Mexico, and at the Charles Machine Works, Inc. (CMW) Directional Drilling Range. The EMWD with the gamma ray spectrometer sensor system was demonstrated in the field in April 1996 at the Savannah River Site (SRS) in the F-Area Retention Basin. Phase I of the demonstration determined the radiological background. Phase II was a "hot site" demonstration that continuously monitored for gamma activity in real time while drilling two boreholes. Contaminant levels of cesium-137 recorded by the EMWD during drilling agree with the contaminant levels previously determined through quantitative off-site laboratory analysis of the soil samples. In addition, previously unidentified gamma radiation "hot spots" were identified. The successful demonstration resulted in no radiation-contaminated equipment or waste.

The EMWD with an orientation sensor package for guidance and location was successfully tested at the CMW Perry “cold site.” No problems were experienced in taking the orientation sensor package data along with the gamma spectrometer data. SNL, Lockheed Martin Hanford Corporation (LMHC) Tank Waste Remediation System, and A & L Underground successfully demonstrated horizontal directional drilling and the EMWD tool at Hanford. The demonstration at Hanford included drilling one directional borehole each at the Mock Tank Leak Simulation Site and the Drilling Technology Test Facility.
The technology demonstration consisted of the development of one borehole under a mock waste tank at a depth of approximately 27 feet following a predetermined drill path, tracking the drill path to within a radius of 5 feet, and monitoring for zones of radiological activity using the EMWD system. The purpose of

the second borehole was to demonstrate the capability of drilling to a depth of 70+ feet, the depth needed to obtain access under the Hanford waste tanks, and continue drilling horizontally. The EMWD system tracked the drillbit location to within 2 feet of the reference provided by a commercial tracking system.

The EMWD sensor delivery system can be used in site characterization for contaminant detection and delineation. This system will allow for appropriate sampling activities and guide borehole emplacement options (i.e., a drill operator can back out of contaminated soils and redirect a drilling operation around the contamination). Other potential users of EMWD include the utility emplacement and petroleum industries.

TECHNOLOGY NEED

Information on drill bit location and temperature and subsurface contamination during drilling is required in many environmental restoration operations. An inexpensive data collection system for identifying and tracking contaminant concentrations and monitoring drill bit conditions is needed for many waste site operations. Places such as the Hanford tank farms need to be characterized below the tanks for the presence of cesium-137 and other contaminants. A two- or four-man crew probing underground to evaluate soil conditions with a steerable drilling sensor system could quickly map contamination zones, provide for field screening, operate safely, and greatly reduce clean-up costs.

The Site Technology Coordination Group (STCG) Needs addressed are:

ID-6.1.02 and ID-S.1.04 – Real-time field Instrumentation for characterization and monitoring of soils and groundwater.
ID-7.2.06 – Remote characterization.
OH-F037 – Improved *In Situ* determination of uranium and other gamma-emitting radionuclides in soil.
RF-DD02 – High-speed, integrated characterization system for 1radioactive, hazardous, and toxic contamination.
RF-SS16 and RL-SS16 – Improved, *in situ* characterization to determine the extent of soil contamination of one or more of the following radionuclides: uranium, plutonium, cesium, cobalt, strontium.

TECHNOLOGY BENEFITS

There are time, cost, and safety advantages to using the EMWD field screening approach:

- Data on the nature of contamination is available in minutes (as opposed to weeks or months from an off-site laboratory).
- Field screening while drilling can reduce the number of costly drilling operations.
- Substantial cost savings will result by minimizing the number of samples required for off-site confirmatory analyses.
- Worker safety will be enhanced as a result of minimizing waste generation and by quickly alerting field personnel to potentially hazardous conditions.

TECHNOLOGY CAPABILITIES/LIMITATIONS

The EMWD system is compatible with directional drilling techniques that use standard mud systems and with systems that use minimal drilling fluids and generate little-to-no secondary waste. Non-walk-over guidance and location capabilities are included in the current system. The orientation sensor package was integrated with the EMWD system without significant modification to the EMWD system. Sensors are also needed for the detection of heavy metals, volatile organic compounds (VOCs), and natural gas.

COLLABORATION/TECHNOLOGY TRANSFER

SNL project representatives collaborated with the U.S. Department of Energy (DOE) Environmental Restoration personnel at the Westinghouse Savannah River Company (WSRC) to conduct a demonstration of the EMWD tool at the WSRS F-Area Retention Basin. In FY 1999 SNL project representatives collaborated with the LMHC to conduct a demonstration of EMWD technology and directional drilling at the Mock Tank Leak Simulation Site and the Drilling Technology Test Site. Hanford anticipates deploying this technology in the tank farm vadose zone for its FY 2000 characterization activities.

A & L Underground, Inc. is our industrial partner. SNL Technology Transfer is in negotiations with A & L Underground Environmental LLC, Inc., for the licensing of the cable coil and the Decom software. They are seeking an exclusive license in all fields of use. A signed license agreement is expected by April 1999. In addition, SNL Technology Transfer has negotiated a Cooperative Research and Development Agreement (CRADA) with A & L Underground Environmental LLC for the cooperative advanced development and commercialization of the EMWD tool. This CRADA includes services-in-kind as well as funds.

ACCOMPLISHMENTS AND ONGOING WORK

FY 1996 Accomplishments:

- The Geiger Mueller Tube (GMT) EMWD tool was successfully tested in the laboratory and in the field at the Charles Machine Works Directional Drilling Range.
- The Gamma Spec EMWD tool is also fully operational and was field-tested at the Charles Machine Works Directional Drilling Range.
- SNL and WSRC completed the Cost-Integrated Contractor Order (CICO) Statement of Work (SOW) for conducting a demonstration of the EMWD-GRS at the SRS.
- The Test Plan and Work Plan for the EMWD Demonstration at the F-Area Retention Basin was reviewed and accepted by WSRC. The directional drilling for this demonstration was conducted by Geneva Corporation's Ditch Witch of Georgia. The purpose of the demonstration was to evaluate the radionuclide concentration data collected in real-time while drilling using the GRS-EMWD tool against the radionuclide concentration data obtained from the off-site soil samples. Two boreholes were directionally drilled through the F-Area Retention Basin to intersect previous soil sample locations (FRB-05, -06, -07, and -08) and adjacent to another soil sample location (FRB-19). We detected and quantified the gamma radiation emitting contamination at the previously known sites. In addition, we identified two new gamma radiation "hot spots." The pull back of the drill rod was successful in that it resulted in no radiation-contaminated equipment or waste brought to the surface; this was possible because drilling could be stopped once gamma radiation was detected prior to entering the contaminated zone.

FY 1997 Accomplishments:

- The EMWD system has been improved by the integration of a magnetometer, a miniature angular-orientation sensor. This added capability gives precise positioning information by providing pitch, roll, and azimuth. Additionally, we integrated three accelerometers into the package. This added capability provides us with pitch and roll information that is redundant to that from the magnetometer.
- "Final Report on the Environmental Measurement While Drilling Gamma Ray Spectrometer System Technology Demonstration at the Savannah River Site F-Area Retention Basin." SAND97-2028.

FY 1998 Accomplishments:

- Chapter 1 of the patent application was completed to address the requirements of the Patent Cooperation Treaty (PCT). Chapter 1 of the patent application protects the coaxial cable coil patent in foreign markets. Chapter 1also contains the results of a search to determine the patentability of

the coaxial cable coil. A favorable report has been received from the PCT examiner. SNL is in Chapter 11 of the PCT; Chapter 11 is the national phase in which the foreign patents are granted.

- The modified EMWD system including the magnetometer, an array of three accelerometers, and a continuous distance measurement capability was successfully demonstrated at the Charles Machine Works, Inc., Directional Drilling Range.
- U.S. Patent 5722488 - Apparatus for Downhole Drilling Communications and Method for Making and Using the Same was issued on March 3, 1998, for the EMWD cable coil.
- A U.S. copyright was awarded on October 2, 1998, for the protection of the SNL; written Decom software that is used in the EMWD system. Decom is a Microsoft Windows-based software that is used for data reduction, storage, and display.
- The Environmental Measurement While Drilling (EMWD) system and Horizontal Directional Drilling (HDD) were successfully demonstrated at the Mock Tank Leak Simulation Site and the Drilling Technology Site at Hanford, Washington. The technology demonstration consisted of the development of one borehole under a mock waste tank at a depth of about 27 feet., following a predetermined drill path, tracking the drill path to within a radius of 5 feet, and monitoring for zones of radiological activity using the EMWD system. The purpose of the second borehole was to demonstrate the capability of drilling to a depth of 70+ feet, the depth needed to obtain access under the Hanford waste tanks, and continue drilling horizontally.

TECHNICAL TASK PLAN (TTP) INFORMATION

TTP No./Title: AL27C221 - New Environmental Measurement While Drilling

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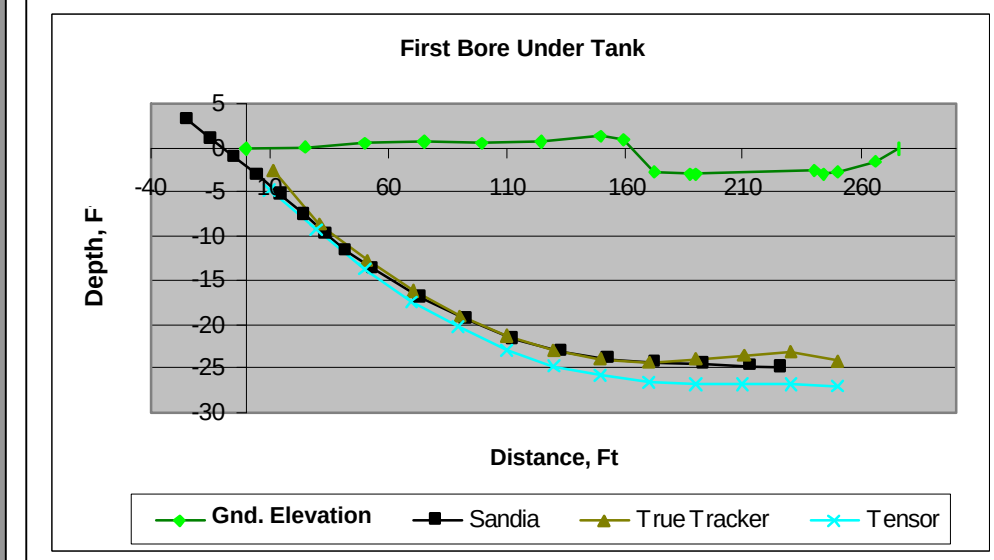
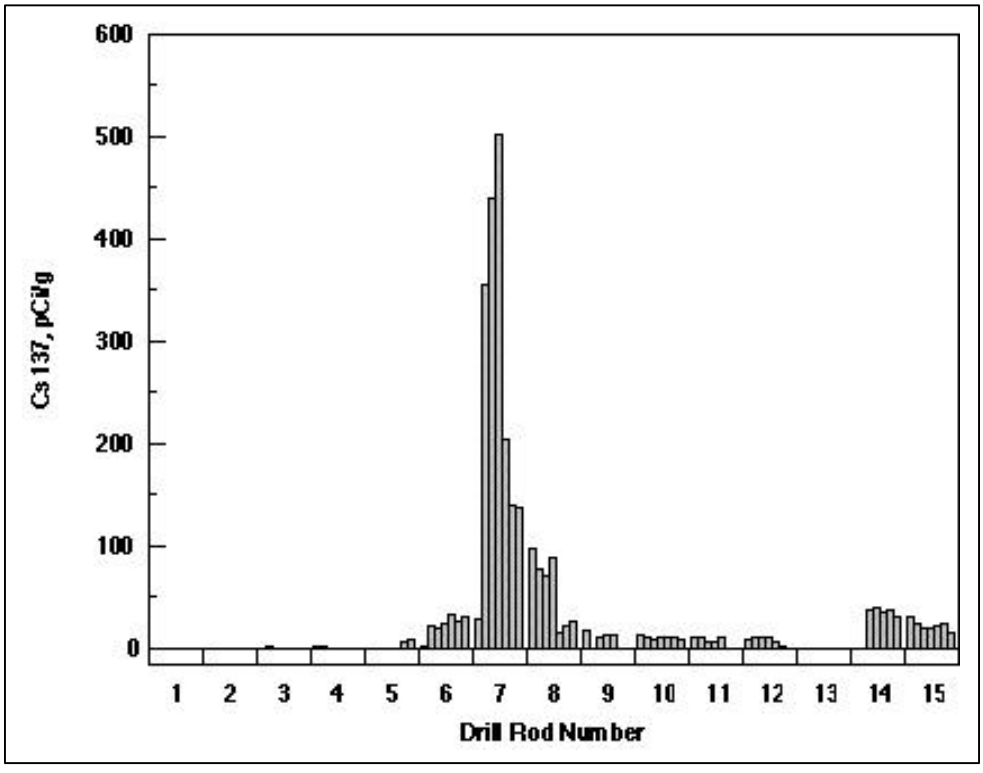
Drilling crew prepares to bore under a tank at Hanford to demonstrate Environmental Measurement While Drilling (EMWD) Technology of a mock tank leak.



Tracking the Depth of Slant Hole Under Mock Tank Leak Demonstration at the Hanford Site



Cesium-137 Concentrations at the Savannah River Site (SRS) F-Area Retention Basin Obtained with Environmental Monitoring While Drilling (EMWD) Technology