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DOE-ORP Hanford Tank Farms
Vadose Zone Monitoring Project

Radionuclide Assessment System Operational Test Plan

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U.S. Department of Energy
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1.0 Introduction

The Radionuclide Assessment System (RAS) is being developed by MACTEC-ERS for the U.S. Department of Energy Grand Junction Office (DOE-GJO) to perform routine monitoring in existing monitoring boreholes adjacent to Hanford single-shell tanks (SSTs) for the DOE Office of River Protection (DOE-ORP).

The baseline vadose zone characterization project recently completed by MACTEC-ERS under the direction of DOE-GJO identified and quantified man-made gamma-emitting radionuclides associated with contaminant plumes in the vicinity of the SSTs. Data acquired during this project indicate the contaminant plumes have migrated within the vadose zone beneath the tanks and may be continuing to migrate. This conclusion is supported by evaluation of historical gross gamma logs collected from 1975 to 1994 in the tank monitoring boreholes and from evaluation of groundwater data. In response to these findings, DOE-ORP has authorized DOE-GJO to implement a monitoring program within the single-shell tank farms at Hanford that will be performed utilizing geophysical logging of selected intervals in the existing monitoring boreholes. The RAS was initially constructed to perform logging in 1996, but funding was discontinued. Beginning in Fiscal Year (FY) 2001, funding for the RAS was reinstated and the system is being prepared for field use.

2.0 Purpose

An Operational Test Plan (OTP) was developed for the RAS to evaluate the performance of the individual components, subsystems, and the RAS as a whole. The major tests were associated with the following:

1. Field Verification
2. Depth Control
3. Winch Speed Control
4. Log Header Completion
5. Detector Response
6. Gain Stabilization
7. Fundamental Gain
8. Data Resolution
9. Data Handling

The purpose of this document is to describe the elements of the OTP.

3.0 RAS Description

The RAS utilizes three sodium-iodide (NaI) detectors: a large (3-in. by 12-in.) detector for measuring background levels of gamma radiation; a medium (1.5-in. by 2-in.) detector for measuring moderate levels of contamination; and a small (1-in. by 1-in.) detector, which has been shielded with a lead collimator to provide a lateral view of the borehole. The small detector is used to measure moderate to high levels of contamination. Pulse-height data are digitized down-hole to maximize performance of the system. Each of the detector sections plugs into a common pulse height analyzer (PHA)/telemetry section, which digitally transmits full-spectrum data uphole to a personal computer (PC) controlled logging program. The combination of a detector and the telemetry section constitute the logging sonde. The LVMON logging software controls the PHA, stores the spectra for later processing, and displays the data. Five count rate windows are displayed: total gamma count rate, potassium, uranium, thorium, and cesium. The RAS is mounted on a standard-size pickup truck, which supplies power to operate the logging system.

Each of the detectors contains a separate high-voltage power supply/preamp, which is adjusted to make the gain of the three detectors comparable. A preamp sends pulses to the PHA, a Micro NOMAD manufactured by EG&G Ortec. The PHA communicates with a laptop computer at the surface through a serial link, which is multiplexed over a 0.125-in.-diameter single-conductor logging cable. The logging software control signals to the PHA, and the PHA sends an accumulated spectrum upon command. Power to the PHA and detectors is also supplied through the logging cable.

The laptop is also interfaced to a digital depth odometer, which in turn is interfaced to the logging winch. Depth and spectral data are assembled within the laptop by the logging program and stored internally on a hard disk. Concurrently with these activities, the logging program reduces each spectrum and extracts count rates in each of the five windows:

- total or gross gamma count rate over the entire spectrum
- ^{40}K, centered at the ^{40}K peak at 1461 keV
- ^{238}U, overlapping the two ^{214}Bi peaks at 1765 keV and 2204 keV
- ^{232}Th, centered at the ^{208}Tl peak at 2615 keV
- ^{137}Cs, centered at the ^{137}Cs peak at 662 keV

These count rates are displayed as borehole logs during the logging activity. Optionally, each spectrum may be displayed as it is collected and stored. The five windows are highlighted by color in the spectrum display.

Additional documentation for the individual components of the RAS and the logging software are located in the RAS system notebook and MACTEC-ERS office files. Modifications, repairs, and maintenance records for the RAS are documented in the RAS maintenance notebook and are also on record in the office files. Both notebooks will be available for reference and documentation during this test procedure.

4.0 Test Procedures

The following sections describe the procedures required to complete each of the components of the operational test plan. The results from these tests will be described on the summary sheets provided for the specific tests. Any deviations from these procedures will also be noted on the summary sheets.

4.1 Field Verification Test

Field verification measurements are required prior to and after a logging event by a particular detector to verify it is functioning within given parameters. These verification spectra are also used to provide channel to energy calibration. Spectra collected at GJO in 1996 by logging the K, U, and T models indicate that the conversion from MCA channel number to energy (the energy calibration) is nonlinear. Spectral nonlinearity is normal and expected with scintillation detectors using NaI(Tl) crystals. This being the case, each detector will have its own nonlinearity characteristics. Therefore, if we expect to obtain energy calibrations from field verification spectra, we must have a field verifier that gives gammas over a wide energy range. The Amersham KUTh field verifier (Serial Number 082) utilized with the spectral gamma logging system (SGLS) will be tested to see if its gamma output is intense enough to serve as a field verifier for the RAS. If the Amersham source is too weak, an alternative source will have to be found.

The detector will be placed in the field verifier (Amersham KUTh field verifier) and allowed to count for a specified time. After the time has elapsed, the count rates from each spectral window will be compared with acceptance criteria to determine if they fall within the specified limits. Acceptance criteria will be developed during the system's annual calibration and will not be available during this test. The purpose of this test is to determine if the verification procedure is acceptable and if the field verifier will produce adequate gamma flux for all detectors.

During testing, the following checks will be made:

- The software allows the operator to identify the spectra as a pre-cal and/or post-cal verification spectrum.
- The file is properly saved in the Ortec *.chn format.
- The software allows the operator to extract count rates from the windows in the field.

The verification files will be taken to the office for analysis utilizing the Aptec software, allowing the MACTEC-ERS technical lead to determine if the field verifier provides adequate gamma flux for each of the three detectors and if the counting times are sufficient for each detector.

4.2 Depth Control Test

Depth control is vital when evaluating possible contaminant movement in the vadose zone. Several components should be considered when testing the depth measurement and recording systems. An optical depth encoder on the winch provides signals to a digital readout mounted near the winch and to the computer so the software can track the current depth value. To test these components, a steel tape will be attached to the zero point on the large detector. The sonde will be zeroed at the top of the casing and run into the borehole. The sonde will be stopped every 10 feet (ft) and the value from the digital readout, the depth readout from the computer, and the measured depth from the steel tape will be recorded. This will be repeated every 10 ft to the bottom of the borehole and every 10 ft withdrawing from the borehole. Following withdrawal from the borehole and return to the "zero" position, the sonde will be lowered at least 20 ft into the borehole to simulate a repeat log. When the sonde returns to the zero depth reference (top of casing), a measurement will be made of the difference between the sonde zero reference and the top of the casing. All depth readings shall agree within a tolerance of +/- 0.10 ft.

The winch must also be able to hold the logging sonde at a constant depth while the winch control is in the stop position. This is necessary for the RAS to acquire stationary measurements in a borehole. The sonde shall not creep downward or upward while the 10-ft depth measurements are taken (as described in the previous paragraph).

The Mount Sopris MX series winch controller is supplied with an emergency brake switch. Applying the emergency brake disconnects the winch from the controller and applies a resistance across the winch motor armature, allowing the sonde to slowly creep downward but preventing a runaway sonde if power is lost. Application of emergency stop may allow the sonde to slowly creep down the borehole, but must prevent the sonde from freewheeling to the bottom of the borehole. The brake will then be released and the test will continue. Application of the brake should not introduce a variation in the depth readouts for the depth counter and computer.

4.3 Winch Speed Control Test

Most routine logging will be performed in the continuous logging mode. Speed control is vital for producing spectra with relatively consistent count times in the continuous logging mode. Winch speed control will be tested during this phase. The operator must be able to adjust and control the hoist speed while moving the sonde. The hoist must be able to maintain speeds as low as 0.5 ft/min and as fast as 20 ft/min. The speed of the hoist can be monitored on the laptop computer. At a logging rate of 0.5 ft/min, the speed should not fluctuate more than +/- 0.1 ft/min, and at a logging speed of 20 ft/min, the speed should not fluctuate more than +/-2 ft/min. A stopwatch will be used to measure the elapsed time between depth readings, and this time will be used to calculate the logging speed during this test.

The sonde will be positioned at the top of the borehole and lowered to a depth of 110 ft at 20 ft/min. The time to move the sonde from 0.0 to 110.0 ft will be recorded as well as the rate displayed by the computer. The distanced moved divided be the time recorded by the stopwatch will determine the logging rate. The time of each log run and the logging speed during the detector response test will be recorded. This will be repeated for each detector as specified in Section 4.5. The calculated rate must be within 10% of the rate displayed on the computer.

4.4 Log Header Test

Each log run will require the operator to complete a log header using the computer. The log header contains vital information regarding the borehole, pre- and post-survey verification, logging system, and the log run. This test will evaluate the LVMON software's ability to perform this task. To begin this test, the sonde will be positioned over a borehole and energized. The operator will initialize the LVMON logging program and after the header is invoked, will attempt to enter all borehole and logging information. While this is being performed, any errors in the software performance or deficiencies will be recorded. If a field is not required or is redundant, the software will be modified to remove the field. Likewise, data fields will be added as deemed necessary.

4.5 Detector Response Test

This is the final field system check and will evaluate the performance of all three detectors. A borehole will be logged with each detector using logging parameters that will be determined by the technical lead.
A 10-ft repeat section will be logged with each detector to assess the repeatability of the RAS data.

Successful completion of this evaluation will require that no computer lock-ups occur during logging and that spectra with ample count rates in each window be recorded at each sample interval. The small detector may not provide adequate spectra in regions of low gamma flux, which is acceptable because it will only be used to monitor intervals of high gamma flux.

4.6 Gain Stabilization Test

Gain stability of the RAS will be critical because of the use of spectral windows. Gain shifts may cause a portion of a spectral peak to move beyond the limits of a window, which would incorrectly affect the count rate in that window. Therefore, it is imperative that some sort of gain stabilization be utilized by the RAS during data collection.

Test spectra collected at GJO in 1996 and during the logging of borehole 41-09-39 in 1997 suggest that the system experiences gain shifts during operation. If the RAS has gain stabilization circuitry, it must always be operating during data acquisition. Whether or not the RAS has gain stabilization, gain shift should constantly be monitored during logging. The source(s) for these tests should have gammas over a wide energy range, and the tests should be conducted over the widest temperature range that can be reasonably achieved.

This test will be performed utilizing the large detector and an Amersham source (Serial Number 082). The system will be set up following the normal operating procedures and the large detector will be placed in the Amersham field verification source. Six 600-s spectra will then be collected at each time interval. The suggested time intervals are approximately 3:00 p.m., 9:00 p.m., and 3:00 a.m. The ambient air temperature and the temperature of the sonde housing will be recorded during the collection of each spectrum. The system will be left on between the time intervals and all spectra saved to the same directory. No attempt will be made to adjust the gain setting at any time during this test. The data will be transferred to the office for analysis to determine if any gain shift has occurred.

Several spectra taken over moderate counting times (e.g., six 600-s spectra) will be better than one spectrum taken over a long counting time (e.g., one 1-hour spectrum). In the spectra taken over moderate counting times, gain shifts would be revealed as changes in peak centroid positions that would be easy to measure and would allow detection of reversals in gain shift direction. If one spectrum were taken over a long counting time, gain drift would cause peak broadening that would be difficult to quantify (because of the poor energy resolution) and would obscure information about changes in the direction of gain shift.

Detector temperature is the main cause of system gain shift. The time periods during which spectra will be collected were chosen to provide the greatest range in ambient air temperature. A digital thermometer, similar to those used in the SGLS's, will be used to measure the temperature.

If the intensity of the Amersham source is insufficient, the tests may be conducted by logging various zones of the Hanford borehole calibration models. A disadvantage of conducting the tests in the models would be the relatively low temperature fluctuations that would be encountered.

4.7 Fundamental Gain Test

The physical gain setting for each detector was initially set so the gains settings of all three detectors were similar. These settings will be checked for each detector to verify there have been no significant changes. A small ^{137}Cs source will be used to collect spectra for each detector. Once the ^{137}Cs 662-keV peak has developed, gain adjustments will be made using the LVMON software to center the ^{137}Cs peak in the center of the ^{137}Cs window. The gain setting feature of the software will allow ample range for increasing and decreasing gain adjustments. If gain cannot be set for a particular detector with the LVMON software, the high voltage on the PMT bases will have to be adjusted.

The high voltage is adjusted by disassembling the detector and turning the potentiometer on the back of the PMT base. Small adjustments are recommended. This test may have to be repeated until the ^{137}Cs 662-keV peak centroids for all three detectors are within 20 channels.

4.8 Resolution Test

The resolution of each detector will be checked using a ^{137}Cs source. The as-built resolution of each detector is reported to be less than 8%. This was verified during the initial acceptance testing when the detectors were delivered to DOE-GJO in FY 1996.

One spectrum for each detector will be collected using a ^{137}Cs source. The spectra will be collected long enough to allow a clearly defined 662-keV peak to develop. The Aptec software will be used to calculate the FWHM of the 662-keV peak in each spectra. The FWHM shall be less than 10% for each spectrum to pass this test.

4.9 Data Handling Test

Log data will be transferred from the field to the main office using the proposed protocol. The proposed protocol will ensure the data and any log data sheets are transferred to the office, and copied to the server within 24 hours of data collection. Feedback will be provided from the technical lead that data have been received and backed-up successfully. An analyst will process the data copied to the server to ensure that all files were transferred and that the data were not corrupted during the transfer process.

5.0 Other Considerations

All other RAS components will be evaluated during these tests. In particular the motor vehicle, sheave wheel assembly, hoist brake, power inverter, and storage racks will be examined closely for possible problems. Identified problems will be noted and corrected before the RAS is field deployed.

A test procedure outline is provided in Appendix A. This outline will be used as a guide by the logging engineers performing the individual tests in the field.

Some portions of this test may have to be repeated or revised as problems are discovered and the system repairs are made. These changes will be discussed in the OTP test results report.

6.0 Test Conclusions

Upon completion of this test, all data sheets will be compiled and a summary report will be prepared. The summary report will describe all deficiencies observed and their resolution. Recommendations will also be made to improve the system's performance and a "lessons-learned" document will be prepared to discuss improvements to the RAS and to aid in future system design.

Sections should also be included to discuss implementation of the routine operational and data handling procedures. Finally the report will discuss any additional testing that should be performed for further evaluation of the RAS.

Appendix A
Test Procedure Outline

1.0 Field Verification Test

- Collect one 300-s live time spectra with each detector from the Amersham verifier.

2.0 Depth Control Test

- Zero sonde at the top of the casing and attached steel tape.
- Run sonde into borehole stopping every 10.0 ft to record digital readout from encoder, the depth readout from the computer, and from the steel tape.
- Repeat this process while withdrawing the sonde from the borehole and return to the zero. position (top of casing). Record the difference between the sonde zero and the top of the casing.
- Simulate a repeat by lowering the sonde at least 20 ft into the borehole and repeat the process.
- Apply the emergency brake at least twice during this test.

3.0 Winch Speed Control Test

- Performed in conjunction with the Detector Response Test.
- Move the sonde from 0.0 to 100.0 at 20.0 ft/min and record the time.
- Record the time required for each log run and the logging speed.
- Repeat for each detector used during the Detector Response Test.

4.0 Log Header Test

- Power up system and enter log header information.
- Turn off computer, then reboot and attempt to reenter header information.

5.0 Detector Response Test

- Log entire borehole with all three detectors using provided logging parameters.

6.0 Gain Stabilization Test

- Collect six 600-s live time spectra with the large detector in the Amersham verifier at 3 p.m., 9 p.m., and 3 a.m.
- Record air temperature and sonde housing temperature during the collection of each spectra.
- The system will be left on during the entire test.

7.0 Fundamental Gain Test

- Collect 1 spectrum with each detector using a ^{137}Cs source.
- Compare the centroid channel of the 661-keV peak for each spectra. They should be within 20 channels of each other.

- Adjust the high voltage on the PMT base to bring the gain of each detector to with in 20 channels of each other.

8.0 Resolution Test

- Collect 1 spectrum with each detector using a ^{137}Cs source.
- Use the Aptec software to calculate the FWHM. The FWHM should be less than 10% for each detector.

9.0 Data Handling Test

- Transfer data collected from the Detector Response Test to the office using the proposed protocol.

Appendix B
Operational Test Results Summary Sheets

Field Verification Test Results		
Date:	Logging Engineer:	
Location of Test:		
Large Detector Test		
File Name:	Time:	Counting Time:
Gross Counts:	Dead Time:	
Total Counts in ^{137}Cs Window:		
Total Counts in ^{40}K Window:		
Total Counts in ^{238}U Window:		
Total Counts in ^{232}Th Window:		
Medium Detector Test		
File Name:	Time:	Counting Time:
Gross Counts:	Dead Time:	
Total Counts in ^{137}Cs Window:		
Total Counts in ^{40}K Window:		
Total Counts in ^{238}U Window:		
Total Counts in ^{232}Th Window:		
Small Detector Test		
File Name:	Time:	Counting Time:
Gross Counts:	Dead Time:	
Total Counts in ^{137}Cs Window:		
Total Counts in ^{40}K Window:		
Total Counts in ^{238}U Window:		
Total Counts in ^{232}Th Window:		
Signature:		Date:
Geophysicist/Technical Lead:		Date:

Depth Control Test Results		
Date:	Logging Engineer:	Borehole:
Steel Tape Serial Number:		Detector Used:
Recorded/Measured Depths (ft)		
Steel Tape	Optical Encoder Readout	Computer
Notes:		
Return Error:		
Signature:		Date:

Winch Speed Control Test			
Date:	Logging Engineer:	Borehole:	
Detector Used:			
10 - 110 ft	Rate from computer:	Time:	Rate:
110 - 10 ft	Rate from computer:	Time:	Rate:
Detector Used:			
10 - 110 ft	Rate from computer:	Time:	Rate:
110 - 10 ft	Rate from computer:	Time:	Rate:
Detector Used:			
10 - 110 ft	Rate from computer:	Time:	Rate:
110 - 10 ft	Rate from computer:	Time:	Rate:
Comments:			
Signature:		Date:	

Log Header Test Results	
Date:	Logging Engineer:
Note any bugs in software:	
Note data fields that are not required:	
Note additional data fields that need to be added:	
Comments:	
Signature:	Date:

Detector Response Test Results	
Date:	Logging Engineer:
Large Detector Response Test	
Borehole:	Depth Interval:
Depth Start:	File Start:
Depth Finish:	File Finish:
Counting Time:	Logging Speed:
Sample Interval:	Depth Return Error:
Medium Detector Response Test	
Borehole:	Depth Interval:
Depth Start:	File Start:
Depth Finish:	File Finish:
Counting Time:	Logging Speed:
Sample Interval:	Depth Return Error:
Small Detector Response Test	
Borehole:	Depth Interval:
Depth Start:	File Start:
Depth Finish:	File Finish:
Counting Time:	Logging Speed:
Sample Interval:	Depth Return Error:
Comments:	
Signature:	Date:

Gain Stabilization Test Results

Date:	Logging Engineer:
Location of Test:	
Detector Used:	Counting Time:

File Name	Start Time	Temperature		Centroid (Channel)	
		Ambient Air	Sonde	609.3 keV	1460.8 keV

Comments:

Signature:	Date:

Fundamental Gain Test		
Date:	Logging Engineer:	
Detector:	Source:	Counting Time:
File Name:	661 keV Centroid Channel:	
Detector:	Source:	Counting Time:
File Name:	661 keV Centroid Channel:	
Detector:	Source:	Counting Time:
File Name:	661 keV Centroid Channel:	
Comments:		
Signature:		Date:

<table>
<tr><th colspan="3">Resolution Test</th></tr>
<tr><td>Date:</td><td colspan="2">Logging Engineer:</td></tr>
<tr><td>Detector:</td><td>Source:</td><td>Counting Time:</td></tr>
<tr><td>File Name:</td><td colspan="2">661 keV Peak FWHM (%):</td></tr>
<tr><td>Detector:</td><td>Source:</td><td>Counting Time:</td></tr>
<tr><td>File Name:</td><td colspan="2">661 keV Peak FWHM (%):</td></tr>
<tr><td>Detector:</td><td>Source:</td><td>Counting Time:</td></tr>
<tr><td>File Name:</td><td colspan="2">661 keV Peak FWHM (%):</td></tr>
<tr><td colspan="3">Comments:</td></tr>
<tr><td colspan="2">Signature:</td><td>Date:</td></tr>
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