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OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DEVELOPMENT PLAN (DP) CHECKLIST AND COVER SHEET

QA: QA

DI No.:	MYPS No.:	Technical Product Title:	Rev. No.:
TDP-EBS-ND-000003	12012383MT	Engineered Barrier System Thermal/Hydrologic/Chemical (EBS THC) Column Testing	00

Requirements Checklist (Ref. QARD Subsection 2.2.5 and Supplement III)

Requirement	Applicable to This Product? (Y?N)	If Yes in Previous Column, Describe Satisfaction of Requirement (Add Attachments and Reference if Necessary). If NO in Previous Column, Justify.
(1) Define work scope and objectives, and list the primary tasks involved.	Y	See Sections I and II on page 2
(2) Identify scientific approaches or technical methods used to collect, analyze, or study results of the work.	Y	See Section VIII on page 7
(3) Identify applicable standards and criteria.	Y	See Section VIII on page 7
(4) Identify and/or create implementing documents (procedures) required to perform the work.	Y	See Section VIII on page 7
(5) Identify equipment (and the functional requirements of the equipment) required to perform the work.	Y	See Section VI on pages 4-6
(6) Identify records required to verify completion of the work and results obtained.	Y	See Sections IV and V on pages 2-4
(7) Identify QA program applicability including QA/QC verification of work. If necessary, perform a QAP-2-0, *Conduct of Activities*, evaluation.	Y	See Section X on page 8
(8) Identify prerequisites, special controls, environmental conditions, processes, or skills.	Y	See Section V on page 3-4
(9) Identify computer software required to perform the work and the qualification status of the software.	Y	See Section VI on page 5
(10) Does this work impact baseline (see AP-3.4Q)?	N	
(11) Coordinate planning with organizations providing input or using results. Document concurrence, if appropriate. (Develop an Interface Control Document.)	N	
(12) Identify accuracy, precision, and representativeness requirements for, and limitations on, the results.	Y	See Section IV on pages 2-3
(13) Identify any personnel safety hazards and corresponding hazards controls in accordance with the Integrated Safety Management principles.	Y	See Section VII on page 7

Preparer/Originator: (Printed Name) Veraun Chipman	Signature: Veraun Chipman	Date: August 5, 1999
Lead/Supervisor: (Printed Name) William Lowry	Signature: William Lowry	Date: August 5, 1999
Responsible Manager: (Printed Name) John Pye HEMISPHERE NUCLEAR	Signature:	Date: August 16, 99

I. OBJECTIVE

The objective of this Development Plan is to define the design, implementation, and reporting requirements for a series of scaled thermal-hydrologic-chemical (THC) column tests to be performed by the Engineered Barrier System (EBS) Testing Department. Testing results will: (1) characterize potential backfill and invert materials, (2) evaluate THC coupled processes that could impact EBS performance, and (3) provide needed data for validating THC models for the EBS Process Model Report (PMR), Rev. 01.

II. SCOPE

The goals of the THC column testing are:

1. Compare THC effects in different materials (e.g. crushed tuff, quartz sand, or limestone).
2. Characterize THC coupled processes that could affect drip shield performance, particularly the magnitude of permeability reduction, the nature of minerals produced at or near the drip shield surface, and chemical fractionation (i.e. concentrative separation of salts and minerals due to boiling point elevation).
3. Analyze the composition of fluid that reenters the backfill after heating, and remobilizes the precipitates.
4. Generate data for validating THC predictive models which will support the EBS PMR, Rev. 01.

III. BACKGROUND

The EBS Degradation, Flow & Transport PMR will be based on supporting models for in-drift THC coupled processes, and the in-drift physical and chemical environment. These models describe the complex chemical interaction of EBS materials, including backfill and invert materials, with the thermal and hydrologic conditions that will be present in the repository emplacement drifts. Test data are needed for model validation, and to support selection from among candidate materials. Preliminary data obtained from the tests described in this DP will be used for the EBS PMR Rev. 00, and more complete information will be supplied for Rev. 01.

IV. DESCRIPTION OF THE TECHNICAL DOCUMENT

The level of detail contained in the report will be sufficient to reproduce the tests. The report will specifically identify test results (i.e. data) which can be used to support model validation and material selection. Selected data as appropriate to satisfy the objectives will be submitted to the Technical Data Management System (TDMS). The report will contain the following:

1) **Title Page**
   Includes: complete title; appropriate document identifier; QA designator; signatures and dates for the Preparer, Checker Concurrence, and Approver of the Technical Document; organizational/company affiliation(s), if applicable; security notices, if applicable; and contract numbers, if applicable. The Reviewer's signature, indicating concurrence, may be included on the title page(s).

2) **Table of Contents, List of Figures, and List of Tables** (as applicable)

3) **Objective and Scope**
The Objective and Scope of the report are to be defined.

4) **Quality Assurance**
The applicability of the Quality Assurance program shall be noted including the applicability of the *Quality Assurance Requirements and Description* (DOE 1998b) program. This section should note if an activity evaluation in accordance with QAP-2-0, *Conduct of Activities* (CRWMS M&O 1998b) was conducted. Describe the use of computer software, if applicable.

5) **Description of the Test Configuration**
Describe how the test was configured and performed.

6) **Description of the Information to be Produced**
Describe the results (i.e. data) obtained from testing and how the results will be used to support the EBS PMR. Also identify data to be submitted to the TDMS.

7) **Summary**
Provide a summary of the entire testing process, describe how the results were affected by the test configuration, and make any appropriate recommendations.

8) **References**
Provide a list of references used in the report. All references used shall be in the Technical Information Center or the Records Information System. Provide the DIRS for each reference.

9) **Attachments**
Provide attachments used in the report. This will include the schedule information.

V. RESPONSIBILITIES

The following table summarizes the various personnel and their respective responsibilities for the design, fabrication, implementation, analysis and reporting of the THC columns tests described in this DP. Responsibility for the review and approval of the Development Plan as well as the Technical Report lies with the EBS Performance Testing Department. The Department Manager will provide final approval authority. All personnel participating in THC column testing are expected to be qualified by a combination of education, technical training, experience and Quality Assurance training. All personnel directly participating in the THC column tests are also expected to keep a Scientific Notebook in accordance with AP-SIII.1Q. In addition, the following will be documented by objective evidence:

- Procurements
- Measurement and Test Equipment and calibration

- Samples and their chain of custody

Table 1: Responsibility Matrix

Title/Role	Person/Organization	Comments
Responsible Manager	John Pye (M&O)	Responsible for test requirements and specifications
Lead Supervisor	William Lowry (SEA)	Responsible for test oversight, design, fabrication, implementation and data analysis
DP Preparer/Originator	Veraun Chipman (SEA)	Responsible for test design, fabrication, implementation, data analysis and technical reporting
Predictive Modeling	Ernest Hardin (M&O/LLNL)	Also responsible for test specifications and data analysis
Field Test Data Manager	Fred Homuth (TCO)	Responsible for Data Collection System configuration, operation, data management and data transmittal
Water Sampling and Analysis	USGS	
TCO Project Engineer	Douglas Weaver (M&O/LANL)	Responsible for field work packages, work instructions, field test coordination and ES&H reviews

VI. TECHNICAL APPROACH

General Test Description

Initially, two column configurations will be used for THC testing (alternative configurations may be developed instead, and appropriate changes to this DP will be made accordingly). The test program assumes that the two configurations will be run simultaneously. The general designs are similar and will require similar test hardware.

Saturated Alteration Test

This test will replicate a previously reported test by Rimstidt (Rimstidt and Williamson 1991). A vertical column will be closed on the bottom and vented at the top. A heater will be installed in the bottom, and the column will be filled with backfill or invert material. Purified water will be

introduced near the bottom from a reservoir, which keeps the liquid level constant so that the bottom 10% (approximate) of the column is saturated. The column will be boiled vigorously, and condensation will occur in the upper, unsaturated part. Condensate will percolate downward through the column. Escaping water vapor will be collected at the top, condensed, and measured for mass balance. Probes at several elevations in the column will measure temperature, and water samples will be obtained from the saturated part using a syringe, wicks or lysimeters. A permeability survey will be conducted pre-test, and after the heated test. Ports in the side of the column will allow sampling of fluids and access for temperature probes and permeability testing. Expected test duration will be 4 to 6 weeks. Heating will conclude when one of the following conditions occurs: (1) significant decrease in water consumption; or (2) significant change in temperature of the lower (nominally saturated) region of the column. Before cessation of heating, the water inlet port will be removed, cleaned, and replaced to verify that clogging of the port is not a factor (clogging of the column is a factor and will be the basis for cessation of the test). After testing, the column will be disassembled and the contents recovered in sections for chemical and mineralogical analysis.

Unsaturated THC Column Test

The unsaturated THC column test will consist of two plates separated by a prescribed distance (nominally 10 times the maximum grain size of the granular material), and insulated on the sides. Water of known composition (e.g. 10x J-13) will be introduced at a metered rate to the top of the column. The input power and the injection rate will be adjusted so that boiling is complete about halfway down the column. Water vapor will be collected, and temperature will be measured similar to the saturated test described above. Water samples may be obtained using wicks or lysimeters. A permeability survey will be repeated as described above. The initial heating phase will end when permeability and chemical conditions have changed significantly, whereupon small samples of the granular material will be obtained from within the column. The column will then be reassembled and the input power level gradually decreased as injection continues. Water will be collected from the bottom of the column when it breaks through, and analyzed for key constituents such as halides. Injection will continue until ambient temperature, or stable output composition is reached.

Predictive Modeling

Each column test will require a predictive model using NUFT 3.0. Predictive modeling should provide scoping results which will guide the column test configurations and should be completed prior to starting the test. The predictive analyses may be run concurrently with column test planning, design and fabrication.

General Test Sequence

1. Prepare water, granular material, and test hardware in the appropriate configuration.
2. Fill the test column with granular material.
3. Measure the baseline air permeability distribution in the column.
4. Apply heat to the column and monitor baseline conditions at elevated temperatures (dry).
5. Introduce water at the prescribed rate.
6. Adjust thermal power input to achieve prescribed thermal or mass transfer conditions.
7. Run at a constant thermal and water flux conditions for a prescribed period or until endpoint conditions are achieved. Test durations of 4 to 6 weeks are anticipated.
8. Measure temperature and obtain water samples periodically.

9. Periodically stop water injection, cool, and survey the air permeability distribution in the column.
10. Terminate the test after the prescribed endpoint conditions are met or exceeded.
11. Perform a post-test permeability survey.
12. Obtain granular samples from the column for analysis of precipitate and salt deposits.

Primary Measurements, and Method of Measurement

- Heat input (power meter on heater plate)
- Temperature distribution (array of RTD temperature sensors)
- Location of boiling front (obtained from vertical temperature distribution)
- Infiltration rate (platform scale on injection fluid tank)
- Vapor loss rate (flow vented water vapor through condenser and collect in tank on platform scale)
- Air permeability distribution before and after the test, and at selected points during the test as described above (flow metered air through column and measure pressure at various positions)
- Water composition at various times in the test duration (use wicks or lysimeters to collect water from unsaturated granular material, and use syringe to collect from saturated zones. Analyze for constituents as appropriate)
- Distribution of minerals and salt in granular material (visual inspection, sampling, splitting, leaching into purified water, chemical analysis of dissolved species, mineralogical analysis of solid material)

For each column test assembly, the following approximate number of measurements will be recorded on periodic basis:

- 15 temperatures (RTDs)
- 2 platform scale outputs
- 1 heater power input

Data Acquisition, Management and Distribution

All measurements will be logged by qualified and calibrated Geomation dataloggers, managed by the TCO. Data will be distributed by the TCO in similar manner as the pilot-scale tests (i.e., quick-look access to non-Q data, CDs of Q data distributed as required).

Facility Requirements

Each of the two column tests will require a bench space of nominally 3' by 8'. An additional bench is needed for sample handling and water preparation. The column tests will be conducted in a room or laboratory with air conditioning for ambient temperature control. The tests may be conducted in the Atlas facility. The maximum electrical load per column is the column heater, at a maximum of 500 watts (110 VAC). Running water in the immediate vicinity is not required. The water evolved from the column tests is essentially distilled water and will be suitable for disposal in the facility drains.

VII. HEALTH AND SAFETY

No dye tracers are anticipated. For some tests water will be prepared to match the composition of J-13 water, which will require the addition of minerals and salts prior to injection in the column. In the column tests a significant amount of heat will go into vaporization of the infiltration water, which will be condensed in a chiller system. Consequently, high temperatures (up to 200 or 300°C) will exist and protective features will be incorporated into the test design and procedures. Under normal operation no high temperature surfaces will be exposed. Site specific hazard identification, mitigation and site specific hazard training requirements will be included as a section both the Field Work Package and subsequent Work Instructions. In addition, a Job Safety Analysis may be developed for a set of activities exhibiting specific hazards.

VIII. SCIENTIFIC APPROACH, STANDARDS, AND PROCEDURES

The scientific approach and technical methods, standards, and procedures used to collect, analyze and interpret the results of the THC column tests will be identified. Where applicable, existing procedures and standards will be used for the following:

- General test conduct
- Testing water fabrication
- Water sampling, handling, and chemical analysis
- Air permeability measurement
- Granular material sampling, handling, and analysis
- Data collection and management

Where procedures or standards do not exist, and are needed for the tests, they will be written in accordance with applicable requirements and procedures, and appropriate changes to this DP will be made. General documentation of the THC column test configurations, progress, observations, and results will be accomplished using scientific notebooks per AP-SIII.1Q. Each separate organization involved with THC column testing will be responsible to maintain its own respective scientific notebook(s). In addition, all procedures and notebooks will be either included as references or as actual attachments in the Technical Report.

IX. SCHEDULE

Two column tests are expected to be underway by the end of fiscal year 1999 (September 30). Any pertinent results or data obtained prior to the end of FY99 will be reviewed and submitted to appropriate users as scoping data. Depending on the number of subsequent column tests, the final Technical Report will be written during FY00. Interim reports will be written as specific column tests are completed. Results and data to be used will be verified and submitted to the TDMS concurrent with this schedule. The review process for this Technical Report will be in accordance with Section 5.4 of AP-3.11Q *Technical Reports* (DOE 1999). The final document will be approved in accordance with Section 5.5 of the procedure. Specifically, the document will be compared to this DP for accuracy and completeness. After comparison to this DP, the document will be accepted after

it is signed by the Manager of the EBS Performance Testing Department. The approved document will be submitted to the Document Control Center for distribution.

X. QUALITY ASSURANCE

A QAP-2-0 *Activity Evaluation of the EBS Testing Program* (CRWMS M&O 1999) concludes that the testing program is quality-affecting. The QAP-2-0 Activity Evaluation also revealed that the EBS Testing Program affects items on the *Q-List* (DOE 1998a) and is therefore subject to the *Quality Assurance Requirements and Description* (QARD) (DOE 1998b).

XI. REFERENCES

CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor) 1999. *Publishing Style Guide* A00000000-01717-5600-00002 REV 5. Vienna, Virginia: CRWMS M&O. ACC: MOV.19990726.0003.

CRWMS M&O 1998b. *Conduct of Activities*. QAP-2-0, REV 5. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980826.0209.

CRWMS M&O 1999. *Activity Evaluation of the EBS Testing Program*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990630.0473.

DOE (U.S. Department of Energy). 1998a. *Q-List*. YMP/90-55Q, REV 5. Las Vegas, Nevada: Office of Civilian Radioactive Waste Management. ACC: MOL.19980513.0132.

DOE 1998b. *Quality Assurance Requirements and Description for the Civilian Radioactive Waste Management Program*. RW-0333P, REV 8. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19980601.0022.

DOE 1999. *Technical Reports*. AP-3.11Q, REV 0. Las Vegas, Nevada: Office of Civilian Radioactive Waste Management. ACC: MOL.19990701.0620.

Rimstidt, J.D. and Williamson, M.A. 1991. Vertical Thermal Gradient Experiment Results - Draft. Las Vegas, Nevada: Mifflin and Associates, Inc. TIC: 205125.