ENGINEERING CHANGE NOTICE

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1. ECN **163514**

Proj.
ECN

2. ECN Category (mark one) Supplemental ☐ Direct Revision ☒ Change ECN ☐ Temporary ☐ Standby ☐ Supersede ☐ Cancel/Void ☐	3. Originator's Name, Organization, MSIN, and Telephone No. DF Iwatate, Numatec Hanford co., Process Systems Design	4. USQ Required? ☐ Yes ☒ No	5. Date 2/11/98																					
12a. Modification Work ☐ Yes (fill out Blk. 12b) ☒ No (NA Blks. 12b, 12c, 12d)	12b. Work Package No. N/A	12c. Modification Work Complete N/A Design Authority/Cog. Engineer Signature & Date	12d. Restored to Original Condition (Temp. or Standby ECN only) N/A Design Authority/Cog. Engineer Signature & Date																					
13a. Description of change Document HNF-SD-HTI-SDS-001, Rev. 1 (Specification for Soil Multisensor and Soil Sampling Cone Penetrometer Probes) has been revised to incorporate new/additional information. The subject document was revised to include additional details regarding multisensor probe sensor performance characterization. The section regarding the CP data acquisition system (DAS) was also revised with clarifying information. The document will present technical and performance specifications for the second phase of CP probe development work during FY-98 to support the HTI Plume Characterization task.																								
13b. Design Baseline Document? ☐ Yes ☒ No																								
14a. Justification (mark one) Criteria Change ☒ Design Improvement ☐ Environmental ☐ Facility Deactivation ☐ As-Found ☐ Facilitate Const. ☐ Const. Error/Omission ☐ Design Error/Omission ☐																								
14b. Justification Details Updated document (technical specification) required to support procurement for services.																								
15. Distribution (include name, MSIN, and no. of copies) <table border="1"> <tr><td>JW Bloom</td><td>H6-12</td><td>1</td></tr> <tr><td>JJ Huston</td><td>H5-61</td><td>1</td></tr> <tr><td>DF Iwatate</td><td>H5-49</td><td>1</td></tr> <tr><td>RW Root</td><td>H6-12</td><td>1</td></tr> <tr><td>AF Noonan</td><td>K9-91</td><td>1</td></tr> <tr><td>Central Files</td><td>B1-07</td><td>2</td></tr> <tr><td>HTI Project Files</td><td>H6-08</td><td>2</td></tr> </table>				JW Bloom	H6-12	1	JJ Huston	H5-61	1	DF Iwatate	H5-49	1	RW Root	H6-12	1	AF Noonan	K9-91	1	Central Files	B1-07	2	HTI Project Files	H6-08	2
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17. Cost Impact

ENGINEERING

CONSTRUCTION

18. Schedule Impact (days)

☐ Yes
☒ No

Additional	[NA]	\$
Savings	[NA]	\$

Additional	[NA]	\$
Savings	[NA]	\$

Improvement	[NA]
Delay	[NA]

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

DD/DD		Seismic/Stress Analysis		Tank Calibration Manual	
Functional Design Criteria		Stress/Design Report		Health Physics Procedure	
Operating Specification		Interface Control Drawing		Spares Multiple Unit Listing	
Criticality Specification		Calibration Procedure		Test Procedures/Specification	
Conceptual Design Report		Installation Procedure		Component Index	
Equipment Spec.		Maintenance Procedure		ASME Coded Item	
Const. Spec.		Engineering Procedure		Human Factor Consideration	
Procurement Spec.		Operating Instruction		Computer Software	
Vendor Information		Operating Procedure		Electric Circuit Schedule	
OM Manual		Operational Safety Requirement		ICRS Procedure	
FSAR/SAR		IEFD Drawing		Process Control Manual/Plan	
Safety Equipment List		Cell Arrangement Drawing		Process Flow Chart	
Radiation Work Permit		Essential Material Specification		Purchase Requisition	
Environmental Impact Statement		Fac. Proc. Samp. Schedule		Tickler File	
Environmental Report		Inspection Plan			
Environmental Permit		Inventory Adjustment Request			

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision

Document Number/Revision

Document Number Revision

NA

21. Approvals

Design Authority

Signature

Date _____

Design Agent

Signature

Date _____

Engineer .DF Iwatate

HTI Mgr. RW Root

QA JJ Huston

Safety JW Bloom

Environ.

Other

2-11-98
2/12/98
2/12/98
2-12-98
2/12/98

Design Agent

PE

QA

Safety

Design

Environ.

Other

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature

ADDITIONAL

Specification for Soil Multisensor and Soil Sampling Cone Penetrometer Probes

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Numatec Hanford Company, Richland, WA 99352-1300
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 163514 UC: 2030
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B&R Code: EW3130010 Total Pages: -37 *39 ja*

Key Words: Single-Shell Tanks, waste, leakage plume, cone penetrometer, gamma, xray fluorescence, vadose zone, soil, soil sampling, AX-104

Abstract: Specification requirements for engineering, fabrication, and performance of cone penetrometer (CP) soil multisensor and sampling probes (CP-probes). Required to support contract procurement for services. The specification provides a documented technical basis of quality assurance that is required to use the probes in an operating Hanford tank farm. The documentation cited in this specification will be referenced as part of a readiness review and engineering task plan for a planned FY-1998 in-tank-farm CP-probe fielding task (demonstration). The probes discussed in this specification support the Hanford Tanks Initiative AX-104 Tank Plume Characterization Sub-task. The probes will be used to interrogate soils and vadose zone surrounding tank AX-104.

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Janis Nordal 2-17-98
Release Approval Date

Release Stamp

Approved for Public Release

**SPECIFICATION FOR
SOIL MULTISENSOR AND SOIL SAMPLING
CONE PENETROMETER PROBES**

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February 12, 1998

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1.0 SCOPE

This specification establishes the requirements for cone penetrometer (CP) soil multisensor (MSP) and soil sampling (SSP) probes engineering, fabrication, performance, and acceptance testing. This specification is required as part of the documentation supporting contract procurement for hardware and services. This information also provides a documented technical basis of quality assurance that is required in order to use the final product hardware in Hanford tank farms. The documentation prepared to support this specification will be referenced and incorporated into a CP probe deployment Engineering Task Plan (ETP), a key operations document that will present all CP task fielding activities and approvals related to the use of the product hardware at Hanford.

The entire CP probe effort is being implemented as two major phases over a two-year period from FY-97 through FY-98. The Phase I effort is ongoing at the current time and will conclude early in FY-98. The Phase II effort may start while Phase I work is continuing, and will include the final characterization of CP probe performance, acceptance testing, and technology transfer activities. Phase II is planned to complete by the end of the 3rd quarter of FY-98. For the purposes of this specification, the phase of work that is ongoing (i.e., I or II) is irrelevant. The requirements described in this specification apply to all CP probe products and tasks.

This technical specification is applicable to all requested CP probe tasks and deliverables and will be used as the final review and reference document during acceptance testing and technology transfer to the BUYER. Those items, within the specification text that follows, that are enclosed in bordered "boxes", are considered essential to the successful performance of the item, and the overall CP deployment task at Hanford. These items must be performed, or prepared, as stated. Wherever the word, "should", has been used in the following specification text, this is intended to mean that the SELLER will pursue the stated specification to the greatest extent possible. When, "should", has been applied the BUYER is stating that attainment of the stated specification requirement is highly desirable for optimum performance, however, there is acknowledgment that technical constraints (unforeseen at the outset) may limit achievement of those stated requirements. The SELLER must justify why the requested level of performance, or requirement, was not attainable, and the BUYER must concur.

2.0 BACKGROUND

The CP probes discussed in this specification are needed to support the Hanford Tanks Initiative (HTI) project. The HTI is an ongoing, four-year project resulting from the technical and financial partnership of the U. S. Department of Energy (DOE) Office of Waste Management (Environmental Management [EM]-30) and the Office of Science and Technology Development (EM-50). One of the subtasks of the HTI project is to characterize the extent of vadose zone contamination in specified (Hanford, Washington, DOE site) tank farms. This aspect of the HTI effort has been identified as contaminant plume technology implementation. The overall objective of the HTI project contaminant plume technology implementation and demonstration task is to map the location, extent, and contaminant

concentration gradient of single shell tank (SST) leakage-derived plumes. This task will focus on the backfill soils and vadose zone surrounding tank AX-104 in the 241-AX tank farm on the DOE Hanford Site. This overall [HTI] effort is planned to take place over a three-year period (fiscal years 1997 through 1999). A field deployment activity to accomplish this objective, using the hardware discussed in this specification, is planned to take place in the 200 East Area 241-AX Tank Farm during the period of FY-98 and FY-99.

The general functions of the CP probes are to obtain data regarding waste leakage/contaminant plume extent and content in the soils surrounding SSTs. During the plume characterization effort the 241-AX tank farm soils will be interrogated (using CP-deployed sensors and samplers) for traceable contaminants of potential concern (COPC) including metals and gamma emitting radionuclides. The general CP probe technology and deployment goals of HTI include the following:

- Obtain soil and data samples for analytical speciation of the AX-104 tank [waste] contaminant plumes
- Demonstrate the capability to obtain multiple soil samples during a single CP probe deployment event
- Employ reusable multi-sensor and soil sampling probes
- Detect and avoid sub-surface metal objects during CP probe deployment
- Demonstrate the capability to seal CP penetration points upon extraction of the CP probes.

The CP probes will provide new data about an expanded suite of potential plume constituents, and that information will be combined with existing historic data to support waste retrieval and tank/tank farm closure decisions. These SST vadose zone characterization tools will contribute needed information to waste retrieval and storage functions. In addition, validation of the capability to deploy the CP into tank farm soils will open up new possibilities for emplacement of other soil interrogation tools.

3.0 TECHNICAL OVERVIEW

The CP probe is an enclosed tube that contains sensing or sampling technologies that are pushed by a hydraulic device connected to a small diameter pipe (usually less than 5.0 cm (2 inches) dia.) into the ground using resistive force. The CP pushing platform is typically moved to the push location by driving it into position onboard a truck or by crane lift from a transport trailer (Note: for discussion in the document the abbreviation, "CPP", will be used to refer to either the Hanford CP platform or a CP truck deployment vehicle). Once the CPP is in place heavy weights are typically attached to achieve a maximum push pressure. CP piping strings of 1 meter (3.3 feet) length are then slowly pushed into the ground at a rate of 2-3 cm/sec using hydraulic gripping tools mounted on the CPP. The tip of the CP

piping string is tapered and hardened in order to move as easily as possible through the soil. The pushing operation includes the use of safety features and procedural considerations for both the physical management of the CPP and the guidance and deployment of the CP pipe. Careful planning and procedure preparation are typically associated with both the placement of the CPP prior to the push, and the deployment of the CP piping strings and probes.

Two separate and unique, cone penetrometer-deployable, CP probes are described in this specification: one for analytical instrument interrogation of soils, and one for taking grab samples of soils at specific depths. The probes will be integrated into (i.e., contained within) standard, commercially available, CP piping strings that will be deployed in the arid soils of the Hanford, Washington DOE Site. The probes will be deployed using the CPP by attaching them into the overall piping string and pushing them to a subsurface position as part of a series of piping segments. In this way they are essentially additional sections of CP pipe (approximately 1 meter in length) that are screwed into position along with all the other piping segments. The Multi-Sensor Probe (MSP) will be placed in the first pipe segment position of the CP piping string deployed at a new push location. First position in the piping string will ensure that maximum depth is achieved for data collection and will also position the MSP tip module at the lead position where the magnetometer and inclinometer can provide "safe push" indications (ferrous objects and pipe deflection). This is also true for the Soil Sampling Probe (SSP), which will be at the tip of the second CP string deployed at a push location, in order to obtain soil samples from the "front" of that push string.

During deployment of the MSP, a surface data acquisition system (DAS) will be used to obtain and display data on soil characterization from analytical instrumentation (i.e., tip module, gamma spectroscopy system, and x-ray fluorescence system). The MSP tip module will include CP devices that will contribute to piping deployment control (magnetometer and inclinometer), and also provide soil stratigraphy information (derived from tip and sleeve pressure data). Data from the MSP instrument modules will be integrated with push control data generated by the CPP equipment (e.g., push depth, speed, etc.). The SSP will be used to withdraw soil samples, at specific depths and locations identified by the MSP data, from a separate CP push hole, that will be located in close proximity (less than 1/2 meter or 18 inches) to the previous MSP push hole. If required, the holes created by both the MSP and SSP will be "closed", using grout or another appropriate closure media, as required by regulatory guidance. Hole closure will be conducted by either a separate grouting pipe that will be deployed into the previous CP pipe hole, or (as in the case of the SSP) by attaching a specialized grouting head to the probe to allow grouting upon withdrawal.

4.0 CONE PENETROMETER PROBE REQUIREMENTS

Two completely separate and unique CP probes will be prepared: a soil multisensor probe, or MSP (that will include a gamma spectroscopy system, an x-ray fluorescence system, and a tip module), and multi-sample soil sampling probes, or SSPs.

4.1 General Requirements for both MSP and SSP Probes

The MSP and SSP CP probes will have several similar engineering, configuration, and performance features and capabilities that will enable general compatibility with existing CP deployment tools and specific compatibility with the Hanford CPP. These capabilities will enable the probes to achieve the overall HTI Plume Characterization/CP goals at the Hanford 200 East area, 241-AX tank farm. Design and operation of the probes must be compatible with the capabilities and requirements of the Hanford CPP. These similar requirements for the probes include the following:

- a. Compatibility with existing CP piping thread standards and piping dimensions to the greatest extent possible.
- b. Compatibility with the CP push capabilities and operating conditions of the Hanford CPP (size of probe/pipe in diameter and length, method of storage prior to deployment, etc.). The SELLER shall make every effort to reduce the likelihood of incompatibility of the product CP probes with the planned Hanford CPP.
- c. Engineered capability, to the greatest extent possible, to survive deployment into Hanford soils and gravels, under push pressures and anticipated CP loading that may be possible using the Hanford CPP (maximum 35 - 40 tons push pressure/retraction force). The unpredictability of sub-soil conditions and the potential for probe damage or breakage during CP deployment is acknowledged. However, the engineered configuration and features of the probes shall attempt to reduce this potential as much as possible. For example, the probe may be fabricated from steel which is subsequently heat-treated to appropriate Rockwell hardness.
- d. Probes must be capable of deployment and functioning at a depth of 46 meters (150 feet) or less in the vadose zone, backfill soils, and native soils in and around the Hanford 200 East SST tank farm (specifically 241-AX tank farm).
- e. The CP-probes shall be engineered to function under normal/routine atmospheric and geologic conditions anticipated during Hanford deployment and within the operating tank farm environment.
- f. The data collection format and driver software (for the MSP systems) must be compatible with current industry standards and Hanford Site platforms (e.g. IBM compatible computer systems with DOS, Windows or Windows NT operating systems). Electronic and hard-copy printout of MSP data is required (i.e., data translation to "useful" display at the field site). The SELLER must ensure that the data collection and software driver elements of the data acquisition system are compatible with Hanford and/or industry standards.

- g. The SELLER must ensure that the data collection and software driver elements of the MSP data acquisition system are compatible with other Hanford CPP data platform systems. Final agreement between the BUYER and SELLER regarding data acquisition capabilities and design must be documented and transferred as part of the deliverables to this task. (Section 4.2.5 provides additional data acquisition information and requirements)
- h. The SELLER shall provide voltage and power parameters for the MSP to the BUYER for concurrence and this concurrence will be documented (Phase I). This is to ensure that the BUYER will not have unforeseen compatibility or safety issues associated with the CP probe use at Hanford.
- i. Probe engineering shall accommodate the need for maintenance after transfer to the BUYER. Probe disassembly and replacement or repair of components must be possible.
- j. The MSP must be capable of deployment and functioning in compliance with Hanford radiation control requirements and protocol (i.e., the design and operation of the probe shall not be such that it precludes/prevents handling and operation in accordance with Hanford radiation control requirements (Reference ANSI-N43.5).

4.2 Multisensor Probe (MSP)

The MSP will include, at a minimum, a gamma spectroscopy (GS) detector system, an x-ray fluorescence (XRF) system, and a tip module (i.e., TM; magnetometer, inclinometer, and cone tip/sleeve sensors). The MSP sensor data will be used to provide a depth profile of soil characteristics and plume contaminants information (extent and content). Sensor data reports from the MSP DAS shall include sensor measurement results. The data acquisition system (DAS) must allow for correlation of displayed values with deployment depth. All technologies integrated into the MSP must incorporate commercially available components and/or available sensor technologies (i.e., no new sensor development work required). MSP sensors may be prepared by sub-contractors to the SELLER. The SELLER will, however, ensure that these (and all other sub-contracted components) are properly integrated into the overall MSP.

4.2.1 Gamma Spectroscopy (GS) System

The GS system must resolve and measure the intensity of gamma radiation emitted by potential radiological contaminants of concern (as noted in performance guidelines, below) when deployed at anticipated soil depths. The SELLER shall provide the BUYER with a summary of GS system operating parameters and capabilities [as part of the final acceptance testing documentation].

Engineering/configuration guidelines

- a. The GS detector system must be capable of operation within the anticipated CP pipe housing (i.e., consideration must be given to pipe housing materials, thickness, assembly constraints, etc.).
- b. Temperature compensation of GS output should be accommodated.
- c. GS data collection must be correlated with data streams from other MSP data streams and integrated with Hanford CPP data platforms. Design of the GS data acquisition system must ensure that such successful integration is not precluded (e.g., hardware, cabling, connectors, data format, data availability, communication software/firmware, etc.). Section 4.2.5 discusses DAS requirements.
- d. Engineering and configuration of the GS detector system and related data acquisition components must allow for field verification of operability within established performance parameters (e.g., quality control measurements of check source(s) prior to and after deployment).
- e. The SELLER shall provide procedures that clearly and concisely describe the GS set-up, deployment, energy calibration/performance checks, operation, data handling, and routine maintenance.
- f. The SELLER shall provide the BUYER with a summary of GS system operating parameters and capabilities as part of the final acceptance testing documentation.

Performance guidelines

- a. The GS system must provide the capability for user-selectable count period (Note: the anticipated nominal count period for the HTI CP MSP probe task will be from 10 - 10,000 seconds).
- b. The GS system must provide the capability to record gross gamma counts during penetrometer push activity and/or during operator-selected park time.
- c. If the performance of the detector/probe sensor is affected by temperature changes anticipated to be encountered during MSP deployment, the capability to perform temperature compensation of the sensor shall be provided. Such temperature compensation must be applicable over the range of 40 °F - 120 °F.
- d. The GS and related DAS must be capable of operating both concurrently with, or independent of, other MSP sensors.

- e. The GS system should be capable of detecting and measuring gamma radiation in the energy range of 100 - 2600 keV.

- f. The GS system must be optimized for detection and measurement of cesium-137 (Cs-137) contamination (at a minimum detection limit of 100 pCi/gram). Other isotopes shall be detectable commensurate with the Cs-137 optimization. This detection and measurement capability must be demonstrated within a Cs-137 spiked test matrix (i.e., Hanford soil simulant) with a target count time not-to-exceed 300 seconds real-time. The minimum detection limit (MDL) shall be computed as:

$$MDL = 4.66 (\text{background counts})^{1/2} \times (1/\text{counts}) (\text{pCi/gm})$$

- g. The GS detector should be targeted for a sensitivity "range of view" (i.e., the soil sphere of interrogation around the detector) of approximately 12 inch - 18 inch radius from the center point of the detector.
- h. The GS system shall be designed to withstand the anticipated CP push conditions (mild shock and vibration) anticipated in the arid native soils and gravels of the Hanford Site.
- i. The GS system must be capable of continuous operation for a minimum of 10 hours (anticipated maximum length of time for a single deployment data gathering session).
- j. The minimum set of check source isotopes must include ¹³⁷Cs (cesium), ⁶⁰Co (cobalt), and ²²⁸Th (thorium). Individual point check sources of these isotopes will be provided to the SELLER, by the BUYER. These sources will later be used by the BUYER, in the field, to establish continuing quality control that is anchored to the primary performance characterization (performed by the SELLER per this specification).

4.2.2 X-ray Fluorescence System (XRF)

The XRF system (i.e., MSP XRF instrument, cabling to surface, and DAS components) will be used for elemental characterization of soil contaminants. The XRF system will be used to excite, resolve and measure the characteristic x-ray fluorescence of potential elemental contaminants of concern (as noted in performance guidelines, below) when deployed at anticipated soil depths.

Engineering/configuration guidelines

- a. The XRF instrument shall be totally enclosed within the MSP housing (i.e., CP push pipe). A single, x-ray transparent window in the MSP housing will allow interrogation of materials (e.g. soils, check standards, etc.) adjacent to the MSP-XRF module.
- b. The MSP design and construction must accommodate the detection and control of temperature within the MSP housing. Means for efficient dissipation of heat generated by probe electronics must be provided. If required, the XRF system design and construction must include the capability to provide adequate cooling of the XRF source and/or detector and to monitor the detector temperature in the CP control cab.
- c. Engineering and configuration of the XRF system must allow for field verification of operability within established performance parameters by pre- and post-push QC measurements. Also, the XRF system configuration must not preclude top-side (on the surface) measurement of independent, discrete samples.
- d. The XRF system (including the source, detector, internal mounting hardware, window, window fixatives, sensor umbilical, and up-hole electronics) must be operational over a temperature range of 40 °F - 120 °F.
- e. The XRF system (including the source, detector, internal mounting hardware, window, window fixatives, sensor umbilical, and up-hole electronics) must be capable of withstanding the rigors of CP push conditions (mild shock and vibration) anticipated during deployment in the arid native soils and gravels of the Hanford Site.
- f. The SELLER shall provide the BUYER with a summary of XRF sensor operating parameters and capabilities as part of the final acceptance testing documentation.
- g. The SELLER shall provide procedures that clearly and concisely describe the XRF sensor system's set-up, deployment, energy calibration/ performance checks, operation, data handling, and routine maintenance. Procedures and documentation must include precautions or warnings to instrument operators.

Performance guidelines

- a. The XRF sensor must, at a minimum, be capable of detecting fluorescent X-ray lines, with energies exceeding 8.0 keV, that are emitted by elemental components of a test matrix whose concentrations exceed 1000 ppm by weight. Detection of strontium (Sr), zirconium (Zr), technetium (Tc), lead (Pb), and uranium (U) are of particular interest. Counting times required to achieve this performance guideline shall not exceed 300 seconds real-time.

- b. The minimum detection limit (MDL) of the XRF sensor for U in a test matrix should not be greater than 100 ppm by weight. This target MDL shall be pursued to the greatest extent possible and the BUYER shall be notified at the earliest possible time (prior to final acceptance testing) if this desired MDL is not achievable with the XRF sensor. Counting time required for this performance level shall not exceed 300 seconds real-time. The MDL shall be calculated as:

$$MDL = 4.66 (Background\ Counts)^{1/2} (ppm/Counts_{Net})$$

- c. The intensity of the excitation source shall be sufficient to meet the detection limits of performance guidelines "a" and "b", above. The SELLER shall provide the following information characterizing the radionuclide excitation source:

- Isotope / Activity
- Source Birth date
- Details of source capsule fabrication
- Documented smear test results [or other acceptable documentation of sealed nature of capsule]
- Dose rate (mR/hour) information for both the window and rear side of the source capsule measured at:
Surface -
 - 10 cm in direction of maximum flux
 - 30 cm in direction of maximum flux
 - 100 cm in direction of maximum flux
- Identification of dose rate measurement instrument(s) and any applied corrections.

- d. The signal output of the detector should be linear with respect to measured x-ray energy to within +/- 0.5% over the operating range of the sensor.
- e. The energy resolution of the XRF sensor should be less than 5% for X-ray lines within the operating range of the sensor.

- f. The repeatability of the instrument should have a relative standard deviation (RSD) of $< 1\%$ for 10 repeated measurements of count time not exceeding 300 seconds real time. RSD shall be calculated as follows:

$$RSD = (Standard\ Deviation / Mean\ Value) \cdot 100$$

- g. The XRF sensor and related data acquisition system must be capable of operating both concurrently with, or independent of, other MSP sensors.
- h. The XRF system must be capable of continuous operation for a minimum duration of 10 hours (anticipated maximum length of time for a single deployment, data-gathering session).

4.2.3 Multisensor Probe Tip Module

The MSP will be configured as a single, tubular, CP pipe segment that will be pushed as the first unit into the target soils. The forward-most segment of the MSP will consist of tip module (TM) sensors (i.e., tip and sleeve pressure, magnetometer, and inclinometer). The SELLER will be responsible for integrating the tip module into the overall MSP physical configuration. Integration will include physical location and attachment to the MSP housing and accommodation of cabling.

A magnetometer and inclinometer will be included in the MSP tip module and will provide essential information to ensure that the MSP is not moving "blindly" into the soil surrounding the target tank. The function of these sensors is considered critical to enabling, to the greatest extent possible, a safe and controlled push of the MSP into tank farm soils. General considerations regarding the tip module components include the following:

- a. The BUYER acknowledges that the SELLER may enlist the services of sub-contractors for component fabrication of the MSP tip module (including inclinometer/ magnetometer/ soil stratigraphy components). The SELLER shall act as the MSP system integrator, and in that role will advise sub-contractor/ vendors (if used) and will be responsible for ensuring that the BUYER's performance needs and design requirements are met.
- b. The SELLER shall ensure that all QA, performance verification, maintenance, factory calibration, and other documentation related to the MSP tip module are complete and satisfactory to support the requirements of this specification (and provided to the BUYER).

- c. MSP and umbilical design shall not preclude appropriate and successful interface with the Hanford CPP. The SELLER shall provide for the physical interface (cabling and connectors) of the tip module instruments to the Hanford CPP DAS.

- d. The SELLER shall ensure that the MSP umbilical cable accommodates tip module sensor needs (e.g., cabling, power, data transfer, appropriate length to reach plug-in points on the Hanford CPP, etc.).
- e. The SELLER shall ensure that the engineering and performance goals for the MSP analytical sensors are not jeopardized by the operation or presence of the tip module and its components.

4.2.3.1 Tip Module Sensors

Standard (i.e., commercially available) load cell (pressure), inclinometer, and magnetometer sensors shall be incorporated into the MSP tip module. The load cell sensors must be configured to provide data regarding CP tip and sleeve pressures. This information will be translated via the MSP umbilical to the Hanford CPP DAS. The SELLER shall be responsible for ensuring that the TM sensors meet industry standards; supply required data for soil stratigraphy determinations (i.e. appropriate load cell data and conversion programs); and, supply required data to facilitate CPP push control. The SELLER shall also be responsible for compiling reference documentation.

4.2.3.2 Magnetometer

A magnetometer shall be included in the MSP to provide the capability to detect [ferrous] metal objects in the path of the probe tip during deployment. The SELLER shall be responsible for ensuring that the magnetometer meets requested requirements, and for compiling reference documentation. The requirements for features and capabilities of the magnetometer include the following:

- a. The magnetometer shall provide indication of ferrous objects directly in the path, and in close proximity, of the CP pipe/probe tip, during push activity. The magnetometer must be capable of providing these indications in anticipated Hanford soil conditions.
- b. Indications/data from the magnetometer must be adequate and appropriate (in speed of acquisition and reporting) to allow for the Hanford CPP push controls to respond and take appropriate action (i.e., stop or slow down, or withdraw slightly, etc.) in sufficient time to avoid hitting a detected object. The magnetometer should detect such objects at a minimum distance of 3 inches in front of the moving probe.

4.2.3.3 Inclinometer

The purpose of the inclinometer is to determine whether the CP tip is out of vertical alignment; to help determine approximately where the CP probe is located with respect to a perfectly vertical path; and, to indicate where the probe could potentially be heading. The SELLER shall be responsible for ensuring

that the inclinometer meets requested requirements, and for compiling reference documentation.

- a. The inclinometer shall provide an indication of change in the angle of deflection of the CP probe tip out of a vertical direction of travel during the push cycle and when stationary at depth. The inclinometer shall provide indications within the range of $0 - 10^{\circ}$, $\pm 2^{\circ}$.
- b. Indications/data from the inclinometer must be adequate and appropriate (in speed of acquisition and reporting) to allow for the Hanford CPP push controls to respond and take appropriate action (i.e., stop or slow down, or withdraw slightly, etc.) in sufficient time to avoid hitting an object that may be within the probes altered path and reduce the risk of damage to the CP push string.

4.2.4 Multisensor Probe Umbilical Cable

The MSP will include an integrated (hard-wired) umbilical cable that will connect MSP instrumentation (i.e., TM, GS, and XRF sensors) to surface data collection devices (i.e., the CPP/MSP DAS). The umbilical cable is an essential part of the overall deliverable for this task and will play a critical role in the collection of data from the probes when they are deployed. The following guidelines shall be followed, at a minimum, regarding the umbilical cable engineering and performance:

Engineering/configuration guidelines

- a. Provide sufficient bending flexibility to allow deployment within the anticipated number of multiple CP piping elements.
- b. Provide sufficient cable length to accommodate handling, DAS hookup, and storage requirements. The current HTI CP probe deployment target depth is 15-50 meters (45-150 feet), which will require an umbilical cable length of approximately 100 meters to meet these guidelines.
- c. The umbilical cable must be constructed to ensure that CP pipe strings can be added or removed from the entire pipe string, if needed (i.e., plugs and joints must not prevent removal or addition of the umbilical through the pipe segments by "threading").
- d. Dimensions (i.e., diameter and length) must be optimized to accommodate all sensor cable needs while at the same time allowing for CP pipe assembly, disassembly, and deployment conditions (i.e., construction and size/diameter must address friction/tightness within pipe sections, wearing due to pipe wall rubbing and pipe twisting, and tensions on the overall cable during deployment.

Performance guidelines

- a. Maintain integrity of MSP sensor signals.
- b. Address friction, abrasion and wear on the cable surface within the CP pipe during deployment.
- c. Prevent "cross-talk" of power and data signals in wires.
- d. Provide sufficient longitudinal and lateral strength to withstand the physical stresses of deployment without degrading or damaging the wire integrity or performance.

4.2.5 Data Acquisition System

The data acquisition system (DAS) will consist of hardware and software that will support data collection, processing and display from all components of the MSP. Rack-mounted electronics and signal conditioning equipment and data acquisition/processing computer equipment will be procured for use with the MSPs described in this specification. This equipment will be used for development, characterization, and testing of the probes and will be provided to the BUYER as part of the hardware deliverables for the task. The equipment will be tested and configured for installation in the Hanford CPP.

The DAS shall be designed in such a way as to maintain, to the greatest degree possible, the independence of the data streams from the MSP sensors through the up-hole processing electronics. Due to limited CPP control/cab space for mounting electronic and computer equipment, however, it is desirable to limit the number of computers and monitors used for data acquisition, processing, storage, and display. Therefore, it is recommended that multi-functional processors, display devices, or multiple window control systems be used to the greatest possible extent.

Designations of separate data acquisition systems for the CPP and MSP data streams (CPP DAS and MSP DAS) in this specification are functional only. The SELLER may propose the development of independent CPP and MSP DAS modules. The SELLER is not, however, precluded from proposing DAS architecture in which related DAS functions for multiple CP data streams are executed within common hardware and/or software resources.

Engineering/configuration guidelines

- a. The DAS electronic equipment is expected to include components such as the following. Final DAS component inventory will be recommended by the SELLER and reviewed/concurred by the BUYER during the course of the task.
- Pentium PC controller computer
 - NIM bin with $\pm 6V$, $\pm 12V$, and $\pm 24V$ power supply
 - Appropriate NIM-based detector bias supplies and signal processing modules
 - Miscellaneous electronic components to ensure intended performance
 - Appropriate display monitor and data storage devices
 - Miscellaneous computer codes and software, as required.
- b. Data from the MSP sensors must be generated and captured in a format that is compatible with both the hardware/firmware resources of the Hanford CPP and with the CPP and MSP DAS modules.
- c. The DAS must provide the capability of converting TM load cell sensor data into soil stratigraphy data. The DAS must also have the capability to capture, store and display this depth correlated soil stratigraphy information.
- d. SELLER shall provide documented and validated source code for all software and scripts (e.g., macros and command codes) that are prepared by them, during the DAS and MSP development and configuration effort. This guideline does not apply to commercially available software that may be utilized.
- e. Where acquisition of MSP and CPP data streams are controlled by disjoint, autonomous systems (computers/ controllers), methods, using common system resources, shall be provided for transfer of data to a common computer within the system and for unambiguous identification of related data elements..

Internal Data Requirements

The following items define the requirements for how data acquired with the MSP sensors are stored and maintained by the DAS.

- a. The SELLER shall provide the BUYER with documented description of data structures, formats, and element definitions for all stored data.

- b. Basic data storage shall be performed using common ASCII-delimited records/files suitable for direct importation into commercial applications such as spreadsheets or data base engines.
- c. All relationships of data structures and processing shall be documented as data flow diagrams which include data source, processing, and destination.
- d. All raw sensor data shall be electronically stored, as captured, for reference, data reduction, and post acquisition operations. A unique date and time stamp shall identify and be included in all stored raw data files (See Internal Data Requirements - h.).
- e. The DAS must include the capability to apply near real-time corrections/adjustments (i.e. immediately following raw data capture) to MSP raw data files. Applied corrections will include corrections required to enhance the quality of the MSP sensor data and assure its timely use in making CP operational decisions.
- f. Where corrections or adjustments are applied to raw data files, the original and final data files and the compensation factors applied shall be stored and maintained sufficient to recreate or trace the calculation process. The SELLER shall provide the BUYER with documentation of the calculation algorithms employed and storage processes used.
- g. The DAS must provide the capability of processing MSP data files. Data processing and reduction capabilities shall include, at a minimum, background correction; basic, operator defined, region-of-interest (ROI) spectrum processing; and, multiple pass processing of ROIs. The processed data must be saved as part of the final MSP data files and must be retrievable for subsequent data processing/display functions.
- h. All CPP and MSP data files must be tagged with a unique date and time stamp identifying the time the (stamped) data was acquired. The resolution of this time stamp shall be sufficient to allow unambiguous correlation of the MSP and CPP operational data streams. If multiple processors are utilized, the internal clock of one of the processors will be designated as the master clock. The capability of synchronizing all other processor clocks with the designated master clock (to within a tolerance consistent with the sampling frequencies of the MSP sensors and CP control inputs) must be provided within the DAS architecture.
- i. The CPP DAS will generate an estimate of the depth-below-grade (DBG) associated with each data element in the date/time stamped sensor data files. The estimated DBG will be captured as an integral part of the TM data streams

such that the estimated DBG for any specific TM data element can be clearly identified and correlated with the corresponding acquisition date/time stamp.

- j. Final (corrected and/or processed) MSP sensor data files shall be electronically stored for reference, data reduction, and post acquisition operations. The estimated DBG associated with each final MSP data element should be captured in the corresponding final data file in addition to the date/time stamp identifying all MSP sensor data files. If this is not possible, documented DAS capability must be provided for unambiguously retrieving and assigning the correct estimated DBG to all MSP data files bearing an identical data/time stamp.
- k. The CPP/MSP DAS shall provide the capability to produce depth profile trend charts for all MSP data inputs. The capability to display the variation of specific, operator-selected, processed, MSP sensor data inputs vs. estimated DBG (i.e. log-type display) must be provided. Trend charting should also include the capability to simultaneously display the complete spectrum collected by each MSP spectroscopic sensor at each estimated DBG (i.e. pseudo-seismic display). The depth profile trend charts must be available on demand during CPP operations.
- l. Data storage files should, where practical, utilize a file type designation structure for classes of data (e.g., file extension names could identify data categories). Both file designation conventions and deviations must be documented. Where file extensions are used to enumerate an acquisition data set, a processible log or list of names shall be created which identifies the file set components.
- m. If the SELLER proposes the use of commercial, proprietary, data storage formats for MSP data storage, utilities such as cross reference tables, logs, or accessible, internal data tags must accompany the data storage process. The data identification/storage format must be specifically documented in order to ensure the accessibility of MSP data for subsequent processing or presentation. Use of such data storage formats is discouraged and the basis for selection must be presented to BUYER for concurrence prior to implementation/use.

Data Output Requirements

The following items define the output capabilities/ requirements for the CPP/MSP DAS.

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- a. The raw data from the MSP sensors must be viewable on the system monitor(s) in real time.
- b. Corrected spectra and processed data must be viewable either in real time (immediately following completion of raw data collection) or on-demand. The capability of operator selection of real-time or on-demand display of the corrected MSP data is suggested.
- c. Depth profile trend charts of operator selected MSP sensor data must be viewable on DAS system monitor(s) on-demand. The DAS should provide the capability of simultaneously plotting and displaying multiple, log-type trend charts (for differing combinations of probe sensor data inputs).
- d. The DAS must support on-demand display of corrected and processed MSP data. This capability should include, at a minimum, display of corrected/processed sensor spectra and reporting of gross and net intensities of multiple, operator selected ROIs. ROI data reporting should include ROI identification, centroid ROI energy, counting error(s), and appropriate reporting units.
- e. The DAS must support generation of data reports consisting of annotated, operator selected collections of MSP data including raw or corrected data files, raw or corrected spectra, processed data files, and depth profile trend charts. DAS resources or documentation must support generation of data report headers including the following minimum information:
 - Report title
 - Date and time of report generation
 - Identification of data files and data acquisition dates/times
 - Code identifier(s) and revision numbers for software used in acquisition, correction, or processing.
- f. The DAS shall support generation of hard copy reports using the existing CPP Hewlett Packard LaserJet III printer. Hard copy capability shall include sensor spectra, ROI data, depth profile trend charts and reports collecting system data files.
- g. The capability of down-loading all data files and data reports (in final format) to common removable media that may be removed from the DAS and transported out of the CPP and tank farm for output on remote systems must be provided.

4.3 Multi-sample Soil Sampler Probe (SSP)

The SSP will be used to obtain multiple, discrete soil samples, at specified/desired depths. Selection of sampling DBGs will be based on the observed output of the MSP sensors or other external criteria. The SSP will provide for the retrieval of multiple soil samples during a single CP push event without having to withdraw the main, outer, CP pipe string in which the sampling device operates. This approach provides efficient sampling from only the most promising locations and allows retrieval of only the desired amount of soil needed for analysis.

Engineering/configuration guidelines

- a. The SSP shall be capable of use with the Hanford CPP (e.g., pipe length, diameter, handling clearances, etc.).
- b. The sampling functionality shall be completely contained within the [main] CP SSP piping string.
- c. The sampling canister and assembly must be of materials that are rugged enough to withstand the rigors of sampling, while at the same time light enough to be withdrawn and managed, by hand, by operators on the surface, even when the full length of CP pipe is deployed (i.e., 50 meters).

Performance guidelines

- a. Provide for retrieval of the soil sample/container from inside the CP piping string without having to withdraw any of the CP pipe.
- b. To the greatest extent possible, the design of the SSP shall minimize the opportunity for internal CP piping contamination, sample cross-contamination, and mixing of samples when multiple samples are taken.
- c. The SSP design and operation must accommodate a [specially designed] grouting module that will be placed in the SSP tip upon completion of the sampling effort, so that the SSP push hole can be closed [with grout] upon withdrawal (See Section 4.4 for grouting capability requirements).
- d. The entire sampling tube/rod "system" must address potential bending of the CP push pipe string during deployment (i.e., binding of the inner, sampling mechanism which prevents sampling under "normal" conditions must not

occur).

- e. The sampling probes shall be engineered to provide the capability to obtain a minimum of five (5) samples during a single CP push event. Enough one-time use per sample equipment must be provided with the two SSPs to enable collection of 10 samples. The internal sample canister push rods and the tip release rods must also have backup units in case of wear, breakage, or contamination during use. Of particular concern is the forward most portion of SSP outer push pipe, since the cutting edge will be subjected to significant and repeated abuse during sampling. Also, there shall be backup sections of sample canister emplacement (inner pipe) tubes.

4.4 Grouting Capability

The deployment strategy for the CP probes includes a provision to "close", or plug, the CP push holes once soil/plume interrogation or sampling has been completed. The initial plan to accomplish this goal was to incorporate a grouting capability into the soil sensor probe configuration. This was determined, during Phase I activities, to be technically non-feasible. Therefore, if required, grouting will be accomplished during a separate, follow-up push into the MSP push hole with a dedicated CP pipe string with a grouting module. Closure/grouting of the SSP push hole, if required, will be accomplished by using a specially designed grout module that will be compatible with the SSP unit and will allow for grouting of that hole as the SSP outer pipe is withdrawn.

Based upon previous experience in pushing CP probes in Hanford soils, there will be a need to "cycle" the CP pipe string (i.e., occasionally move the pipe up for several inches of travel and then proceed down again) in order to release accumulated tip and side load [soil] pressures. This cycling action is a necessary part of the deployment strategy in order to reach maximum depth. This approach must be considered when engineering the grouting modules. The cycling approach precludes the use of grouting tip design(s) that use the backward/pull-up stroke of the CP pipe to release the grout tip plug, and allow grout to flow. A "blow off" grout tip is the most likely alternate approach that should be considered for the HTI CP design.

Engineering/configuration guidelines

- a. The SELLER shall provide a grouting module that can be used as a "plug in" to the tip of the SSP plus at least one backup (additional) SSP grouting module.
- b. The SELLER shall provide a grouting module that can be used with a dedicated grouting push pipe string.

5.0 MATERIALS OF CONSTRUCTION

The MSP and SSPs must be specifically designed and constructed for fielding in the arid soils of the DOE Hanford Site 200 East area tank farms. Selection of materials for probe construction, fabrication methods and controls, and design shall accommodate this intended final use/location.

- a. Material selection for and construction of the CP probes must consider/address the anticipated deployment conditions (e.g., soil characteristics, potential for radiological contamination) expected at the Hanford tank farms (specifically the 241-AX tank farms).
- b. Basis for selection and processing (e.g. heat treatment) of materials used in the fabrication of probe housings, push pipe strings, and probe tips must include minimization of the amount of abrasion (scoring and scratches) resulting from deployment in Hanford soils.

6.0 PERFORMANCE VERIFICATION

Verification action and documentation is required to ensure that the requested CP-probes address the performance and engineering requirements of this specification. Verification will be achieved by completing acceptance tests and compiling requested documentation.

6.1 Acceptance Testing

Acceptance testing will include three basic types of tests: vendor acceptance tests (VAT), general construction acceptance tests (CAT), and final acceptance tests (FAT). All acceptance testing will be the responsibility of the SELLER and will be successfully completed before the equipment is released for transfer and/or shipping. Final acceptance test procedures and test reports will be prepared and included as part of the SELLERs information and report submittals. Acceptance test activities and test plan will be prepared jointly between the SELLER and BUYER and will focus on such product aspects as:

- a. Confirmation that the requirements of this specification have been met,
- b. Checkout of wiring continuity and electrical protective devices,
- d. Characterization of sensor and systems performance,

- e. Testing of instrumentation loops to ensure proper function and response within required times/parameters,
- f. Adjustment and setting of controllers, switches, and similar devices,
- g. Bench-testing and laboratory checkout of deliverable equipment,
- h. Performance confirmation that the probes operate as a complete unit (coupled with a CP string) as planned/required.

VATs will be performed by the SELLER to demonstrate that fabrication, assembly, installation, construction, and performance requirements cited in this specification have been met. The VATs will be performed at the SELLER's facilities (Note: some sub-contracted items will be tested first at the sub-contractor's location). The SELLER will develop, document, retain, and submit all relevant test procedures to the BUYER, as required and appropriate for the equipment procurement specifications. These procedures will be reviewed and approved by the BUYER to ensure that testing is adequate to demonstrate compliance with equipment specifications. Performance of the VATs by the SELLER will be witnessed by members of the BUYER staff (i.e., Hanford/HTI staff).

The SELLER will perform CATs on individual components and subsystems during fabrication/assembly of the probes. The CATs shall include standard construction tests such as electrical continuity checks, pre- and post-installation checks, system operation verification checks, and final assembly operational checks, as appropriate. The CATs may be conducted according to existing SELLER guidelines and practice. The CATs shall be conducted by the SELLER and documented as part of the overall task records. The SELLER will perform and monitor all CATs to ensure that proper test documentation is prepared and must include this documentation as part of the final submittal to the BUYER at the time of deliverable transfer and final acceptant test proceedings. The CATs may be observed by the BUYER, or the documentation may be provided to the BUYER, when requested/appropriate during the course of the task.

The FAT will represent the final task completion and checkout, performed by the SELLER and witnessed by the BUYER, before the equipment will be released for shipment/transfer. The SELLER will perform all FAT actions and ensure that FAT documentation is prepared and included as part of the vendor information deliverable.

6.2 Characterization of Instrument Performance

Proper characterization of the performance of MSP instruments and systems is essential to providing credible data from the deployment activity. Characterization must be performed to document actual performance criteria and benchmarks for the CP probes and support systems. The characterization process will be initiated at the SELLER's location (or at a sub-contractor's location) and will continue at the BUYER's location, during technology transfer and cold deployment exercises, in order to establish continuity and correlation of development and characterization records with actual field indications.

The analytical sensor modules of the MSP (i.e., GS and XRF sensors) will require characterization in order to, 1) establish the range of the MSP measurements, 2) establish credibility of the data, and 3) provide certifying documentation for that data and supporting equipment/instruments. The characterization documentation will also demonstrate to reviewers [of this preparation activity and the actual operational deployment of the probes] the adequacy of test methodologies; the validity and pedigree of calibration sources and standards; the qualifications of resources applied to the characterization process (staff and equipment); and, the application of proper procedures for handling and use of characterization equipment and resources.

The CP-probe preparation task will include characterization of both the GS and XRF systems [separately], and the completely assembled MSP. The following list summarizes major characterization-related topics and documents that must be addressed:

- a. The SELLER and BUYER will jointly prepare MSP performance characterization procedure documents. The SELLER shall manage/implement the characterization activities (and/or supervise a sub-contracted service).
- b. The SELLER shall maintain and submit characterization-related documents that describe certification standards applied, the characterization procedure(s) used, and verification of credentials for certifying staff and equipment that is employed.
- c. Characterization documentation shall include such records as 1) certification of calibration standards, 2) characterization procedures, 3) characterization data, 4) records on characterization equipment and characterization staff credentials, and 5) a final characterization report.
- d. Where characterization efforts are sub-contracted by the SELLER, the SELLER shall ensure that the sub-contractor fulfills the SELLER's obligations and requirements for characterization.

- e. The characterization test plan shall include measurements designed to simulate and characterize the anticipated performance of the sensors in the target environment of use (i.e., Hanford Site soils and tank farm conditions).

Minimum MSP/DAS Performance Characterization Requirements

During final acceptance testing, the tests described in this section (resolution, output linearity, throughput, temperature compensation, intrinsic detector efficiency, minimum detection level, check standard measurement and deployment) must be performed with the fully assembled, final deliverable MSP (i.e., the complete MSP unit, umbilical cable, all system connections, and MSP DAS). During preceding test activities, configuration of the MSP and supporting DAS shall be equivalent to that to be used during actual deployment in the Hanford CPP. The SELLER may, however:

- a. Replace the radionuclide source capsule of the XRF sensor with an empty capsule of identical design (i.e. containing no radionuclide) for tests not related to XRF sensor performance.
- b. Perform all characterization and performance definition activities without any attached push pipe segments or with the minimum number of segments required for the particular test.

Proposed MSP or DAS configuration changes for the test measurements must be reviewed and explicitly approved by the BUYER.

The performance characterization test plan must show that the MSP GS and XRF sensors meet the guidelines of Section 4.2 of this specification. The plan must, at a minimum, demonstrate and, where applicable, quantitatively define the following MSP GS and XRF parameters:

RESOLUTION

- a. The energy resolution of the GS and XRF sensors shall be determined and documented.
- b. The energy resolution of the GS will be determined by examination of the gamma spectra of a Cs^{137} source of appropriate activity. The measured resolution should be $\leq 8.5\%$.
- c. The energy resolution of the XRF spectrometer should not exceed 5% for x-ray energies within the operating energy range of the sensor. The operational energy range will be defined by the transmission properties of the sensor windows and

the energy of the x-rays emitted by the excitation source and is anticipated to cover the range of 8 - 24 keV.

OUTPUT LINEARITY WITH ENERGY

- a. The linearity of the signal output of the GS and XRF sensors shall be determined over the working energy ranges of the sensors.
- b. The signal output of the GS should be linear to within 0.1% over the range of 100 KeV to 2.6 MeV.
- c. The signal output of the XRF sensor should be linear to within 0.5% over the operational energy range.

THROUGH-PUT

- a. The counting throughput of the GS and XRF sensors will be defined.
- b. The GS should be capable of processing > 20,000 cps count rates with < 5% loss in resolution and < 0.1% gain shift. The actual count rates at which these criteria are exceeded should be documented.
- c. The maximum count rate capabilities of the XRF sensor will be documented. The reported throughput limits will be based on SELLER measurements or on vendor specifications. The background count rate and spectrum (i.e. the count rate and spectrum observed with no sample adjacent to the window) will also be determined.

TEMPERATURE COMPENSATION TEST

- a. The ability of the MSP sensors to function over a temperature range of 40 - 120 F shall be demonstrated.
- b. The ability of the XRF detector cooling mechanism to maintain the detector at the vendor recommended temperature throughout the specified 40 - 120 F range will be demonstrated.
- c. The functionality of the temperature compensation system for the GS will be demonstrated. Energy shifts of recorded spectra should not exceed 1%

throughout the specified 40 - 120 F range.

INTRINSIC DETECTOR EFFICIENCY

- a. The intrinsic detector efficiency (counts/second/ μCi) of the GS, for three gamma radiation energies, shall be determined.
- b. The intrinsic detector efficiencies will be determined through separate measurements on individual calibrated sources of Th^{228} , Co^{60} and Cs^{137} placed 25.4 cm from the center of the GS NaI detector crystal. Measurement times will be adjusted such that 1-sigma counting errors do not exceed 1 %.

MINIMUM DETECTION LEVEL

- a. Analyte Detection Performance: The ability of the GS and XRF sensors to detect, resolve, and identify specified analytes in a prepared test matrix, must be demonstrated (See Section on Characterization Documentation).
- b. Detection Levels: The minimum detection levels (MDL) of the GS and XRF sensors must be determined for specific target analytes in a prepared test matrix. Measured performance should meet the following benchmarks:

Sensor / Target Analyte	MDL	Count Time
GS / Cs^{137}	100 pCi/g	300 seconds (real time)
XRF / U	100 ppm	300 seconds (real time)

The reported MDLs will be calculated as:

$$\text{MDL} = 4.66 (\text{Background Counts})^{1/2} (1 / \text{Sensitivity})$$

where

$$\text{Sensitivity} = (\text{Counts} / \text{Quantitation Unit})$$

- c. Matrix Efficiencies: The matrix efficiencies (counts/second/ $\mu\text{Ci/g}$) of the GS for Co^{60} and Cs^{137} gamma signals will be determined.
- d. Test Matrix: The MDL and matrix efficiency measurements will be performed by deploying the MSP in a test matrix which will be representative of that

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expected to be encountered during the Hanford CP deployment. The base of the test matrix should emulate the characteristics of the AX-104 vadose zone material. Those characteristics are summarized in the following table. BUYER and SELLER must agree on an appropriate test matrix prior to performance of these measurements.

Characteristic	Description
Morphology	Fine to Medium Grain Sand (0.25 to 0.5 mm)
Average Porosity	12% to 22%
Average Composition: Balance:	60 % to 90 % basaltic sand quartz sand
Representative Basalt	Frenchman Springs Member <div style="margin-left: 40px;"> Na_2O 2.8% MgO 4.5% Al_2O_3 13.2% SiO_2 50.9% K_2O 1.3% CaO 8.3% TiO_2 2.9% MnO 0.2% Fe_2O_3 (FeO) 15.2% </div>
Estimated Density	2.4 g/cm ³ [Assuming 17 % porosity and densities of 2.65 g/cm ³ for quartz and 3.0 g/cm ³ for basalt.]

- e. The test matrix will be spiked with the following target analytes:

Co-60	100 pCi/g
Zn	500 ppm
Zr	200 ppm
Cs-137	100 pCi/g
U	200 ppm

- f. The physical properties, chemical composition and homogeneity of the spiked test matrix will be determined by independent measurements with traceability to certified reference standards.
- g. Following completion of these tests, a 500 ml aliquot of the test matrix shall be retrieved and delivered to Hanford with the MSP probe.

CHECK STANDARD MEASUREMENT

- a. Repeatability: The relative standard deviation (% RSD) calculated for repeated measurements of stable check standards will be determined for the GS and XRF sensors. The RSD values will be calculated for sets of 10 repeated measurements of 300 seconds each for each sensor. Each measurement shall require removal and re-positioning of the check standards.
- b. Check Standards: The BUYER will provide appropriate check standards and measurement holders.

- c. The check standard measurements must be performed in two sets: 1) one set immediately preceding the characterization deployment test, and 2) one immediately after the final characterization deployment test.

DEPLOYMENT TEST

- a. The SELLER will demonstrate that the deliverable MSP is fully functional during an actual CP deployment at the SELLER's site. Test measurements will be carried out, witnessed by the BUYER, and appropriately documented as part of the final acceptance testing process.

CHARACTERIZATION DOCUMENTATION

The following documentation related to the preparation, performance, and record-keeping for the characterization task must be prepared:

- a. *Characterization work/test plan:* Prior to the initiation of performance characterization activities the SELLER will prepare a work/test plan describing specific tests, test methods, test sequences, test documentation, and reporting formats. The work/test plan shall be submitted for BUYER review and concurrence prior to initiation of test activities.

- b. *Definition of roles and responsibilities:* Definition of the roles and responsibilities of BUYER and SELLER personnel involved in the execution and certification of the characterization activities will be provided in the work/test plan.
- c. *Description/experience of personnel performing characterization:* Identification and qualifications of SELLER personnel performing the performance characterization measurements will be provided in the test plan.
- d. *Description of test/characterization apparatus:* A listing of all test and support equipment and apparatus utilized in the course of the performance definition measurements will be included in the test plan. Where applicable, calibration records, methods and standards shall accompany the identified items.
- e. *Test matrix preparation:* A detailed description of the test matrix preparation and characterization will be included in the test plan. Description of the materials, methods and equipment used shall be included.
- f. *Test matrix analysis:* Results of the independent analysis of the prepared test matrix will be provided. Analytical results will demonstrate the overall chemical and physical composition of the matrix, the spiking levels of target analytes, and the homogeneity of the target analytes in the matrix. Documentation shall include procedural references sufficient to establish traceability of the results to the protocols and standards of recognized, national certification bodies.
- g. *Description of reagents/standards:* Description, sources, data sheets, expiration dates, etc. shall be provided for all reagents and standard materials used in performing these test measurements.
- h. *Test data:* All raw, corrected and processed data generated in the course of the characterization/performance definition activities will accompany the final summary report.
- i. *Summary report:* Report summarizing the execution and results of MSP performance characterization activities.
- j. *Description of probe capabilities:* The SELLER will provide a comprehensive summary description of the capabilities and performance envelopes of each of the MSP sensors. The summary descriptions should include the sensor

identification, basic mode of sensor operation, range of application and specific performance characterization criteria.

7.0 DOCUMENTATION

The SELLER shall prepare and maintain documentation during the course of the task. In addition to routine status communications, SELLER documentation relating to compliance with this specification shall be maintained and compiled into a final summary report for transfer to the BUYER at the completion of the task. Performance characterization documentation (Section 6), any relevant final configuration drawings of the requested hardware, and summary reports, from the SELLER and any subcontractors to the SELLER, shall be compiled for transfer to the BUYER at the completion of the task. Documentation that is considered part of, and essential to this task include: configuration drawings, reports, test plans, acceptance test documents, operating procedures, and characterization/verification data. The content and plan for submittal of these items shall be finalized between the BUYER and SELLER early in Phase II. All requested/required documentation shall be transferred to the BUYER at the time of final acceptance test proceedings and deliverable/technology transfer. Specifically, the SELLER shall provide to the BUYER, in advance of the FAT proceedings, an inventory of documentation, hardware, and all deliverables that will be conveyed to the BUYER. This listing shall be reviewed and verified as a major item during the FAT. The related SOW for this task provides a listing of major documentation deliverables that are associated with this task.

7.1 Configuration Drawings

Configuration drawings that detail the design of the requested probes/hardware shall be included with the final task documentation submittal. In particular, drawings that document basic engineering, physical configuration/layout, and construction shall be prepared and conveyed to the BUYER. These drawings will be used to document the final probe configuration upon completion and to assist with future reference, maintenance, and modification, if needed, after the hardware is delivered to the BUYER.

7.2 Reports

Periodic status reports and final task reports shall be prepared to support this work. The SELLER shall compile all required documentation, as stated/requested in this specification as a deliverable. The format and Quality Assurance (QA) for these reports shall be consistent with current BUYER standards. The SELLER shall recognize that the completeness and quality of the reports and data supporting the subject task are essential to ensure that the final product (CP-probes) will be allowed for use in the Hanford tank farms operating environment.

7.3 Operating Procedures

Operating procedures for the requested CP-probes shall be prepared and conveyed at the completion of the task (during the FAT proceedings). The operating procedures shall address operational activities related to field setup, checkout, deployment, breakdown, and return to storage. The operating procedures will also be used as a reference base for both SELLER and BUYER to establish the safe and appropriate sequence of actions to test, deploy and operate the CP-probes. The operating procedures should be followed during the final acceptance testing process.

- a. Operating procedures shall include discussion of instrument operation pertaining to data gathering and data transfer (i.e., the use of the DAS for the MSP instruments).
- b. The SELLER shall provide the BUYER with draft operating procedure documents for review and comment prior the actual FAT proceedings.
- c. Final versions of probe operating procedures shall be transferred to the BUYER as deliverables during the FAT proceedings.

7.4 Test Plans

Tests plans will document the acceptance and operational testing that will be conducted to establish that the CP soil multisensor and soil sampler probes are properly built and will function as planned/designed when placed into service. The SELLER shall prepare test plans that will be submitted to the BUYER for review, approval, and witnessing. Test plans shall include, at a minimum, the following information:

- a. Traceability to the BUYER's purchase order document number
- b. Description of what is being tested (e.g., component, assembly, performance, subassembly, etc.)
- c. Sequential test steps
- d. Sequential points/items within test steps that must be performed
- e. Method that is used to perform the test (i.e., characteristic or attribute evaluated, report form used, fulfilment of purchase order requirement, etc.)

7.5 Miscellaneous Documentation

- a. Source code and/or script for software generated by the SELLER in the development and configuration of the MSP and CPP/MSP DAS shall be provided.
- b. XRF source capsule documentation (i.e., birth date documents, leak testing, etc.) shall be provided.

8.0 MISCELLANEOUS CONSIDERATIONS

8.1 Operating Environment

Engineering and construction of the CP-probes must consider/address the expected conditions at the planned deployment location (i.e., DOE Hanford Site, Washington).

- a. Radiation contamination control and decontamination of the probes during the hot deployment inside a tank farm must be considered.
- b. The fabrication/design of the probes shall include and document decisions regarding materials of construction in light of the anticipated deployment environment.

Examples:

- Excessive exterior wear on the probe surface (during the push action into Hanford soils) may translate into difficulty for decontamination efforts and may limit the reusability of the probes.
- Specification of the probe design, materials, wiring, and operation must address anticipated dust, moisture, humidity, heat, and cold conditions during actual deployment at the Hanford Site location.

8.2 Longevity

The currently planned operating period for the CP probes is a minimum of two years under normal operating conditions (i.e., Hanford deployment in tank farm). This period is expected to be achievable with normal usage and storage modes per directions from the SELLER.

- a. The SELLER shall consider the planned/anticipated period of use as part of the engineering requirements for the probes (e.g., materials, robustness of design, maintenance capability, etc.).
- b. The SELLER shall provide recommended operating and storage procedures to maximize longevity.
- c. The BUYER acknowledges that "normal" operating conditions do not include CP deployment equipment misuse or CP pipe/probe structural failure due to downhole pressures and conditions. The SELLER shall, however, describe and demonstrate that robust construction/assembly, and parts/materials selection, will support the expected period of use under normal conditions and following SELLER-prescribed deployment, storage and maintenance guidelines.
- d. Degradation of performance of the XRF sensor due to decay of the isotopic source is acknowledged to be "normal usage". Loss of operational life due to radiological and/or hazardous material contamination is also understood to be an unavoidable operational risk in the Hanford environment.

8.3 Packaging, Shipping, Storage, Handling of the CP-probes

When shipping, storage, or handling of the CP-probes is required the SELLER will provide:

- a. Appropriate protection from shock and dropping during shipping and handling.
- b. Stipulation of appropriate storage environmental conditions to ensure operability and longevity.
- c. Instructions regarding the packaging, storage and handling of the CP probes during use/operations and during non-operational (i.e. storage periods, in order to achieve the engineered longevity (Section 8.2).
- d. Provide any instructions and/or requirements for recharacterization, recalibration or realignment of the CP-probes prior to, during, or after use in the field
- e. Shipping, packaging, and labeling of all radioactive sources and samples shall comply with appropriate DOT regulations (49 CFR, Subpart 1).

8.4 Maintainability

During the planned period of intended use, and for periods of additional use and storage, the CP-probes will be in the care of and maintained by the BUYER. The SELLER shall provide the BUYER with documents, instructions, and information to enable appropriately qualified BUYER personnel to maintain the CP-probes in good working order without requiring the services of the SELLER.

- a. In addition to the operating procedures (Section 7.3) and the acceptance procedures (Section 6.1) the SELLER shall provide the BUYER, at the time of conveyance, with appropriate instructions, documentation, and call-out of special or needed tools, to perform general use and maintenance of the probes. General use includes installation/incorporation into the CP push piping string and field testing.
- b. The configuration and construction of the probes shall provide for disassembly to facilitate required repairs and maintenance.

8.5 Staff Qualifications and Training

Personnel selected to perform the work/activities to fulfill this specification shall have the experience and/or training commensurate with the work, complexity, or special nature of the activity.

8.6 Use of Sub-Contractors

The SELLER shall ensure that all sub-contracted work will be performed in conformance with the guidance and requirements provided in this specification. The SELLER shall be responsible for compiling and conveying, from sub-contractors, all required documentation and information that is requested from the BUYER.

8.7 Transfer of Final Product to BUYER

Technology transfer and conveyance of all associated deliverables for this task will occur via the process of final acceptance testing.

- a. Completion of the task shall be indicated by: signoff/approval of acceptance tests; completion and acceptance of all required documentation by the BUYER; and, receipt of the deliverables by the BUYER.
- b. Packaging and shipment to the BUYER shall be conducted to provide safe conveyance to the BUYER and to ensure that all shipping, handling, and storage requirements (Section 8.3) are met.

9.0 References

- ANSI-N43.2 American National Standards Institute document, *Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment*, dated May 1978
- ANSI-N43.5 American National Standards Institute document, *American National Standard for General Radiation Safety - Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources: Energies up to 10 MeV*, dated Feb 1975
- CFR-49 Code of Federal Regulations, 49 CFR, Subpart I - *Radioactive Materials*, Department of Transportation