ADDENDUM D

Description of Phase 3 of the Ventilation Test

(Added for Revision 3)

Civilian Radioactive Waste Management System

Bechtel SAIC Company

Description of the Phase 3 of the Ventilation Test

Rev 1, May 30, 2001

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PREFACE

This document was prepared as an addendum to the Office of Civilian Radioactive Waste Management Technical Work Plan (TWP) for the subsurface performance testing program to describe the Phase 3 of ventilation test in greater detail than contained in the TWP. The TWP briefly describes the four phases of the ventilation test as follows:

Phase 1- Heat-only test using ambient air for ventilation
Phase 2- Heat-only test using conditioned air (heated or cooled) for ventilation
Phase 3-Heat-moisture test using ventilation air with moisture added
Phase 4- Blast cooling test using ambient air ventilation

The phase 3 of the test is being designed to acquire data for the validation of the MULTIFLUX Version 2.0 or other similar computer codes. The Phase 1 and 2 of the test implementation was managed through Interoffice Correspondence (IOC), (Kalia, H.N., 2000, "Guidance for the Ventilation Test" June 20, 2000, LV.SSPTS.HNK.06/00-006, ACC: MOL.20000907.0244).

This document is a plan giving guidance for how to conduct Phase 3 of the ventilation test. Changes or additions may be made in the test details to accommodate new knowledge, insights, model needs, and test method developments as the experiment is installed and conducted. All activities carried out during conduct of this test, whether following the specifications in this document, or deviations from the plans described herein, will be documented in appropriate YMP records.

This test description has been reviewed for the technical content by:

Reviewer	Initial	Date	Affiliation
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DISCLAIMER

DESCRIPTION OF PHASE 3 OF THE VENTILATION TEST

Description of Phase 3 of the Ventilation Test

1.0 APPLICABILITY OF QUALITY ASSURANCE AND INTEGRATED SAFETY MANAGEMENT SYSTEM PROGRAM

This test will be performed in full compliance with the Yucca Mountain Quality Assurance (QA) and Integrated Safety Management (ISM) requirements.

1.1 Quality Assurance

This test will be performed in full compliance with the Yucca Mountain Quality Assurance (QA) and Integrated Safety Management (ISM) requirements. Some or all of the following QA procedures apply to this activity:

AP-3.10Q	Analysis and Models
AP-3.11Q	Technical Reports
AP-3.12Q	Calculations
AP-3.14Q	Input Request
AP-5.2Q	Testing Work Packages
AP-7.6Q	Procurement of Items and Services
AP-12.1Q	Control of Measuring and Test Equipment and Calibration Standards
AP-17.1Q	Record Source Responsibilities for Inclusionary Records
AP-SI.1Q	Software Management
AP-SIII.1Q	Scientific Notebooks
AP-SIII.3Q	Submittal and Incorporation of Data to the Technical Data Management System
AP-SV.1Q	Control of the Electronic Management of Data

This test will be managed in accordance with the Technical Work Plan: "Subsurface Performance Testing for License Application for Fiscal Year 2001". Quality verification will be accomplished through surveillance and self-assessments.

1.2 Integrated Safety Management

This test will be performed in the Yucca Mountain Site Characterization Project (YMP) Engineered Barrier Systems (EBS) test facility located in North Las Vegas (NLV) Complex U.S. Department of Energy (DOE). The testing in the NLV is subject to the ISM requirements of Bechtel Nevada (BN) and the YMP.

Section 4 of the Field WorkPackage (FWP), "Engineered Barrier Systems-Pre-Closure Ventilation Testing" describes various aspects of Environment, Safety, and Health (ES&H) requirements and compliance. This document also contains a hazard analysis for testing activities.

2.0 PURPOSE AND OBJECTIVES OF TESTING

The design of the YMP potential repository Lower Temperature Operating Mode calls for keeping the host rock temperature below boiling (slightly less than 100^{o} C). During the preclosure period, the heat produced by the waste packages will be removed by forced or natural ventilation to achieve this potential repository design goal. The ventilation system design will be based on calculations of how much heat can be removed under a range of conditions. Examples of the design aspects affected are quantity of airflow, ventilation air temperature, and drift and waste package configuration. The relations between the heat removal and moisture removal to ventilation conditions needs to be better understood to reduce uncertainties in the ventilation system design. This test will provide data that will remove a significant amount of this uncertainty.

2.1 Purpose of Testing

The purpose of Phase 3 of the ventilation test is to acquire data to reduce uncertainties in the models of heat removal and for the validation/verification of the ventilation model MULTIFLUX Computer Code Version 2.0 (MULTIFLUX). The MULTIFLUX code is an application that couples the NUFT porous medium code (to calculate the heat and mass transport within the waste emplacement drift host rock) with a computational fluid dynamics code (CFD) that can evaluate the free air movement and heat and moisture transport inside the potential repository emplacement drifts. The MULTIFLUX CFD module uses a lumped parameter approach to simulate airflow along the length of the drift, producing bulk (average) values of air temperature and moisture content and spatial distributions of waste package temperature and drift wall temperature.

A unique feature of the MULTIFLUX simulation is the manner in which it represents changes to the water vapor content in air in the CFD module. Water vapor affects the overall drift heat transfer due to the effect of phase change (and associated energy absorption) from the liquid to vapor state (latent heat), redistribution of vapor, and energy absorption in another location. This process is represented within MULTIFLUX and influences the amount of heat removed from the host rock and the invert. The test will measure the moisture and heat removal from the controlled system that is one fourth the scale of the potential repository emplacement drifts. Test data will be used to validate models for this process quantitatively. The models will be used to simulate the thermal response of the potential heated emplacement drifts.

This test will enhance confidence that the emplacement drifts in the potential repository can be maintained at or below the boiling temperatures of water and reduce uncertainty in predicting the thermal environment of the emplacement drifts.

2.2 Models to be Tested/Refined with Acquired Data

The data obtained from this test will be used for the validation of the ventilation model implemented with the MULTIFLUX Computer Code Version 2.0. The acquired data will also be used to guide the design of ventilation system for the potential repository.

3.0 WORK SCOPE

3.1 Product Description

Pretest predications and uncertainty analyses will be completed before the start of the test. These predictions may be used as a guide to procure and calibrate test instruments, identify needed control of variables and establish appropriate boundary conditions requirements and instrument calibration requirements.

At the conclusion of the test, a report will be prepared to describe any problems encountered during the performance of the test. This report will also describe the application of data for the validation of computer models.

The products of this activity will consist of scientific notebooks, pretest predictions, sensitivity and uncertainty analyses, comprehensive test report, Data Tracking Numbers (DTN), procurement records, and instrument calibration records.

3.2 Responsibilities

Overall, technical direction for test design and conduct, customer interface, and technical data management will be the responsibility of the EBS Integration and Implementation Manager. The Test Coordination Office (TCO) Manager will be responsible for test operations, procurement, installing test and installing and operating DCS. TCO staff will prepare Work Instructions and FWP. The TCO staff will integrate operational ES&H related activities with BN and the YMP staff. BN will provide the test support facility and craft/labor support to install the test.

3.3 Activity Identity and Tasks Definition

Validation of the ventilation model requires quantifying the amount of moisture evaporated from a wet surface area within the test configuration. This wet surface area is where moisture is introduced into the ventilation air. The present ventilation test configuration will be modified to include a suitable wet surface for adding water within the heated test section. This test modification will be accomplished by placing a series of shallow, open trays containing porous media such as crushed welded tuff, sand or blocks of welded tuff. The porous media will be selected based on a small-scale laboratory test. Provisions will be made to add and quantify water to the trays as it is removed from the test train by the air. Reconfiguration of the ventilation test to enable the conduct of Phase 3 testing will occur following the completion of the Phase 2 of the ventilation test. A detailed schedule is presented in Figure 1. Some of the major activities are as follows:

- Prepare Test Description
- Develop List of Required Instruments
- Prepare Test Installation Details
- Procure Heaters and Instruments
- Perform Pretest Predictive Calculations and Uncertainty Analysis
- Calibrate Instruments
- Remove Intake and Exhaust End
- Remove Internal Components of the Phase 2 of the Test
- Verify Calibration of Existing Instruments
- Calibrate/Recalibrate Instruments as Required
- Refurbish Waste Packages and Install New Heaters
- Fabricate Water Trays
- Clean Internals of the Phase 2 Test
- Install Water Delivery System and Load Cells
- Install Waste Packages
- Install Instruments
- Connect Power to the Heaters
- Check Out Test Instruments and Cables
- Re-Install Intake and Exhaust Ends of the Test
- Connect Instruments to the Data Collection System (DCS)
- Perform Pretest Checkout
- Conduct Tests in Accordance to the Test Matrix, Table 1
- Start and Complete Test # 1-24
- Start and Complete Test # 25
- Start and Complete Test # 26
- Submit Data to the TDMS
- Submit Test Records To The Records Processing Center (RPC) and the TDMS
- Complete Test Report
- Decommission the Test

3.4 Schedule

Tentative schedule for the major activities for the installation of Phase 3 of the Ventilation Test is shown in Figure 1.

4.0 SCIENTIFIC APPROACH/TECHNICAL METHODS

4.1 Pre-Test Analysis/Model Predictions

Prior to the start of the test pretest calculations will be performed using the ventilation model to be validated to predict the anticipated test response. This information will be used to set the alarm limits for the data acquisition system. The pre-test calculations will also include sensitivity and uncertainty analysis.

4.2 Test Methodology

This test will be performed in the existing ventilation test train to simulate various longitudinal segments of the emplacement drifts. This will be accomplished by setting the test inlet conditions (temperature, airflow rate, and relative humidity) to those predicted by the pretest analysis. The anticipated drift conditions for the test will be determined by pretest calculations using the ventilation model. The existing test train deployed for Phase 2 of ventilation test shall be modified. Major modifications consist of removing the waste packages and reinstalling new heaters, installing trays to introduce water/moisture in the test train, installing load cells under the trays to facilitate mass balance calculations, installing water delivery systems, and installing additional relative humidity and temperature indicators. Ten trays, five on each side of the waste package line will be installed. Each tray will be 22 feet and ten inches long, six inches wide and four to six inches deep. The trays shall be filled with porous media such as crushed welded tuff, having a particle size of ½ inch to ¾ inch, sand, solid blocks of welded tuff or other geologic media. The porous media will be selected based on small-scale bench tests. The geologic material in the trays will provide a continuous source of moisture that can evaporate into the ventilation air moving through the test train as shown in Figure 2, 3, and 4. The trays will be separated into five segments, coinciding with the intervals between the instrumented stations of the test train. Each segment of the tray will be fed by a constant head water supply system that ensures that the trays keep the geologic media moist. The quantity of water used will be monitored. Weight scales and flow-measuring systems will be used to measure amount of water added. Additionally, the waste packages temperatures, air temperature, and relative humidity will be monitored. Relative humidity measurements combined with temperature and flow rate of the air will confirm the water mass balance.

Since the test system as currently configured does not enable the removal of vapor from the ventilation air, it may be necessary to use ambient air for the inlet supply and condition it as necessary to achieve the desired inlet conditions of relative humidity. This system has been found effective to date because the desired inlet relative humidity is typically above the ambient relative humidity.

The tests will span the test conditions such as thermal input, relative humidity, temperature, and airflow previously investigated in Phases 1 and 2 of the ventilation test. It is expected that the sequence for this test will be similar to the test sequence planned for Phase 2 of the ventilation test. The test train will be brought to an initial operating condition (ventilation rate and heating rate), then cycled through increasing temperature steps without shutting down between each test condition. Each test condition is expected to require approximately ten days to reach steady state. Sufficient data will be collected to quantify water removal rates. One to two weeks will be required to cool the system prior to changing the heating rate or ventilation rate.

The ranges of conditions to be evaluated are:

Waste Package Heater output:	0.18 and 0.36 kW/m
Total airflow rate:	0.5 m^3/sec, 1. 0 m^3/sec, 3.0 m^3/sec
Relative humidity at inlet:	10%, 20%, 30%, and 45%
Inlet air temperature:	25^0 C and 45^0 C

The test matrix is presented in Table 1.

Table 1. Ventilation Phase 3 Test Matrix

Test #	Ventilation Rate-CMS	Heat Rate Kw/M	Temperature 0 C	Relative Humidity %	Trays Wet?	Total # of Days
1	0.5	0.18	25	30	Y	10
2	0.5	0.18	25	45	Y	20
3	0.5	0.18	45	20	Y	30
4	0.5	0.18	45	10	Y	40
5	0.5	0.36	25	30	N	50
6	0.5	0.36	25	45	Y	60
7	0.5	0.36	45	20	Y	70
8	0.5	0.36	45	10	N	80
9	1.0	0.18	25	30	Y	90
10	1.0	0.18	25	45	Y	100
11	1.0	0.18	45	20	Y	110
12	1.0	0.18	45	10	Y	120
13	1.0	0.36	25	30	N	130
14	1.0	0.36	25	45	Y	140
16	1.0	0.36	45	20	Y	150
17	1.0	0.36	45	10	N	160
18	3.0	0.18	25	30	Y	170
19	3.0	0.18	25	45	Y	180
20	3.0	0.18	45	20	Y	190
21	3.0	0.18	45	10	Y	200
22	3.0	0.36	25	30	N	210
23	3.0	0.36	25	45	Y	220
24	3.0	0.36	45	20	Y	230
25	NA	0.36	Not Controlled	Not Controlled	Y	240
26	NA	0.36	Not Controlled	Not Controlled	Y	260

At the conclusion of test 24, test 25 and 26 will be performed. The test 25 will be performed without circulating any air i.e., the ventilation fans will be stopped. The damper at the exhaust side of the test train will be closed to allow the circulation to occur by natural convection. The heater power will be maintained at 0.36 Kw/M. This will allow the temperature to evolve due to natural convection dominated flow, balancing waste package heat input with losses through the heated section insulation and through the pipe walls on the exhaust side of the test section. Air velocity, relative humidity and temperatures will be monitored. The trays will be kept moist for this test. The test will continue until it becomes stable and after this, the test will continue for two more days.

Test number 25 will be initiated at the completion of test number 24. For this test, the air inlet side of the water delivery pad will be blocked by placing a plate in the opening. This will stop the full circulation of the air through the test train and allow smaller scale natural convection to dominate. The waste package heaters will be kept on until the test reaches steady state. Air velocity, relative humidity and temperatures will be monitored. The trays will be kept moist for this test. This test will be run for two days after it reaches steady state.

4.3 Data Recording and Data Reduction

The data from this test will be recorded using an automated data acquisition system. Four scan per hour by the data collection system are considered sufficient to measure temperature, relative humidity, water addition rates, and air velocity profiles through the test train during start-up of the test. Other scan rates may be invoked once conditions cease to change significantly or requested by the Principal Investigator (PI).

The electronic data will be converted into engineering units and transferred to the PI for review and acceptance. After initial review and interpretation by the PI, the acquired data will be submitted to the TDMS.

The quality will be accessed data from the TDMS for reduction and use for the validation of the ventilation models.

4.4 Analysis and Modeling During and After Test

The data acquired from the test will be analyzed to detect out of range conditions and to determine if the test is running as designed. Any changes to the controlling test parameters such as airflow rate, heater power output, and water injection rates, if required, shall be documented. The test is designed to permit such changes. Periodic progress reports will be prepared describing status of the test. Upon the completion of the test, the data will be analyzed and reported in project reports. This report will also include performance of the test and a chronology of major events having a potential impact on the data collected. This might include items such as: power failure, instrument failures, changes on operational parameters if any, and out of calibration conditions.

4.5 Accuracy and Precision

To ensure that the collected data meets the project needs, the instruments will be calibrated in accordance with applicable procedures. The instruments for this test either will be calibrated by BN Calibration Laboratory or are procured from vendors qualified by the Project for this purpose. Primary instruments used for this test are listed in Table 2.

4.5.1 Experimental/Sampling Artifacts

4.5.1.1 Control/Determination of Independent Conditional Variables

The independent conditional variables for this test are the temperature at the inlet, relative humidity at the inlet, airflow rates, and heater power output. The dependent variables are the addition of water, evaporation from the trays, relative humidity, and test component temperatures throughout the test train.

4.5.1.2 Control/determination of the Boundary Conditions

The boundary conditions will be controlled by installing insulation to the outside of the test train.

4.5.2 Instrument Calibration and Instrumental Error

4.5.2.1 Instrument Calibration

The test instruments and data collection systems either are procured calibrated from a vendor Qualified under the YMP QA Program or are calibrated by the BN Calibration Laboratory. A list of instruments with their range and accuracy is presented in Table 2. Table 2 also identifies Procedures used by instrumentation vendors and BN to calibrate the instruments. The calibration certificates are submitted to the RPC.

Table 2. List of Instruments Used for Ventilation Test

Instrument	**Range**	**Accuracy**	**Calibration Procedure**
Velocity Meter	0-0.475 inches of water gage	±0.1% of span	Air Monitor Operating Procedure #26.0 Rev 1/18/99
Mass Flow Meter	0-250 SCFM	±2%(10-100% FS) ±FS below 10%	Sierra Procedure AA05 Rev A and 6400 Rev B
Temperature/Humidity Probe	10-100%RH, 0-100^{0}C	RH±2%(10-90%), RH ±3.0% (>90%) Temperature ±2.0^{0}C	BN Procedure # CI-090 Rev0
Resistance Temperature Device	15-100^{0}C	±0.8^{0}C	ASTM E220 Rev 86
Power Monitor	0-4600 Hz	±0.25% FS	Ohio Semitronics VFC Manual, DWG #A700-40
Watthour Meter	0-4kW	±0.5% FS	Ohio Semitronics PC5-Manual-898, DWG #A7007-01 Rev. 799
Input Voltage	0-300vac	±1.0% of reading	BN Manual JF146 Rev 3
Velocity Meter	0-0.18 inches of water gage	±0.10% of span	Air Monitor Standard Operating Procedure # 26.0 Rev 1 8/20/99
Pressure gage	17.5-32.5 inches of Mercury	±0.05% Full Scale	BN Procedure CI-151 Rev 0
Temperature Probe	14-45^{0}C	±1.0^{0}C	BN Manual VA001 Rev 0
Humidity Probe	10-90%RH	±5% RH	BN Manual VA001 Rev 0
Single Point Load Cells	0-200 KG	±0.3%	BN Calibration Procedure CI-142-Rev 0
Pressure Gage	0.61-1.06 Kpa	±0.05% of reading	Bechtel Calibration Procedure CI-151 Rev 0

4.5.2.2 Instrumental Error

With the exception of added water, air velocity, and temperatures measured manually at three locations, all other data is acquired by the automatic DCS. Instrument related errors could occur only if the conversion factors electronic readouts (voltage, amps, etc.) are inaccurate or the calibration factors are input incorrectly.

4.5.3 Handling Unexpected Results/Conditions

4.5.3.1 Unexpected Results

In the event that the collected data differs substantially from the pre-test calculations, the test may be stopped. The differences in the results will be discussed with test team and the analysts to determine why the results are substantially different than those predicted. This may result in model modifications and will be an iterative process. The calibration and unit conversion factors will be verified to ascertain if the conversion factors or the calibration methodology is flawed. If necessary, the test will be repeated or re-planned.

4.5.3.2 Unexpected Conditions

Most likely unexpected conditions are:

- out of range readings from the data collection system
- extended power failure
- significant leakage of air from the test
- inability to control relative humidity in the test train.

Unless such conditions persist, the test will be allowed to run and data gathered at a set frequency. Alarms have been incorporated in the data acquisition system to alert the test attendant whenever the test conditions are outside the predicted operating window. In the event that an unexpected conditions occurs the condition will be evaluated to determine its potential impact on the test to acquire the needed data. If this is the case, the test will be modified as necessary or terminated.

5.0 INTERFACE CONTROL-PERFORMANCE ASSESSMENT (PA), DESIGN, PROCESS MODELS, PARAMETERS

The test is designed to produce the input requested from the Subsurface Design Department through QAP-3.14Q, Input Transmittal. The data needs and test configuration is integrated with the data users. Primary focus of this phase of the test is to produce data for the reduction of uncertainty and validation of the Ventilation Model implemented in the MULTIFLUX Version 20. computer code. The test design is coordinated with data users through routine test coordination and integration meetings. Likewise, the data as it is produced will be discussed with the data users to ensure that the test continues to meet the data needs for validation of the Models.

6.0 SECURITY

Test facility and data security is provided by the DOE/NV Safeguard and Security Division (SSD), YMP/BSC Security Department, and direct security support provided by Wackenhut Services (WSI). All work performed in the EBS test facility will be performed in compliance with DOE, YMP/BSC, and WSI security orders/directives.

7.0 REFERENCES

CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor) Technical Work Plan For: Subsurface Performance Testing for License Application (LA) for Fiscal Year 2001, TWP-EBS-MD-000009, Las Vegas, Nevada, Rev 02, 3/5/01, MOL.20001329.0823.

DOE (U.S. Department of Energy) 2000, Engineered Barrier Systems-Pre-Closure Ventilation Testing, FWP-EBS-00-001, Rev 0, 7/27/00, Yucca Mountain Site Characterization Project, Las Vegas, Nevada.

Security Plan for the YMP/M&O Pilot Scale Engineered Barrier System Testing, NLVF Building A-1 Low Bay and Building B-4, 7/19/00

Daniel G. McKenzie, Office of Civilian Radioactive Waste Management QAP3.14Q Input Request # 00261.R, 5/4/2000.

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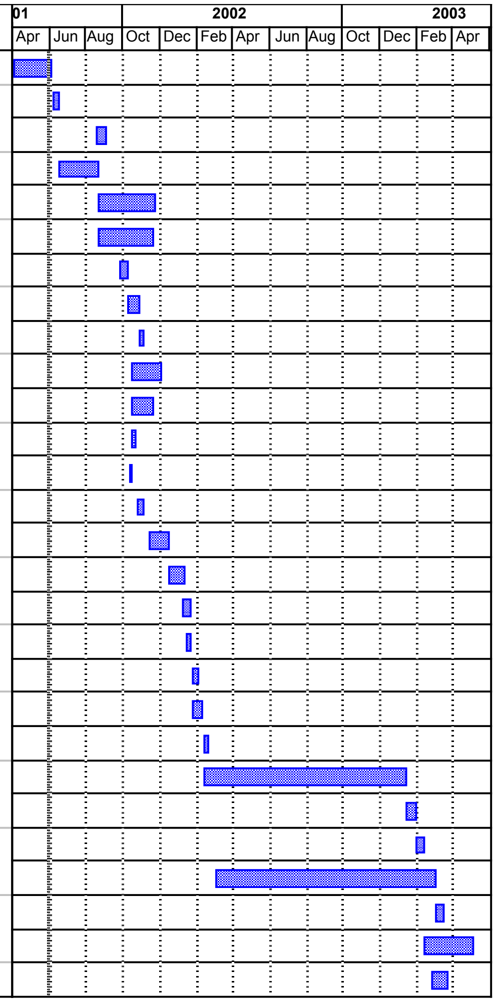
Figure 1 Schedule for Phase 3 of the Ventilation Test

ID	Task Name	Dur	Start
1	Prepare Test Description	43 days	04/03/01
2	Develop List of of required Instruments	6 days	06/08/01
3	Prepare Test Installation Details	11 days	08/17/01
4	Procure Heaters and Instruments	45 days	06/18/01
5	Perform pretest Predictive Calculations Uncertainty Analysis	70 days	08/20/01
6	Calibrate Instruments	65 days	08/20/01
7	Remove Intake and Exhaust end	10 days	09/24/01
8	Remove Internals Components of the Phase 2 Test	15 days	10/08/01
9	Verify Calibration of existing Instruments	3 days	10/29/01
10	Calibrate/Recalibrate Instruments as required	35 days	10/15/01
11	Refurbish waste packages and Install new Heaters	25 days	10/15/01
12	Fabricate water Trays	5 days	10/15/01
13	Clean The Internals of the Phase 2 Test	3 days	10/10/01
14	Install Water Delivery System and Load Cells	10 days	10/22/01
15	Install Waste Packages	25 days	11/12/01
16	Install Instruments	16 days	12/17/01
17	Install Power to the Heaters	10 days	01/07/02
18	Checkout Instruments and cables	5 days	01/14/02
19	Re-install Intake and Exhaust ends of the Test	9 days	01/21/02
20	Connect Instruments to DAS	15 days	01/21/02
21	Checkout the Test Installation	1 day	02/11/02
22	Start and Complete Test # 1 to # 24	240 days	02/12/02
23	Start Test # 25	10 days	01/14/03
24	Start Test # 26	10 days	01/28/03
25	Submit Data to TDMS-Once a Month	260 days	03/04/02
26	Submit Test Records to the RPC and the TDMS	10 days	02/28/03
27	Complete Test Report	60 days	02/10/03
28	Decommission Test	20 days	02/24/03



Main Menu

EXIT

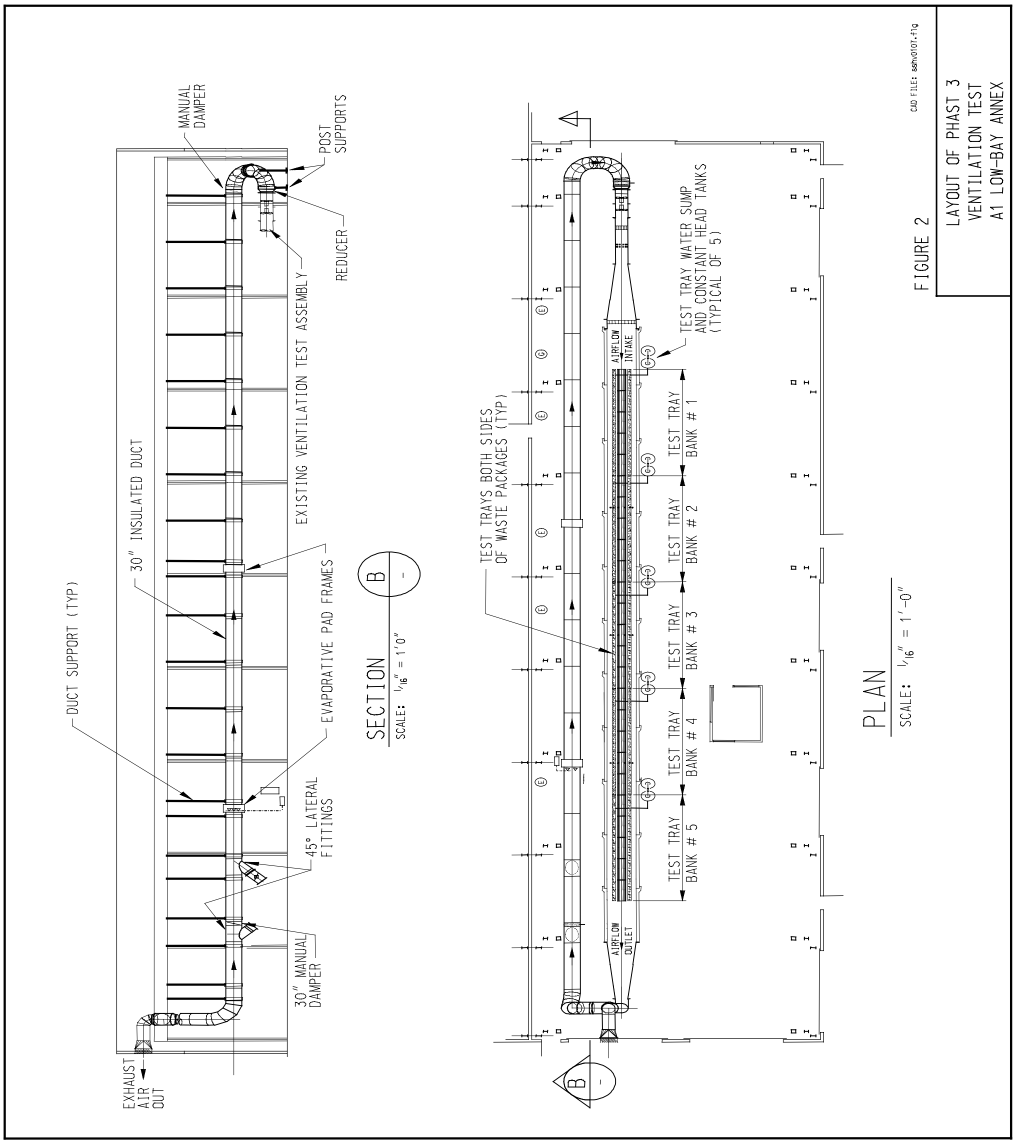


Figure 2. Plan View of the Phase 3 of the Ventilation Test

Figure 3. Section View of the Phase 3 of the Ventilation Test

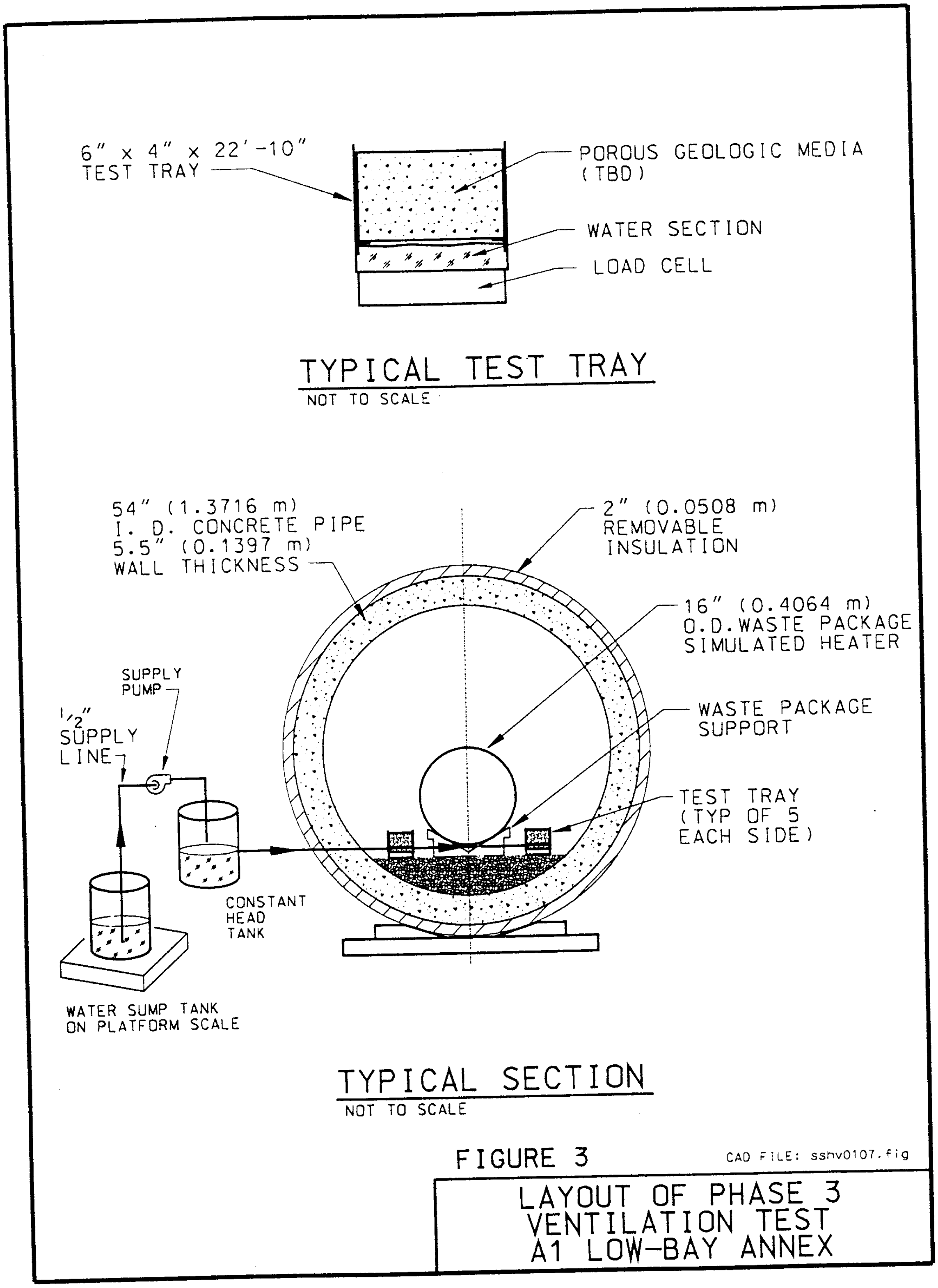


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Figure 4. Details of Phase 3 Ventilation Test