Quarterly Report 6 – Public Page

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Prepared for: *DOT/PHMSA and AwwaRF*

Project Title: *Differential Impedance Obstacle Detection Sensor (DIOD) – Phase 2*

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Objective

The objective of the Differential Impedance Obstacle Device project is to develop a tool that can be coupled with a pipeline drill rig to detect pipeline obstacles in the drill path. The final deliverable is a device that can be commercialized. The form factor of the prototype must be such as to minimally impact the design of commercial drill heads. GTI will conduct a series of in-ground tests to prove that the DIOD can detect obstacles of at least three different materials (plastic, ceramic and metal) in several soil materials and demonstrate that the sensor is robust enough to withstand HDD operating conditions.

Louisiana Tech University's Trenchless Technology Center is also assisting with the technical work. An advisory group with representatives from AGA, AGA, and APGA is overseeing the project.

Team Project Activities from Agreement

- **Task 1: Modeling.** Finite Element modeling of the Phase 1 prototype and the alternate configurations being considered will be discussed with the advisory group. The top choices will then be modeled by GTI and TTC.
- **Task 2: Fabrication/Testing of Prototypes.** One or more prototypes will be fabricated based on the models created by GTI and TTC. These models will be tested at one or both indoor testing facilities. Ideally they will be tested in a variety of soils with a variety of obstacles, but not yet tested with HDD equipment.
- **Task 3: In-Ground Testing/Commercialization.** The successful prototypes from the fabrication tasks will be tested with HDD rigs during simulated or live installations. Some initial testing may take place separately at GTI and TTC, but it is expected the real tests will take place at TTC facilities. A commercial manufacturer will be pursued and invited to the in-ground tests.
- **Task 4: Program Management.** An updated state-of-the-art assessment that outlines different technologies being considered, their pros and cons, etc. will be submitted. The remainder of the task will include reporting, meeting, presentation, and demonstration requirements for DOT. It will occur throughout the life of the project, and will be performed in conjunction with the other work tasks, until such time as they are complete.

Progress to date

The Quarter 1 report described the functioning of the original DIOD model and a proposed modified design. The finite element analysis in that report utilized an electrostatic formulation mode and assumed that the drill head is suspended in air, which is equivalent to the drill head placed on a bench in the laboratory. The dataset generated was intended to form the basis for validating the model during the experimental phase of the project. There was also some preliminary modeling performed to examine the feasibility of incorporating other technologies, such as Ultra-wide band (UWB.) The state-of-art assessment was completed and submitted to DOT/PHMSA.

In Quarter 2, modeling was performed to compare the original and alternative DIOD designs when embedded in soil. The quasi-static electric current mode was used in all simulation series. The analysis demonstrated that by limiting the source to a location in the forefront of the drill head assembly the field lines are better focused towards the center of the object. Furthermore, the field lines are projected further ahead in the case of the modified design and follow shorter return paths.

In Quarter 3, research progressed from the modeling task to the fabrication/testing task. In Q3, most of the external components were replaced by smaller, more efficient components that will fit inside the sensor pod. Tests to validate the finite element models commenced. A stand was designed to rotate the pod and take measurements of pipe obstacles suspended in mid-air. Testing will take place in Q4. If results are similar, modifications will be made to the prototype to verify the results approximated by the alternate configuration. A "Success Story" Document for DIOD Phase 2 was created and submitted to DOT. Non-confidential background material and meeting notes were shared with members from the North American Society for Trenchless Technology (NASTT) Cross-bore Committee and the Common Ground Alliance (CGA) R&D Committee.

In Quarter 4, experimental data was taken in the GTI pit lab with the improved electronics. All of the sensor electronics are inside the pod with an umbilical for power and serial data to the outside. The repeatability of the data was improved with both metal and plastic target pipes in air. LA Tech ran additional simulations requested by GTI. The simulations did verify that there is a change in signal synchronous with the rotation of the drill tip. Sensitivity is still greater to the sides of the drill than to the front. The overall behavior of the sensor matches the simulation data. Quantitatively, the signal strength of the sensor is lower than that of the numerical model. Contact was made with Common Ground Alliance (CGA) during the PHMSA R&D forum in New Orleans. GTI presented the DIOD project at the CGA R&D Forum in Orlando during March. A draft paper for the April No-Dig conference in Houston was submitted. The project annual peer review was completed in March.

In Quarter 5 GTI examined some alternative signal processing methods that can capture phase and magnitude information. The Analog Devices AD5934 can replace several chips currently used in the DIOD prototype. These tests worked reasonably well for one channel but there are practical difficulties to extending the AD5934 to multiple channels. TTC ran additional simulation cases as specified by GTI. Rotations of the drill with respect to the target were simulated. As expected, there is a signal variation that is synchronous with the rotation. These simulations were repeated for soils of various conductivities. The project technical lead was change from Max Kieba to Chris Ziolkowski during this quarter after Max accepted a position with PHMSA.

The following took place in Quarter 6:

Task 1. System Modeling

This work is being carried out at the TTC using the FEMLAB package from Comsol. The simulations are intended to provide guidance as to what changes to the prototype would be most advantageous before construction and testing. A draft of the most recent TTC report is appended to this report.

It was noted that the simulations had not been run for the null target case as of the end of last quarter. The null case is the instance in which there is no target present. Also, several simulations of targets more distant from the drill tip than previously tested were run. This was done for both metal and plastic target pipe in an effort to fill in some gaps in the simulation cases. The simulation results were somewhat at odds with what is observed experimentally. This is covered in more detail in the body of the report.

Task 2. Prototype Fabrication

This work is being carried out at GTI. A mechanical redesign was to be guided by the results of the TTC systems modeling effort. At this point there is no indication that any drastic improvement to the forward sensitivity can be achieved by changes to the sensor physical geometry.

The focus in the 5th quarter was the testing of the AD5934 impedance analyzer chip. While performing many of the functions of the lock-in amplifier, this chip is difficult to extend to 2 channels. Since it is necessary to collect simultaneous data from 2 orthogonal sensors, experiments were performed using the original AD630 circuit during the 6th quarter. The facility for automatically recording 2 channel data was also upgraded during the 6th quarter. The null target and more distant target cases were run experimentally to compliment the TTC simulations.

Task 3. In Ground Testing

No work has been performed in this Task yet. At a minimum, the in soil tests from Phase 1 must be repeated with the improved circuitry to determine the baseline improvement to the sensitivity and noise floor.

In order to facilitate in-ground testing, the project duration has been extended by 3 months. This has been done at no additional cost to the sponsors. The end date for technical work is now December 31, 2007.

Task 4. Project Management.

A No Cost Time Extension (NCTE) was presented to both funding partners during this past quarter. The NCTE has been accepted and the final report should be completed February 28 of 2008. The monthly updates for July and August of 2007 have been uploaded to the PHMSA website. This quarterly report serves as milestone item 42, the 6th Quarterly Status Report.