Test Plan for Prototype Dielectric Permittivity Sensor

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ABSTRACT

The digface characterization project funded by the Buried Waste Integrated Demonstration (BWID) is designed to test a new method of monitoring hazardous conditions during the remediation at waste sites. Often on a large scale, the exact cause of each anomaly is difficult to determine and ambiguities remain in the characterization of a site. The digface characterization concept is designed to alleviate some of this uncertainty by creating systems that monitor small volumes of soil and detect anomalous areas during remediation before they are encountered. The goal of the digface characterization demonstration is to detect changes in the physical properties from one volume to another and relate these changes in physical properties to changes in the level of contamination. Dielectric permittivity mapping is a method that might prove useful in digface characterization.

In this project, the role of a dielectric permittivity monitoring device is under investigation. This project addresses two issues: what are the optimal means of mapping dielectric permittivity contrasts and what types of targets can be detected using dielectric permittivity mapping.

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Test Plan for Prototype Dielectric Permittivity Sensor

1. INTRODUCTION

1.1 Background

Physical modeling to determine the optimal method for monitoring changes in dielectric permittivity is part of the larger digface project being funded by the Buried Waste Integrated Demonstration (BWID).¹ The project is designed to test a new method of monitoring hazardous conditions during remediation at waste sites. The variations in the physical properties at waste sites are complex; they can be caused by metallic objects, liquid and solid contaminants, or other manmade objects. Often on a large scale, the exact cause of each anomaly is indeterminate, and ambiguities remain in the characterization of a site. The digface characterization approach is designed to alleviate some of this uncertainty by creating systems that monitor small volumes of soil and detect anomalous areas during remediation before they are encountered. Small volumes of investigation often minimize complicated signals from outside the volume of investigation. The goal is to detect changes in the physical properties from one volume to another and relate these changes in physical properties to changes in the level of contamination.

The dielectric permittivity prototype testing will begin development on a dielectric permittivity mapping tool for the shallow subsurface that will be used in a digface characterization system. In clean uncontaminated soil, the dielectric permittivity of the volume of investigation is directly related to the water content of soil in that volume. An effective means of monitoring moisture content of soils uses changes in dielectric permittivity within the survey area. However, the presence of organic and inorganic materials, such as hydrocarbons and metallic oxides, also significantly alters the dielectric permittivity of soils in many instances.

To measure dielectric permittivity, high frequency electromagnetic sensors are used. At high frequencies, the displacement currents appreciably contribute to the electromagnetic field along with conduction currents; the electromagnetic field associated with a medium is dependent on both the conductivity and dielectric permittivity of the medium. The most commonly used methods are radar methods with time domain reflectometers (TDR). Radar uses frequencies between 1 MHz and 1 GHz and are often severely attenuated by conductive soils. TDR systems use a probe system to measure the dielectric permittivity between the probes. Another method of measuring the dielectric permittivity is to use high frequency electromagnetic sensors that operate in the range between 300 kHz and 30 MHz. With this type of system, the conductivity can be determined along with the dielectric permittivity. In all three of these systems, the conductivity affects the response of the system. Thus, metallic objects can be detected using high frequency electromagnetic devices.

For this project, two systems will be used, a TDR system and high frequency electromagnetic device developed by the United States Geological Survey (USGS), which offers the ability to vary the depth of investigation. The anticipated benefits of using two systems are three-fold. The first is to monitor changes in dielectric permittivity for small, limited volumes of soil. The second is to investigate the potential of the high frequency system to not only sample a small volume but to also acquire data with information from variable volumes of investigation to help anticipate problems before the excavation system encounters them. The third is to use the information gained from these

tests to evaluate the performance of the devices not only to determine the applicability of dielectric permittivity mapping to the digface project, but after evaluation, to help design an optimal system for digface applications.

TDRs operate using the principle that electromagnetic waves propagate slower through mediums where the dielectric permittivity is high as opposed to mediums with a low dielectric permittivity. Thus, from the propagation time, a measure of the dielectric permittivity can be found. The conductivity of the medium affects the amplitude of the signal not the propagation time. The volumetric limitation of the TDR is 6 in. and cannot be varied. This gives the investigation a limited volume of investigation around the probe. While a very limited volume of investigation is a goal of the digface project, the TDR system has two drawbacks. The first is that it is an intrusive device. During remediation, contamination of the probes would occur. Second, the depth of the instrument is fixed and cannot be easily modified to investigate deeper.

The high frequency electromagnetic sensor measures the quadrature and in-phase components of the total, vertical, and radial magnetic fields. To account for the primary field, the tilt angle and ellipticity parameters for the polarization ellipse are calculated from the quadrature and in-phase measurement.² This is a coil-based system operated at variable frequencies, and the coil separations allow for variable depths of investigation. The present system needs to be modified with smaller coils so that the depth of investigation can be decreased. This modification will be completed before the initial tests. Using this device with the TDR system will give coverage of the entire region of the modeled digface. From these measurements, an optimal system will be designed.

1.2 Test Objectives

The current testing is designed to provide initial information on the feasibility of using a dielectric permittivity sensor at the digface. As an initial demonstration of feasibility (or lack of feasibility), the testing uses simple model targets that are intended to represent real situations but are more amenable to initial demonstration and modeling. The test objectives using these simple model targets are

1. Determine whether changes in dielectric permittivity can be measured and related to physical changes in the model (i.e., target configurations).
2. Determine the optimum way to map dielectric permittivity contrasts by using the target configurations to evaluate the effect of instrument parameters (e.g., frequency) on ability to map contrasts.
3. Evaluate the relative effectiveness of time domain reflectometry and high frequency electromagnetics in mapping dielectric permittivity contrasts. This evaluation is intended to result in a recommendation of a preferred system for further development.

To meet objective 1, several different configurations will be tested. The dielectric permittivity sensor may be able to detect the following classes of objects: solid objects, plume sludges, and contaminated soils. Within these broad categories, there are additional subcategories. However, this initial testing will be focused on the main classes of targets by using the testing targets shown in Table 1.

Table 1. Types of physical models.

Physical targets	Models used in laboratory tests	Quantity measured ^a
Plumes Liquids Sludges	Liquid and clay models	Relative dielectric permittivity
Solid objects Metallic Nonmetallic	Metallic and clay models	Relative dielectric permittivity
Contaminated soils	Clay and liquid models	Relative dielectric permittivity

a. The relative dielectric permittivity is calculated from the phase and amplitude measurements recorded at each station location in the test.

The targets will be placed in a sand matrix that serves as the host material. Salt water will be introduced into the sand as necessary to adjust solid conductivity into the range representative of Idaho National Engineering Laboratory (INEL) soils. (As described in more detail in Section 3, this will be done to match a key parameter affecting signal attenuation.)

The chosen physical models are simple models with simple solutions that can be easily analyzed and compared. A secondary purpose is to perform studies to better understand the effects of contaminants on the dielectric permittivity and determine if these effects are measurable.

1.3 Technology Agreement

The technology agreement with the BWID Program is as defined in the documentation for work package number 3Y5231000, "Prototype Capacitance (Dielectric Permittivity) Sensor."

2. ORGANIZATION AND RESPONSIBILITIES

Key project personnel are shown in Figure 1. The principal investigator is M. C. Pfeifer of the Applied Geosciences Unit at EG&G Idaho, Inc. D. C. Stewart and V. F. Labson of the USGS Branch of Geophysics in Denver, Colorado, developed the prototype system being tested. Physical modeling will be performed in Denver at the USGS Branch of Geophysics. The modeling facility consists of a $15 \times 9 \times 5$ -ft modeling tank with a data acquisition system. USGS participants will set up the laboratory equipment and with the EG&G Idaho principal investigator perform the laboratory modeling and interpret the data collected. The USGS participants and principal investigator are qualified to operate the equipment.

The principal investigator, Pfeifer, will be referred to as the test leader in this report. USGS participant, Labson, is the designated test leader when Pfeifer is absent from the test site.

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Figure 1. Dielectric permittivity sensor project organization chart.

3. DESCRIPTION OF TEST

The purpose of this testing is to investigate the role of a dielectric permittivity monitoring device and address three issues: first, can changes in dielectric permittivity be measured and related to known physical changes within the model; second, what is the optimal means of mapping dielectric permittivity contrasts; and third, what types of targets can be detected using dielectric permittivity mapping. The test objective is to determine the effectiveness of monitoring for dielectric permittivity changes at the digface scale. The tests performed will be used to evaluate this effectiveness and determine the best means of data collection and evaluation. This test is a preliminary test that is not designed to evaluate data collection rates or ease of data collection. The primary purpose is to demonstrate the utility of dielectric permittivity measurements at the digface. At the completion of this test, recommendations on the development of a sensor for the digface system will be made.

3.1 Laboratory Equipment

Physical modeling will be performed at the Denver, Colorado, USGS Branch of Geophysics. The modeling facility consists of a 15 × 9 × 5-ft modeling tank with a data acquisition system (see Figure 2). The USGS sensor can be mounted on a gantry to automatically move the sensor to the measuring positions; however, initially the sensor will be placed manually. During the tests if it is found that the gantry increases efficiency of the modeling facilities, it will be utilized at that time. The TDR probes will be placed manually because they must be placed in the medium.

The matrix used to contain the targets will be sand instead of soil. The use of sand minimizes heterogeneities in the host medium so that response of the targets can be better quantified. Heterogeneities that could arise because of soil compaction from walking on the testbed are reduced by using sand. This approach is appropriate for the initial feasibility demonstration. Future testing, if warranted by initial results, will evaluate interferences arising from soil heterogeneities.

To approximate soil conditions related to a key physical parameter that affects dielectric permittivity measurements, the electrical conductivity of the sand will be adjusted to approximate conductivities of representative INEL soil (approximately 50 milliSeimens per meter). As shown in Figure 2, a pump and leach pipe will be used to saturate the sand with a dilute saline solution to adjust electrical conductivity. The pump recirculates a dilute saline solution until a steady state is reached. Then the pump will be turned off and measurements taken. The use of realistic conductivity in the host medium provides a realistic determination of attenuation of the signal. Severe attenuation could hamper the effectiveness of the dielectric permittivity techniques; therefore, realistic values for host conductivities are necessary for the feasibility demonstration. The conductivity of the sand matrix will be measured at the beginning of the experiments using a Miller soilbox³ and recorded in the laboratory notebook.

3.2 Proposed Physical Models

The physical models chosen fall into three categories: metallic objects, solid dielectric permittivity contrasts, and a liquid target. The geometry of these anomalies will be about 3 × 2 × 1-ft scale. The size of the anomalies is dictated by the size of the modeling tank. If they are too large, there will be interference with the measurements from the sides of the tank. This is

Figure 2. USGS modeling tank.

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appropriate for investigating the technology for the digface system. The bottom of the tank has a similar effect to the bottom of the INEL waste pits because they overlie crystalline basalt. Thus, in many aspects, the concrete bottom of the modeling tank is similar to the bottom of a waste pit. The sides of the tank are not similar to the sides of the INEL waste pits because they are not crystalline, and so the anomalies used need to be well away from the sides of the tank.

The test approach will be stepwise in that initial experiments will be conducted for a simple configuration of major importance in demonstrating feasibility of the technique. This configuration is a clay target in soil that simulates the generic class of nonmetallic objects in soil. Assuming that initial results are positive, tests will be performed to simulate metallic and liquid targets in soil.

3.2.1 Nonmetallic Objects

Nonmetallic objects occurring at waste sites include not only items such as wood, plastic, and other solid objects but also contaminated soils and soils with sludges. The effects of these types of targets are unknown. Therefore, for a preliminary test, clay targets will be used. Clay has an advantage over other materials in that it can be used to simulate many different shaped objects. It is conductive, and if the host medium is conductive, the response measured will be due to the dielectric contrast between the host and target, and the conductivity response will be minimized. The use of clay is not intended to exactly mimic all of the properties of solid objects; it will, however, give an estimate of how such objects effect high frequency electromagnetic measurements.

One or more tests will be performed using the clay targets. An initial test will be conducted with a clay target (approximately 5 ft³) placed approximately 1.5 ft deep in the sand matrix. As described in Section 5, for each target configuration, measurements using the TDR will be performed by placing the TDR probes into the matrix. Probe locations will be defined by the test leader. Details about placement and data collection will be logged by the test leader (or designee) into the laboratory notebook.

The USGS high frequency electromagnetic sensor will be deployed above the target/host medium (see Figure 2). Measurements will be made on a defined grid pattern to be determined by the test leader. All details of target configuration and data collection will be logged into the laboratory notebook by the test leader or designated test participants. It is anticipated that approximately two different target configurations will be used.

Additional tests may be conducted using target/host configurations as determined by the test leader based on evaluation of previous data. All test target configurations will be documented in a laboratory notebook using sketches and narrative descriptions as appropriate. Additional details of activity will be logged into the laboratory notebook.

3.2.2 Metallic Objects

A metallic object will be used to test its effect on the measurements. Metallic objects are most easily detected using magnetometers and conductivity mapping devices. However, metallic objects have an effect on dielectric permittivity devices, and this test will help determine the response. The metallic target object will be chosen by the test leader and documented in the laboratory notebook.

Measurements of geometric shape will be recorded. Testing for various target/host configurations will proceed in a manner analogous to the testing defined above for nonmetallic objects.

3.2.3 Liquid Target

Leakage and transport of contaminants is a concern because the volume of contamination may not be apparent from monitoring solely for solid objects. Thus it is important to model such diffusive phenomena. A liquid target will be used to simulate the effect of contaminants within the soils. A nonhazardous surrogate will be used in the place of a hazardous material. A fluid with a contrasting dielectric permittivity will be used to determine if a diffuse target can be detected.

3.3 Laboratory Measurements

In the laboratory tests, the models used will be explored in a fashion similar to the digface concept of stripping layers from the area and then reinvestigating the area to detect changes in the dielectric permittivity as the target is approached. Using the TDR sensor and USGS high frequency system together has two purposes. The first is to have a comparison of the TDR data set with the USGS system's data set. The second is to investigate the high frequency electromagnetic sensor's ability to accurately distinguish anomalies at different depths. In the second case, the TDR will be used to correlate the near surface TDR measurement with the deeper measurements from the high frequency electromagnetic sensor.

3.3.1 Data Collection

Data will be collected in a spatial array. The data collection will be performed in a fashion similar to the digface characterization system. An array will be laid out manually, and measurements will be taken at each station. Then, the upper portion of the model will be removed. The same horizontal positions will be used at this new vertical position for the next series of measurements. The horizontal station separation of this array will be modified as the tests progress to ensure the optimum coverage of the model. The anticipated scale of the station separation is on the order of 15 to 40 cm. The TDR are single point measurements at each station location, whereas the measurements using the USGS sensor system are more complex. These measurements are multifrequency measurements that also use different sensor separations to vary the depth of investigation. The depth of investigation is limited by the depth of the modeling tank. Multiple frequencies will be collected for each coil separation at each station. These data will be stored on computer diskettes.

4. SEQUENCE OF ACTIVITIES

The anticipated activities for this project are as follows.

1. Modeling facility at the USGS will be prepared for the models used. The models used will be documented in the daily logbook as sketches with the position and type of target indicated on the sketch. The horizontal grid will be permanently placed in the modeling tank and its coordinates sketched in the logbook.
2. USGS sensor coils will be modified to collect closer spaced data.
3. Physical modeling will be performed. A horizontal grid will be laid out covering the internal portion of the modeling tank. The station positions will be recorded in the laboratory daily logbook. These stations will then be used to collect data from the TDR and USGS sensors. The data will be collected on a spatial array. The data will be collected over a horizontal grid that is reoccupied with different sand overburdens to the target. This data will be recorded in the logbook daily and on computer diskettes.

For each target configuration, the stations will first be occupied using the TDR system. The station location and measured value will be manually recorded in the logbook with verification. Verification will be done by the operator of the TDR at the time of data collection by visually confirming that the number recorded into the logbook coincides with the value recorded on the TDR. Initially, measurements at each station will be made. If during the course of the investigation, the applicability of TDR measurements is found to be minimal, or the number of stations is found to be redundant, the frequency of the measurements will be modified. Any change in the data collection will be noted in the logbook and discussed in the final report. The TDR will be used as outlined in the Cambel Electronics operating manual. Data that are recorded manually will be stored on floppy diskettes and verified to ensure data quality.

For each target configuration after the first survey using the TDR system, the USGS system will be used. This system is a two coil unit. At each station, the coil separation will be varied to obtain data for different volumes. The anticipated coil separations used will be .5, .75, and 1.0 m. Different separations may be used if the study finds that different separations would optimize the data content. These changes will be documented in the logbook and final report. The data from the USGS sensor will be collected using the procedures outlined References 2 and 3. Data will be collected and stored on a PC with notations in the logbook as needed.

The TDR system will be manually moved from one station to the next. The USGS system will be moved either manually or with the help of a gantry system. This will be determined at the start of the survey. If it is found that the modeling is facilitated by the gantry, it will be used. If the gantry system does not contribute to the ease of data collection, it will not be used.

For the target configuration after completion of first survey using the two devices, approximately .1 m of sand will be removed from the model. The stations laid out in the initial grid will be reoccupied at this different vertical position.

Horizontal station positions will be permanently laid out so that they may be reoccupied each time, which minimizes errors incurred from positioning inaccuracies.

4. After data from both the TDR and USGS systems have been collected for a specific target configuration (including soil removal sequence of activities), the model tank will be configured for the next test.

5. SAMPLING AND DATA

No soil sampling or analyses will be conducted as part of these experiments. The TDR will be used to determine the dielectric permittivity of the specific sand and clay used in the experiments.

The data from these tests consist of electronic measurements from the TDR and USGS high frequency electromagnetic sensor for each measurement location of each test run. The USGS high frequency electromagnetic sensor data will be collected using the procedures outlined in References 2 and 4. These data will be automatically stored on a PC with logbook notations as needed.

The TDR data will be manually recorded in the logbook by reading off the instrument. These data will be manually entered into a computer file for electronic storage in a BWID data base.

6. DOCUMENT CONTROL

6.1 Data

The data collected during the test will be stored on floppy disks and delivered to the BWID project manager for archiving. A copy will also be made for inclusion in the geophysics prototype dielectric permittivity sensor project file. The disks will be write protected. A daily logbook of the modeling done will be kept. In this book, any changes to the test plan along with the daily operation of the tests will be documented.

A daily logbook will be maintained that documents the station positions, data collected with the TDR system, and daily activities. All entries into the logbook will be made in ink and all pages numbered. Any changes in the test plan will also be documented in this logbook.

6.2 Test Plan

The test plan will be reviewed by the project manager. All changes will be approved by the test leader or the project manager. Any minor deviations or changes made to the test plan will be documented in the logbook along with the approval from the test leader. Major changes will require approval of the test leader and digface project manager. Major changes are those that affect the test objective or compromise the quality of the data. In the event that initial results indicate that completion of all tests is not warranted, this will be documented by the test leader with concurrence obtained from the project manager to discontinue testing.

7. ANALYTICAL METHODS

The data will be reduced to the relative dielectric permittivity. For validation and verification, the resulting relative dielectric permittivity will be compared to the known model to determine the accuracy of the measurements.

8. DATA REDUCTION, VALIDATION, AND VERIFICATION

To analyze the data collected with the USGS sensor, numeric modeling will be performed to determine the dielectric permittivity from the measurements. Details of the modeling technique are found in Reference 2. The equation that is the basis of this modeling is

$$k^2 = -i\sigma\omega\mu + \omega^2\mu\epsilon.$$

where

ω = radian frequency

ϵ = dielectric permittivity (Farads/meter)

σ = conductivity (Seimens/meter)

μ = magnetic permeability (Henries/meter).

All measurements will be converted to resistivity and relative dielectric permittivity. The equation relating resistivity (ohm-meters) to conductivity is

$$\rho = 1/\sigma.$$

The equation for relative dielectric permittivity K is

$$K = \epsilon/\epsilon_0$$

where

ϵ_0 = free-space permittivity of 8.854 pF/m.

The data will then be compared to the known dielectric permittivity of the models to verify the result. Data validation will be performed by the test leader and USGS participants. The test leader is responsible for the data validation.

8.1 Contingency Plan

If a discrepancy arises that cannot be resolved, the data will be retaken for the affected test, unless approval is obtained from the project manager to delete the specific, affected test. Instrument or calibration problems that compromise data quality and cannot be resolved will be brought to the attention of the project manager for resolution. The project manager will decide whether to continue testing under degraded conditions or take another course of action.

9. QUALITY ASSURANCE

The work performed under this test plan will conform to EG&G Idaho Quality Level B. The applicable Quality Program Plan is QPP-337. This includes requirements that all instruments are properly calibrated before use, all test setups are documented in the laboratory notebook, and all changes to the test procedures are documented and approved.

Quality assurance activities include keeping a daily logbook of the data collected. This will be reviewed by a third party. The equipment used will be calibrated with the methods used by the USGS in the tool development. The TDR will be calibrated by measuring a known signal on a routine basis and recording instrument readings in the logbook. The data will be evaluated for reasonableness by the test leader or designee. Any nonconformance issues, such as equipment malfunctions or time delays, will be reported to the program manager who has the responsibility to resolve these issues.

10. EQUIPMENT AND INSTRUMENTS

The majority of the equipment and instrumentation used is either owned by the USGS or EG&G Idaho. The equipment not owned will be leased.

11. SUPPLIES, UTILITIES, AND FACILITIES

The modeling tank facilities and supplies used are located at the Federal Center in Denver, Colorado. The need for facility support personnel is not anticipated.

12. HEALTH AND SAFETY

The anticipated activities for the project are considered routine with no health or safety dangers envisioned. Accordingly, hazardous materials such as flammable liquids or carcinogens will not be used, so there are no health or safety issues involved with hazardous materials. All safety procedures in place at the modeling facility of the USGS will be followed. The EG&G Idaho Waste Technology Development Department Self-Assessment Surveillance Report and walk-through checklist will be used to determine if there are any unresolved safety issues at the modeling facility at the Federal Center in Denver. The Self-Assessment Surveillance Report and checklist are provided in Appendix A.

13. RESIDUALS MANAGEMENT

The residuals are primarily sand, clay, water, and household products such as cooking oil. Remaining sand and clay will be retained for future use. All other residuals will be environmentally safe and disposed of using the existing disposal systems at the Federal Center in Denver.

14. REFERENCES

1. N. E. Josten, "Digface Characterization," Technical Task Plan, TTP ID132003, 1992.
2. D. C. Stewart, W. L. Anderson, T. P. Grover, and V. F. Labson, "Detection of Shallow Subsurface Layers Using High-Frequency Electromagnetic Sounding in the 300 kHz to 30 Mhz Range," *Geophysics*, 1993.
3. American Society for Testing and Materials, "Standard Method for Field Measurements of Soil Resistivity Using the Four-Electrode Method," Annual Book of ASTM Standards, ASTM 6 57-58, 1985.
4. T. P. Grover and D. C. Stewart, *Short Wave Loop-Loop Sounder; United States Department of the Interior Geological Survey*, Open-File Report 90-318, 1990.

Appendix A

**Self-Assessment Surveillance Report
and Walk-Through Checklist**

Appendix A

Self-Assessment Surveillance Report and Walk-Through Checklist

Date:

We need to walk-through the facilities where we are sponsoring work. It is required that we visit the facilities at which we sponsor work each quarter with the following in mind:

1. Is the appropriate safety equipment available (i.e., Is there is a rack for safety glasses and does it have glasses in it? Are there signs indicating that rubber gloves should be used and are gloves available? Are there fire extinguishers, are exits marked, and do alarms look in good shape?)
2. Does the equipment seem to be in good shape? Are there calibration stickers on the equipment and are they current?
3. Is the housekeeping within reason for the work being conducted?
4. Do electrical items look to be in good repair?
5. Do the individuals working understand what we want-need and do we understand what they are going to provide us (deliverables)?
6. Are there any operating procedures being used and are logbooks updated regularly?
7. Are hazardous materials/equipment marked and handled properly?
8. If you were paying for this work out of your own pocket, would you be happy with what you have seen?
9. Is there a need for or do they have freeze protection?
10. Has the safety of hoisting and rigging been addressed now, or is it planned?

This is not an inclusive list nor does every item on the list need to be checked; it is strictly provided as a helpful tool when looking at your areas.

SELF-ASSESSMENT REPORT

CTS No. _____

Date _____

Performer(s) _____ Org Assessed _____

Date of Assessment _____ Assessment Target _____

Facility(s) _____

Source Identification _____ Compliance Code _____

OSHA Code, etc. _____

Document Reference _____

Finding Title _____ Finding No. _____

Finding Description (Detailed description of Compliance Deficiency)

Current Status (% Complete) _____ Corrected on the spot? _____

Remarks/Recommendations/Positive Observations

Responsible Mgr. _____ Org. _____ Cognizant ID _____

Category _____ Priority Level _____ Root Cause Code _____

Due Date _____ Funding Source _____ Funding Amt (\$) _____

Actionee _____

Corrective Action Description

Approval _____

Completion Date _____ Verified _____

Completion Reference _____

A description of each finding category is as follows:

Category I - Addresses a situation for which an imminent danger exists to human health or the environment. Requires immediate attention.

Category II - Addresses a significant risk or substantial deviation from a DOE Order, code, standard, or regulation; violation of a law (State, Federal, Local), written agreement, or permit condition. The situation does not present a clear and present danger to human health or the environment.

Category III - Addresses a deviation from a DOE Order, code, standard, or regulation, or addresses a need for an improvement in the margin of safety. Non-application of a requirement described as Best Management Practice (BMP) is also included in this category.

NOTE: All findings that are categorized as Category I and II shall have a root cause analysis performed. Findings that are Categorized as a III shall have a root cause analysis performed if deemed necessary by the responsible manager. Root cause analysis shall be performed per EG&G Company Procedure CP-1.6.

A description of priority levels is as follows:

Priority 1 - to be corrected within the next five (5) working days

Priority 2 - to be corrected within the next thirty (30) working days

Priority 3 - to be corrected as soon as practicable with consideration given to budget and schedule

OSHA CODES

1. Walking/working surfaces
2. Means of egress
3. Occupational health and environmental control
4. Hazardous materials
5. Personal protection equipment
6. General environmental controls
7. Medical and first aid
8. Fire protection
9. Compressed gas and compressed air equipment.
10. Materials handling and storage
11. Machinery and machine guarding
12. Hand and portable power tools
13. Welding, cutting, and brazing
14. Electrical
15. Powered platforms, manlifts and vehicle mounted work platforms.
16. Special industries
17. Ladders and scaffolding
18. Excavations
19. Demolition
20. Cranes, derricks, hoists, elevators, and conveyors
21. Miscellaneous

Root Cause Codes

- 1A. Defective or failed part
- 1B. Defective or failed material
- 1C. Defective weld, braze, or soldered joint
- 1D. Error by manufacturer in shipping or marking
- 1E. Electrical or instrument noise
- 1F. Contamination
- 2A. Defective or inadequate procedure
- 2B. Lack of procedure
- 3A. Inadequate work environment
- 3B. Inattention to detail
- 3C. Violation of requirement or procedure
- 3D. Verbal communication problem
- 3E. Other human error
- 4A. Inadequate man-machine interface
- 4B. Inadequate or defective design
- 4C. Error in equipment or material selection
- 4D. Drawing, specification or data errors
- 5A. No training provided
- 5B. Insufficient practice or hands-on experience
- 5C. Inadequate content
- 5D. Insufficient refresher training
- 5E. Inadequate presentation or materials
- 6A. Inadequate administrative controls
- 6B. Work organization/planning deficiency
- 6C. Inadequate supervision
- 6D. Improper resource allocation
- 6E. Policy not adequately defined, disseminated or enforced
- 6F. Other management problems
- 7A. Weather or ambient condition
- 7B. Power failure or transient
- 7C. External fire or explosion
- 7D. Theft, tampering, sabotage, vandalism

**DATE
FILMED**

12 / 20 / 93

END