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Hanford Protective Barriers Program Asphalt Barrier Studies - FY 1988

H.D. Freeman
G.W. Gee

May 1989

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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ASPHALT BARRIER STUDIES - FY 1988

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SUMMARY

The Hanford Protective Barrier (HPB) Program is evaluating alternate barriers to provide a means of meeting stringent water infiltration requirements. One type of alternate barrier being considered is an asphalt-based layer, 1.3 to 15 cm thick, which has been shown to be very effective as a barrier for radon gas and, hence, should be equally effective as a barrier for the larger molecules of water. Fiscal Year 1988 studies focused on the selection and formulation of the most promising asphalt materials for further testing in small-tube lysimeters. Results of laboratory-scale formulation and hydraulic conductivity tests led to the selection of a rubberized asphalt material and an admixture of 24 wt% asphalt emulsion and concrete sand as the two barriers for lysimeter testing. Eight lysimeters, four each containing the two asphalt treatments, were installed in the Small Tube Lysimeter Facility on the Hanford Site. The lysimeter tests allow the performance of these barrier formulations to be evaluated under more natural environmental conditions.

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INTRODUCTION

The Hanford Protective Barrier (HPB) Program, managed by Westinghouse Hanford Company (WHC) for the U.S. Department of Energy (DOE), is considering asphalt, clay, and chemical grout as alternates or additions to earthen barriers for restricting infiltration of water into waste sites on the Hanford Site (Adams and Wing 1986). Pacific Northwest Laboratory (PNL)[a] is responsible for evaluating asphalt materials, while WHC is responsible for evaluating clay and chemical grout.

This report covers studies being conducted by PNL on using asphalt layers as part of the Hanford protective barrier system. Asphalt was selected as the initial material studied for the alternate barrier task because it had already been tested by PNL as a cover system at a uranium mill tailings site in Grand Junction, Colorado (Uranium Mill Tailings Remedial Action Project, UMTRAP, also sponsored by DOE). Asphalt has an extremely low permeability to both radon and water and resists penetration by plants and animals.

The primary emphasis of the study reported here is to demonstrate that the technology developed as part of UMTRAP is applicable to protective barriers at the Hanford Site. The asphalt barrier studies for the HPB Program are divided into three categories: 1) laboratory studies, 2) lysimeter studies, and 3) field demonstration. Work for FY 1988 focused on Categories 1 and 2, with the selection and formulation of the most promising asphalt materials. These materials were installed in small-tube lysimeters for further testing.

During the laboratory studies, several asphalt formulations were tested for hydraulic conductivity. From the results of the hydraulic conductivity tests, two formulations were chosen for testing in the small-tube lysimeters: rubberized asphalt and an admixture of 24 wt% asphalt and concrete sand, referred to as an admix seal. If the lysimeter tests show that the asphalt seals are effective, the barriers may be demonstrated on a much larger scale

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(a) Operated for the U.S. Department of Energy by Battelle Memorial Institute.

similar to the tests performed on the Grand Junction tailings pile (Hartley et al. 1983). A large-scale demonstration is necessary to evaluate cost-effective application techniques and develop quality assurance and quality control procedures for monitoring the installation of these barriers.

This report contains the results of the FY 1988 laboratory tests and a description of the ongoing lysimeter studies. Background information is also included on the long-term stability of asphalt and its use in the UMTRAP studies. The appendix provides data on the density and moisture content of the materials placed in the lysimeters.

BACKGROUND

Asphalt is recognized as an excellent moisture sealant, and its use dates back several thousand years. As early as 3000 B.C., asphalt was used as a water stop between the brick walls of a water reservoir (Micropaedia 1974). It was used by early man as a paving material, wood preservative, sealant, adhesive, and mortar (LeMaire 1953; Marschner 1980). Many artifacts (e.g., statues, ornamental pieces) dated 4900 to 5500 years old have been recovered in the Middle East in excellent condition. These artifacts attest to the long-term stability of asphalt under anaerobic conditions.

Because of its excellent sealing and long-term stability properties, asphalt was chosen for study by PNL as a radon barrier in 1976 (Koehmstedt, Hartley, and Davis 1977). The effectiveness of asphalt emulsion as a thin radon barrier material was successfully demonstrated; however, the thin seal did not have suitable mechanical stability for long-term use. In 1979, under UMTRAP, further studies were initiated, and the first admix barrier design was tested on a large scale at the Grand Junction tailings pile (Hartley et al. 1980). The admix seal consisted of asphalt emulsion mixed in situ with uranium mill tailings. This seal produced variable results because of the heterogeneous nature of the tailings. The wide range in particle size and moisture content encountered in the test area resulted in areas where optimum particle coating did not take place, and hence, produced an inferior seal.

Continuing work included a large-scale field test to compare a number of different barrier formulations and application techniques. The techniques included in situ application, pugmill/paver, hot rubberized asphalt, and a commercially available cold mix paver. The cold mix paver produced the most effective seals. This technique uses concrete sand as the aggregate in the seal instead of relying on the heterogeneous tailings. The seal contains approximately 22 wt% residual asphalt, which is enough to completely fill the voids of the aggregate. In comparison, typical road pavements contain 6 wt% asphalt. The high asphalt content produces an extremely tight seal with a very low diffusion coefficient for radon ($<10^{-6}$ cm^2/s). An area of over 3400 m^2 was covered using this technique. On the average, the cold mix paver seal provided a greater than 99.5% radon flux reduction (Hartley et al. 1981). Recent monitoring of this seal, after 7 years of aging, has shown it is still as effective as originally measured (Gee et al. 1989).

Another large test area was sealed using a cold mix paver (Hartley et al. 1983), and two other radon barrier techniques were compared along with asphalt emulsion barriers: earthen covers and multilayer clay barriers. Radon flux monitoring has shown that the asphalt seal was the most effective in reducing radon emissions from the tailings. The only areas that did not seal well could be attributed to errors by equipment operators. The success of the large-scale field tests demonstrates the practicability of using asphalt barriers. It also points out the need to develop proper quality control procedures which can be obtained from large-scale demonstration projects.

LABORATORY STUDIES

The purpose of the FY 1988 laboratory studies was to develop asphalt barrier formulations and conduct hydraulic conductivity testing. The formulations consisted of combinations of emulsion type, total asphalt content, and moisture content. Data from the hydraulic conductivity tests were used to select two formulations for further testing in the small-tube lysimeters.

The two types of asphalt materials being evaluated are very different in appearance. The rubberized asphalt[a] is a solid material at ambient temperatures that is sprayed as a hot liquid (320°F) onto a geotextile fabric. The fabric provides a buffer between the hot asphalt and wet soil to prevent steam holes in the membrane. When cool, the material exhibits dramatic elastic properties that allow the material to stretch up to 13 times its original length without rupturing or exhibiting significant plastic deformation. The material is used commercially to line water storage ponds. An 8-kg block of the membrane material was provided by Deery Oil for testing, along with a sheet of the recommended geotextile material (polyethylene felt).

For laboratory tests of rubberized asphalt, the only parameter that can be investigated is composition (determined by manufacturer). Only the Deery Oil Membrane composition was identified as being suitable, based on previous experience. Test specimens of the rubberized asphalt were prepared by melting a quantity of the solid rubberized asphalt material and pouring a 1-cm layer on the polyethylene felt provided by Deery Oil. Two cores of membrane were cut from this sheet to the proper dimensions for the permeameters, the instruments used for hydraulic conductivity testing.

The asphalt emulsion admixtures are a combination of concrete sand and asphalt which has been emulsified in a water base. Asphalt emulsion typically contains 60% asphalt solids and 40 wt% water. When the two components are mixed, the cationic asphalt droplets adhere to the sand particle through electrostatic and mechanical bonds. The water in the emulsion

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(a) Deery Oil Membrane #6, Deery Oil Company, Fruita, Colorado.

separates from the asphalt in a process known as "breaking." A series of tests were outlined to determine the optimum parameters for the emulsion-aggregate seal. The important parameters investigated included asphalt emulsion type, aggregate type, moisture content of aggregate, and residual asphalt content of the admix. The experimental design for these tests is presented in Table 1. Each sample in Table 1 was prepared in duplicate. The duplicates were identified by a suffix of A or B to the sample IDs in Table 1. For example, the duplicate samples for oven-dried blow sand with 16 wt% of +25 mV emulsions were labeled as HPB-01A and HPB-01B.

TABLE 1. Asphalt Emulsion Mix Tests

Test ID	Aggregate	Moisture Content	Emulsion	Asphalt Content
Effect of Aggregate Moisture Content				
HPB-01	Blow Sand	Oven Dried	+25 mV	16 wt%
HPB-02	Concrete Sand	Oven Dried	+85 mV	16 wt%
HPB-03	Blow Sand	2 wt%	+25 mV	16 wt%
HPB-04	Concrete Sand	2 wt%	+85 mV	16 wt%
HPB-05	Blow Sand	4 wt%	+25 mV	16 wt%
HPB-06	Concrete Sand	4 wt%	+85 mV	16 wt%
Effect of Asphalt Content				
HPB-07	Blow Sand	Optimum[a]	+25 mV	10 wt%
HPB-08	Concrete Sand	Optimum	+85 mV	10 wt%
HPB-09	Blow Sand	Optimum	+25 mV	12 wt%
HPB-10	Concrete Sand	Optimum	+85 mV	12 wt%
HPB-11	Blow Sand	Optimum	+25 mV	18 wt%
HPB-12	Concrete Sand	Optimum	+85 mV	18 wt%
Effect of Asphalt Type at Optimum Conditions				
HPB-13	Blow sand	Optimum	+85 mV	Optimum[b]
HPB-14	Concrete Sand	Optimum	+25 mV	Optimum
HPB-15	Not Used			
Additional Tests (Not originally included in test design)				
HPB-16	Concrete Sand	Oven Dried	+85 mV	20 wt%
HPB-17	Concrete Sand	Oven Dried	+85 mV	22 wt%
HPB-18	Concrete Sand	Oven Dried	+85 mV	24 wt%
T-1	Blow Sand	8 wt%	+25 mV	16 wt%
T-2	Concrete Sand	Oven Dried	+25 mV	16 wt%
T-3	Blow Sand	Oven Dried	+85 mV	16 wt%

(a) Optimum moisture content found in Tests 1-6.
(b) Optimum asphalt content found in Tests 7-12.

The admix test specimens were prepared by adding the water to oven-dried sand to bring the aggregate to the proper moisture content specified in the experimental design and mixing in a 20-qt mixer until uniform. The specified amount of asphalt emulsion was then poured into the mixing bowl and the components were mixed together for ~30 s or until the aggregate was uniformly coated with asphalt. In most cases the mixture was placed in a 10-cm-diameter steel mold and allowed to drain for 24 h. The mixture was then compacted to 80 psi with a hydraulic press. The specimens were allowed to cure for several days and then removed from the molds. The test specimens were typically 4.5 cm thick when compacted.

A few of the samples prepared at the beginning of the program were compacted using an automatic bituminous compactor. This device repeatedly drops a weight on the specimen from a uniform height to provide a way of obtaining repeatable compaction tests. The weight used in this device, however, was not heavy enough to provide sufficient compaction and the method was abandoned in favor of the hydraulic press.

Two different aggregate sources were used in the admix design: concrete sand obtained from near the 200 Area on the Hanford Site, and natural blow sand obtained near the 200 Area lysimeter test site. The concrete sand represents an aggregate source that must meet certain specifications. The blow sand represents a "free" source of aggregate, which would result in a lower-cost barrier. Each aggregate may require a different asphalt emulsion formulation for optimum adhesion of the asphalt to the aggregate. The most suitable emulsions for the aggregate sources were determined by Akzo Chemie America, McCook, Illinois, an emulsifier manufacturer. They found that an emulsion with a +25 mV charge was most suitable for the blow sand and an emulsion with a +85 mV charge most suitable for the concrete sand.

Another important parameter affecting the performance of asphalt admix seals is the water content of the aggregate before mixing in the emulsion. If the sand is too dry, the emulsion will break prematurely and result in poorly coated aggregate particles and balls of asphalt cement in the mixture. If too much water is present in the aggregate, the mixture may not break soon enough and cause difficulties in handling the material and removing all of the water trapped in the admix. Usually, lower moisture content is required for higher residual asphalt contents because of the greater amount of water available from the emulsion.

The final parameter studied in the laboratory tests was the amount of residual asphalt content in the seal. Ideally, only enough asphalt to fill the voids of the aggregate is required to obtain a watertight seal. For example, an aggregate with a 30% void volume and a bulk density of 1.6 g/cm^3 would require about 16 wt% residual asphalt to fill the voids. In practice, however, slightly more asphalt is needed to produce a watertight seal because of the uneven distribution of the asphalt within the aggregate.

LABORATORY TEST RESULTS

The laboratory tests provided data on the effects of moisture content, asphalt content, and emulsion type.

Effect of Moisture Content

Results of tests with varying moisture contents (HPB-01 through HPB-06) were not conclusive. None of the tests produced seals of the desired quality. The asphalt tended to ball up and not coat the particles evenly. A slight increase in seal quality as determined by visual inspection was detected as the moisture content increased. Only one of the samples from this series was submitted for hydraulic conductivity testing. The amount of residual asphalt content (16 wt%) may not be sufficient for these aggregate sources. Based on the results of these tests, the moisture content chosen for the asphalt content tests was 4 wt%. Further tests may be required at higher moisture levels to better define the effect of moisture content at lower asphalt contents.

Effect of Asphalt Content

Only four of six tests originally planned were conducted. The 10 wt% (HPB-07) and 12 wt% (HPB-09) asphalt tests were not performed on the blow sand because extremely poor seal quality was observed at 16 wt% in Tests HPB-01, HPB-03, and HPB-05. The remaining tests were performed at an aggregate moisture content of 4 wt%. The low-asphalt-content tests with the concrete sand (HPB-08 and HPB-10) did not produce desirable seals. Although the sand particles were fairly well coated, the admix was not very cohesive and tended to fall apart with very little stress. The tests at 18 wt% asphalt produced mixed results. The tests with concrete sand produced a very cohesive seal with well-coated particles. The blow sand, on the other hand, produced a seal with many uncoated particles and poor cohesiveness. It is obvious from these tests that the concrete sand is a more suitable aggregate.

Three additional tests (HPB-16, HPB-17, HPB-18) were added to the original plan to investigate formulations with a higher asphalt content. All three tests were run using oven-dried aggregate based on recommendations from Akzo Chemie America. Additional water did not appear to be necessary at the higher asphalt formulations since the emulsion contained a large amount of water. The 22 and 24 wt% formulations produced seals with well-coated particles which molded into a very solid product. The 20 wt% sample, however, contained a number of asphalt balls, indicating heterogeneous asphalt distribution. These tests indicate that a higher asphalt formulation produces the most heterogeneous seals. This observation must not be extrapolated to asphalt contents higher than 24 wt% without further study, however, because there is a point where too much asphalt may result in seals with undesirable mechanical properties (e.g., cold flow at low stress).

Effect of Emulsion Type

The tests designed to investigate the effect of emulsion type (HPB-13 and HPB-14) were not conducted because of the poor results obtained with the blow sand. A similar test was added at a later date (T-2 and T-3) to determine if the +85 mV emulsion would work any better on the blow sand or if the +25 mV would work well on the concrete sand. These tests were conducted with oven-dried sand and at 16 wt% asphalt instead of the optimum conditions specified in HPB-13 and HPB-14. These tests showed that the +85 mV emulsion produced an admix with better particle coating and cohesiveness than the +25 mV emulsion for blow sand. This result is in contrast to the tests performed by Akzo Chemie America. The reasons for this discrepancy are unknown, but further study is not warranted. The concrete sand did not produce as good an admix with +25 mV emulsion as with the +85 mV, as was expected.

HYDRAULIC CONDUCTIVITY TESTS

A number of the seals produced from the emulsion admix tests and two specimens from the rubberized asphalt test were submitted for hydraulic conductivity testing. The results of these tests are presented in Table 2. As can be seen from these results, the hydraulic conductivities of the admix seals originally tested (HPB-02A, HPB-12A, HPB-12B, HPB-18B, T-1B) were much higher than expected. These high hydraulic conductivities are thought to be an artifact of the testing process. Either the specimens were leaking around the walls of the permeameter cell or the specimens were being altered by the trimming process required to fit the specimens into the cells. The two hypotheses were investigated by running two additional tests: 1) pouring hot asphalt around the edges of the specimen and 2) preparing a sample by compacting the admix directly in the permeameter cell.

The first test suggested that the seals were not leaking around the walls of the cell. Pulling a vacuum on the specimen submerged in water revealed bubbles being released from the center portions of the specimen and none from the walls. The second test indicated that the most likely cause of the high hydraulic conductivities was the handling process because the

TABLE 2. Results of Hydraulic Conductivity Tests on Selected Asphalt Barrier Samples

Sample ID	Asphalt Content, wt%	Hydraulic Conductivity, cm/s
HPB-02A	16	2.4×10^{-4}
HPB-12A	18	1.3×10^{-4}
HPB-12B	18	1.8×10^{-4}
HPB-18B	24	7.2×10^{-7}
T-1B	16	2.4×10^{-4}
HPB-18C	24	$<1.4 \times 10^{-14}$
Membrane #6A	100	6.0×10^{-11}
Membrane #6B	100	$<1.6 \times 10^{-12}$

seal (24 wt%) prepared directly in the permeameter cell had a hydraulic conductivity of less than 6 X 10^{-14} cm/s.

The rubberized asphalt specimens showed excellent results. The hydraulic conductivities for the two specimens tested were 6 x 10^{-11} and <1.6 x 10^{-12} cm/s.

CONCLUSIONS

The conclusions reached as a result of the laboratory tests are summarized below:

- Hanford blow sand is not a suitable aggregate for an emulsion admix seal.
- A minimum asphalt content of 16 wt% is required to obtain a seal that is cohesive and pliable.
- The hydraulic conductivity of the admix decreases with increased asphalt content (see Table 2).
- Rubberized asphalt produces a seal with less than 6 x 10^{-11} cm/s hydraulic conductivity.
- The recommended seals for lysimeter testing are rubberized asphalt and emulsion admix with 24 wt% residual asphalt.

LYSIMETER STUDIES

The purpose of the small-tube lysimeter tests is to evaluate the performance of asphalt barrier formulations under more natural environmental conditions. The major focus of the investigation is the effect of infiltration and plant intrusion on seal integrity. The effectiveness of the seals will be bench-marked against two control lysimeters installed at the south end of the Small Tube Lysimeter Facility (STLF) located near the Hanford Meteorological Station. These two lysimeters were build as part of the Hanford Defense Waste Performance Assessment (Gee, Downs, and Rockhold 1989).

For the asphalt studies, eight small-tube (30.5 cm diameter) weighing lysimeters were installed with the control lysimeters at the STLF. The two different asphalt barrier treatments, rubberized asphalt and 24 wt% admix, each with and without vegetation, are being tested in duplicate. The lysimeter configuration is shown in Figure 1.

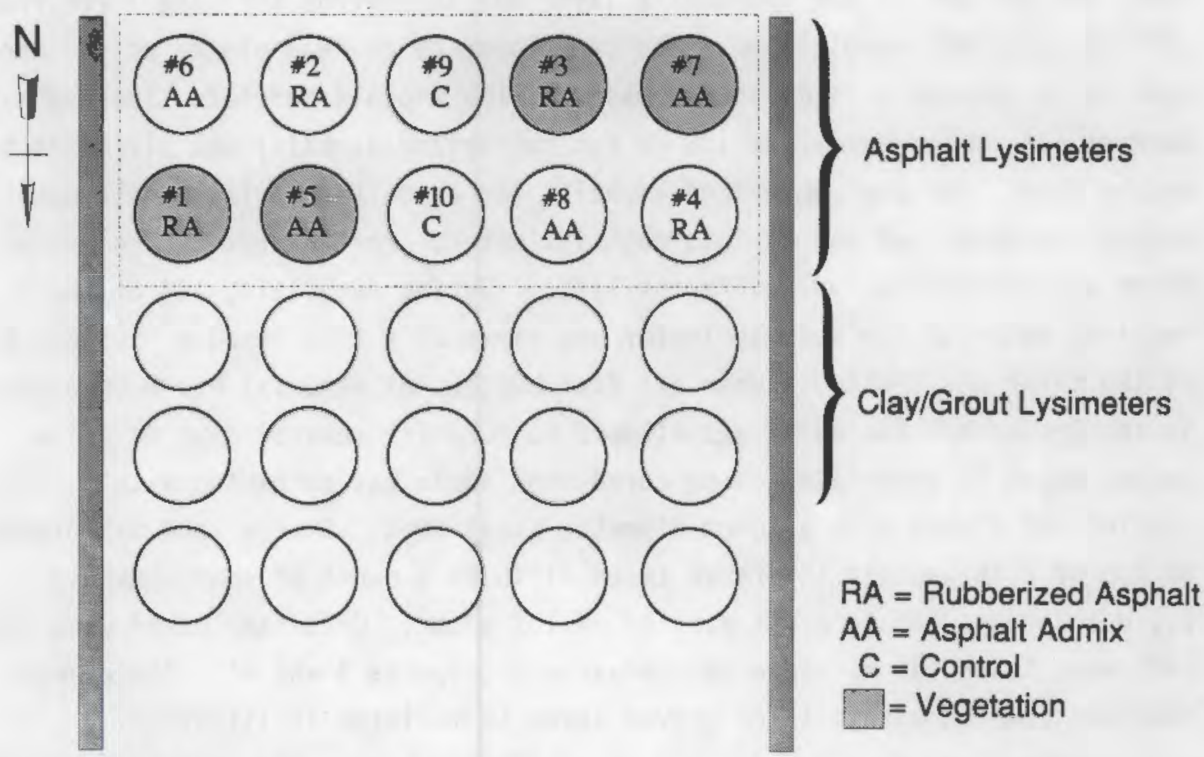

FIGURE 1. Lysimeter Treatment Layout at the Small Tube Lysimeter Facility

The lysimeters were constructed from 1.7-m-long ABS plastic well casing manufactured by Corro-tech, Inc., Seattle, Washington. Each lysimeter was fitted with a drainage fitting coupled to a length of 3/8-in. tubing. A clamp was placed at the end of the tubing to allow any moisture passing through the barrier to be collected. Each column was leak-checked by filling it with water then checking the area around the drainage fitting for signs of moisture after 24 h. If any leaks were detected, the fittings were readjusted and the leak test repeated. No leaks were observed from the welded seams in the bottom of the lysimeters. After the lysimeters were leak-checked, the water was removed, and a piece of heavy-duty screen placed over the drain hole on the inside of the lysimeter to prevent the tubing from plugging once the test materials were added.

The lysimeters were filled with layers of gravel, geotextile, coarse sand, and asphalt (Figure 2). Specifically, the bottom layer consisted of ~20 cm of -25 X +8 mm gravel to facilitate collection of any moisture drainage. The purpose of the geotextile layer was to prevent the sand layer from sifting into the gravel layer. The sand layer (5 cm) was placed on the geotextile to provide a firm, smooth base for the asphalt barrier. The asphalt barrier (15 cm for admix and 1.3 cm for rubberized asphalt) was placed on the coarse sand. For the rubberized asphalt, the asphalt material simply was heated, weighed, and poured into each lysimeter. For the admix, the lysimeters were filled in four different lifts. During each lift, 1/4 of the required material for each lysimeter was mixed at a time because the capacity of the mixer was limited. When all four batches of material had been placed in the lysimeter, the admix was allowed to cure for several days to allow excess water to evaporate. Once cured, the admix was compacted with a steel tamping rod fitted with a 10-cm-diameter steel foot. Coarse sand was placed on top of both asphalt layers in 15-cm lifts to a depth of approximately 1.1 m and compacted to a wet density of 1.7 g/cm^3. Grab samples of each sand lift were taken for moisture determinations (Figures 3 and 4). The coarse sand was covered with a 15-cm gravel layer to maximize infiltration.

Typed versions of the data sheets for each lysimeter are provided in the appendix. The lysimeters were installed at the STLF on July 25, 1988. Four of the lysimeters will be seeded with vegetation, such as Russian

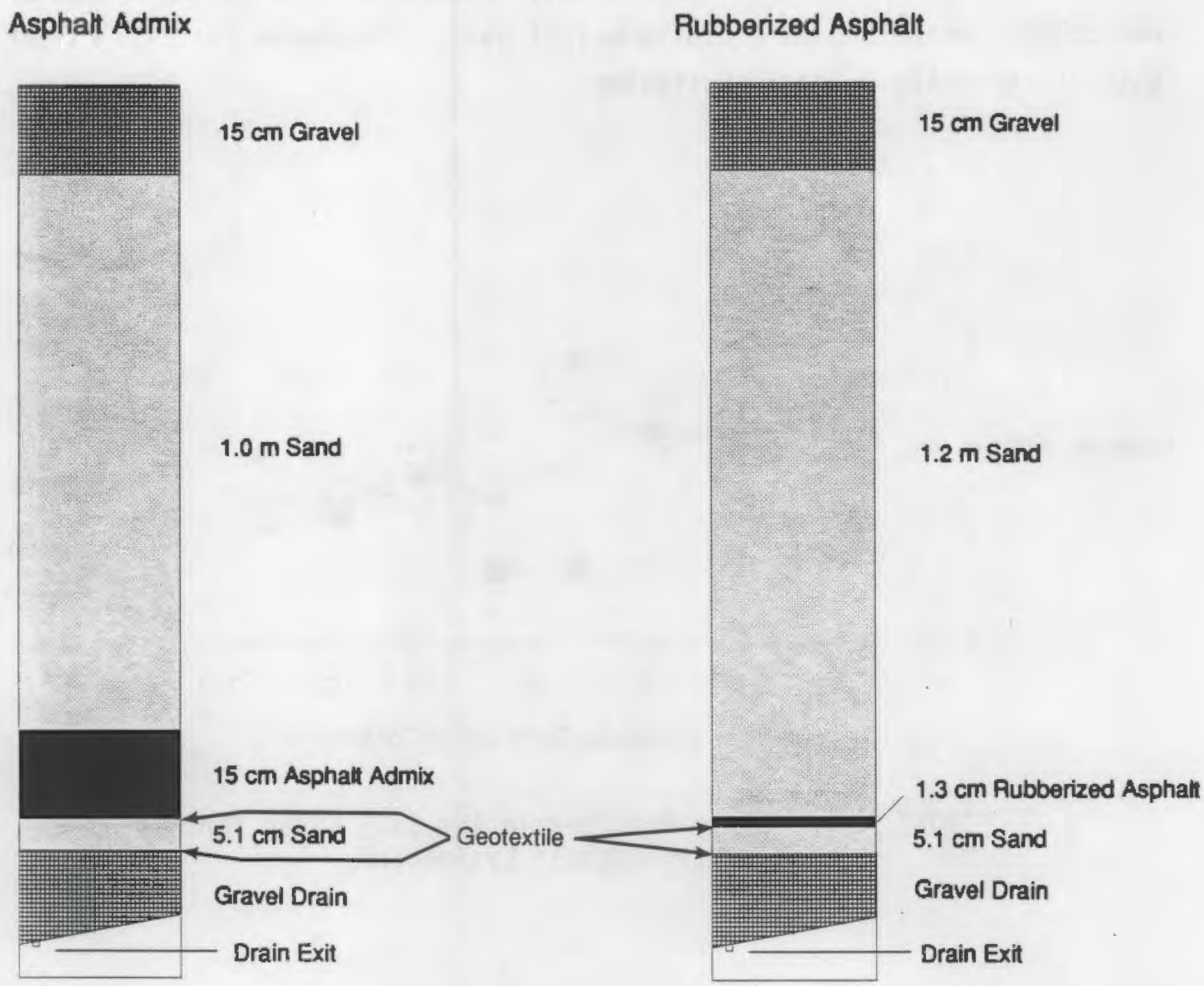

FIGURE 2. Lysimeter Layering Sequence for Asphalt Barriers

thistle (Salsola kali) and cheatgrass (Bromus tectorum), when the weather permits. The other four lysimeters have been treated with an herbicide to ensure the surface remains bare to provide conditions for maximum infiltration.

The lysimeters were weighed using a Measurements System International Model MSI 3260 digital hanging scale during installation and again on August 25, 1988, after 1 month of exposure to the environment. These data are summarized in Table 3. During this 1-month time period there was no rainfall, and hence, the lysimeters were expected to lose a small amount of water. The data in Table 3 confirm this assumption with the exception of one column, which showed a 0.5-kg weight gain. The cause for this weight gain is currently being investigated.

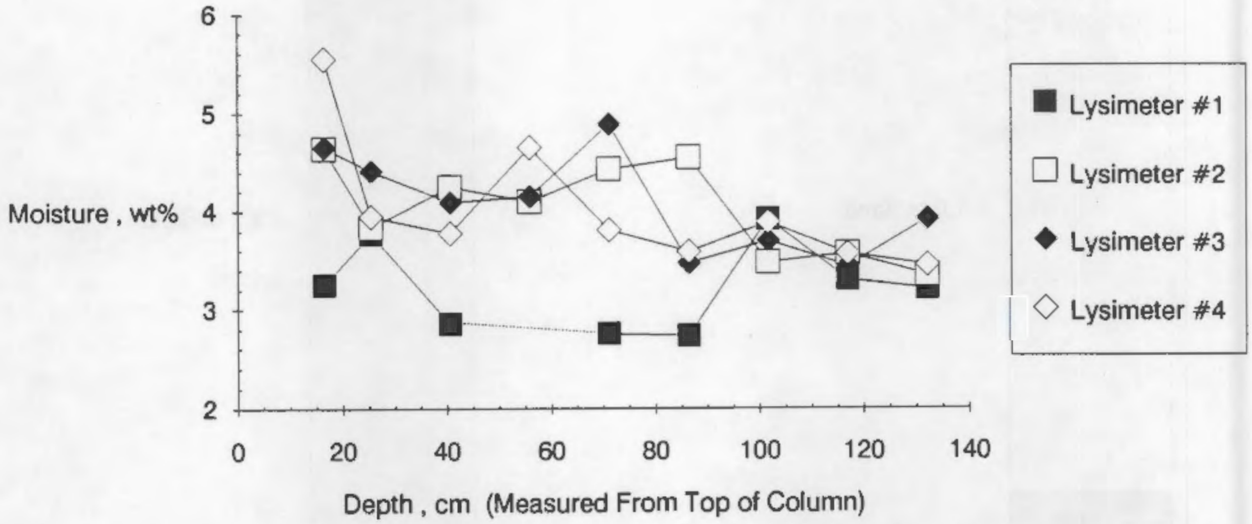

FIGURE 3. Moisture Profiles in the Sand Layer for the Rubberized Asphalt Lysimeters

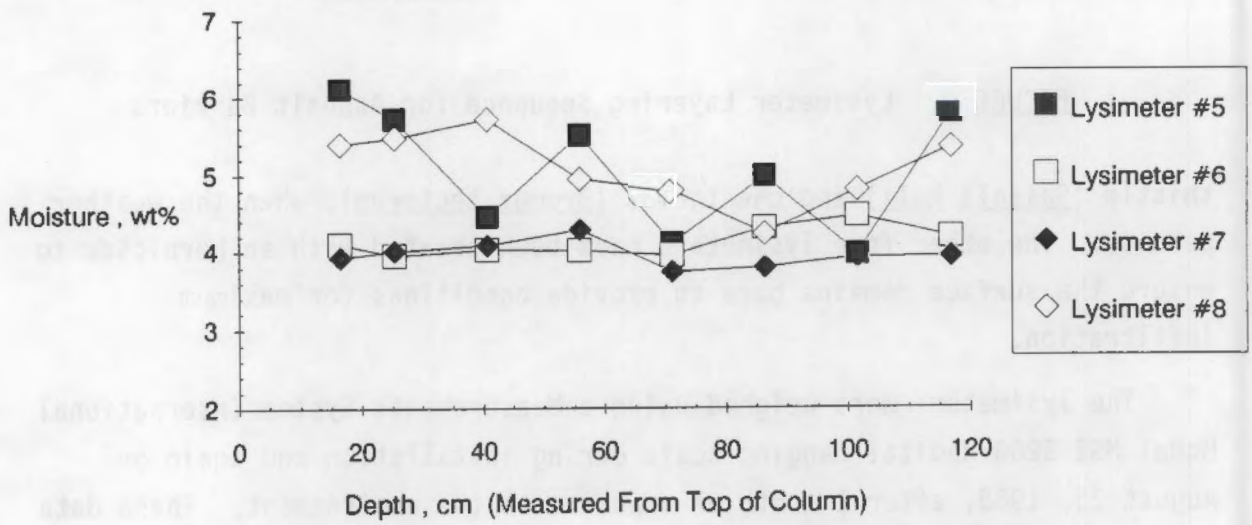

FIGURE 4. Moisture Profiles in the Sand Layer for the Asphalt Acmix Lysimeters

TABLE 3. Weights of Asphalt Lysimeters in the Small Tube Lysimeter Facility

Lysimeter	Treatment	Weight, kg		
		July 25	August 25	Change
1	Rubberized	223.4	223.3	-0.1
2	Rubberized	224.1	223.9	-0.2
3	Rubberized	225.2	225.1	-0.1
4	Rubberized	223.3	222.7	-0.6
5	Admix	225.2	225.5	0.3
6	Admix	224.9	224.6	-0.3
7	Admix	227.7	227.4	-0.3
8	Admix	227.2	226.6	-0.6
9	Control	230.3	229.8	-0.5
10	Control	229.7	229.2	-0.5

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APPENDIX

LYSIMETER DATA SHEETS

Note: The original data sheets are filled in by hand and contain the inspector's actual signature.

Checklist for Tube Lysimeter 1

Treatment Number RUBBERIZED ASPHALT I

1. LYSIMETER INSPECTION

a. Drainage fittings, tube and valve (clamp) installed correctly x WFR

b. Acceptable fit with lifting collar X WFR

c. Acceptable fit with gas exchange chamber collar ____

d. Lysimeter I.D. No. inscribed correctly x WFR

______________________________ ______

Inspector's Signature Date

2. LEAK TEST

			Date/Time
-	Tare wt. of dry lysimeter	21.3 kg	5/27-2:30
a.	Wt. of water added to the lysimeter	113.3 kg	5/27/88 15:25
	Tare Wt. with collar	~~32.1Kg~~	
b.	Lysimeter top covered correctly	x	
c.	Initial wt. of water-filled lysimeter	145.4 kg	5/27 - 3:25
d.	Lysimeter wt. after 24 hours	145.4 kg	5/31 - 4:30
e.	Wt. of water drained	113.3 kg	5/31/88
f.	Visible evidence of leaks*	yes ____	no x 5/31/11:30

g. Scale used 815-66-01=001 (expires 5/10/89) (calibration*)

h. Scale calibration data located in LRB ______

s/WF Riemath 5/31/88

Inspector's Signature Date

-Note: too much water was put in #1; had some drips on the threads after the LC was removed.

Checklist for Tube Lysimeter #1

3. LOWER BARRIER CONSTRUCTION

a. Screen placed over drain hole 6-2988 x

Date		Layer	Size	Lift No.	Weight (kg)	Distance from top (cm)	
6/29/88	b.	Gravel	~1/4"-1"	1	22.8	58"	~8 1/2" Drain to top of gravel
6/29/88	c.	Sand	Course	2	6.1	56"	
?/30/88	d.	Sand	Rubberized asphalt added	3	893 gms	55 1/4	total wt asphalt 1083 gm
7/5/88			over edge of cloth		190 gms		

e. Geotextile cut and installed correctly 6-29-88 x

e(1) Leak test of asphalt 7-6-88 (w/3' H_2O head) ok WFR

f. Sand and gravel layers wetted to field capacity ______

g. Scale used ______

h. Scale calibration data located in LRB______

______ Inspector's Signature

______ Date

Checklist for Tube Lysimeter #1

4. LYSIMETER SOIL BACKFILL DATA (scale calibration in LRB____)

Lift No.	Lift Wt. (kg)	Ht. From Top (cm) 55 1/4	Lift Ht. (cm)	Density (g/cm3)	Moisture Sample No.
4	18.5	49 1/4	6" 15.3	1.7	1-4
5	"	43 1/4	"	"	1-5
6		37 1/4	"	"	1-6
7		31 1/4	"	"	1-7
8		25 1/4	"	"	1-8
9		19 1/4	"	"	1-9
10		13 1/4	"	"	1-10
11		7 1/4		"	1-11
12	3.9	6"	1 1/4"	"	1-12
		Total wt 203.3 kg w/o collar			

s/WF Riemath — Inspector's Signature

7-18-88 — Date

Checklist for Tube Lysimeter 2

Treatment Number RUBBERIZED ASPHALT II

1. LYSIMETER INSPECTION

   a. Drainage fittings, tube and valve (clamp) installed correctly — x WFR

   b. Acceptable fit with lifting collar — x WFR

   c. Acceptable fit with gas exchange chamber collar — ______

   d. Lysimeter I.D. No. inscribed correctly — x WFR

______________________ Inspector's Signature   ______ Date

			5/27---2:30
	2. LEAK TEST		Date/Time
	- Tare wt. of dry lysimeter	21.2 kg	
	a. Wt. of water added to the lysimeter	96.6 kg	5/27/88 1540
	Tare Wt. with Lifting Collar	32.0 Kg	
	b. Lysimeter top covered correctly	x	
w/LC	c. Initial wt. of water-filled lysimeter	128.6 kg	5/27/88 1540
	d. Lysimeter wt. after 24 hours	128.6 kg	5/31/88 11:30
	e. Wt. of water drained	96.6 kg	5/31/88 1140
	f. Visible evidence of leaks	yes ______	no x 5/31/ 1140

g. Scale used 815-66-01-001 (expires 5/16/89) (calibration#)

h. Scale calibration data located in LRB ____________

s/WF Riemath — Inspector's Signature   5/31/88 — Date

Checklist for Tube Lysimeter #2

3. LOWER BARRIER CONSTRUCTION

a. Screen placed over drain hole 6-29-88 x

		Layer	Size	Lift No.	Weight (kg)	Distance from top (cm)	
6/29/88	b.	Gravel	~1/4"x+1	1	23.6	57 5/8"	
6/29/88	c.	Sand	Course	2	5.9	55 3/4"	
6/30/88 7/8/88	d.	Sand	~~Rubberized~~ asphalt ~~"~~	3 ~~x~~	893 gms ~~256 gm~~	55 1/4" OK ~~to seal edge~~	leak test failed first try

e. Geotextile cut and installed correctly 6/29/88 x

1149 gm total to seal edge

f. Sand and gravel layers wetted to field capacity ______

g. Scale used ______

h. Scale calibration data located in LRB ______

______ Inspector's Signature ______ Date

Checklist for Tube Lysimeter #2

4. LYSIMETER SOIL BACKFILL DATA (scale calibration in LRB_____)

Lift No.	Lift Wt. (kg)	Ht. From Top (cm)	Lift Ht. (cm)	Density (g/cm^3)	Moisture Sample No.
4	18.5	49 1/4	6"	1.7	2-4
5	18.5		"	"	2-5
6	"		"	"	2-6
7	"		"	"	2-7
8	"		"	"	2-8
9	"		"	"	2-9
10	"		"	"	2-10
11	"		"	"	2-11
12	3.9		1 1/4"	"	2-12
			Total wt 204.1 kg w/o collar		

s/William F. Riemath — Inspector's Signature

7-18-88 — Date

Checklist for Tube Lysimeter 3

Treatment Number RUBBERIZED ASPHALT III

1. LYSIMETER INSPECTION

a. Drainage fittings, tube and valve (clamp) installed correctly — x WFR

b. Acceptable fit with lifting collar — x WFR

c. Acceptable fit with gas exchange chamber collar — ______

d. Lysimeter I.D. No. inscribed correctly — X WFR

____
Inspector's Signature

______
Date

5/27 - 2:30

2. LEAK TEST

			Date/Time
-	Tare wt. of dry lysimeter	21.8 kg	
a.	Wt. of water added to the lysimeter	98.9 kg	5/27/88 1555
	Tare Wt. with Lifting Collar	32.8 Kg	
b.	Lysimeter top covered correctly	x	
c.	Initial wt. of water-filled lysimeter	131.7 kg	5/27 1555
d.	Lysimeter wt. after 24 hours	131.7 kg	5/31 1145
e.	Wt. of water drained	98.9 kg	5/31/88 1145
f.	Visible evidence of leaks	yes____	no x 5/31/1145

(calibration #)

g. Scale used 815-66-01-001 (expires 5/16/89)

h. Scale calibration data located in LRB____________

s/WF Riemath
Inspector's Signature

5/31/88
Date

Checklist for Tube Lysimeter 3

3. LOWER BARRIER CONSTRUCTION

a. Screen placed over drain hole x 6-30-88

Date		Layer	Size	Lift No.	Weight (kg)	Distance from top (cm)	
6-30-88	b.	Gravel	+1/4"x-1"	1	21.1	58"	
6-30-88	c.	Sand	Course	2	6.3	56"	
6-30-88	d.	Sand	Rubberized asphalt	3	1040 gm	55 1/2" ok	leak test failed 1st try
7-7-88 Add			"	x	67 gm	---to seal air hole	

e. Geotextile cut and installed correctly x 6-30-88 1107 gm total leak test ok.

f. Sand and gravel layers wetted to field capacity ______

g. Scale used ______

h. Scale calibration data located in LRB______

______ Inspector's Signature

______ Date

Checklist for Tube Lysimeter #3

4. LYSIMETER SOIL BACKFILL DATA (scale calibration in LRB____)

Lift No.	Lift Wt. (kg)	Ht. From Top (cm)	Lift Ht. (cm)	Density (g/cm3)	Moisture Sample No.
4	18.5	49 1/2"	6"	1.7	3-4
5	"			"	3-5
6	"			"	3-6
7	"			"	3-7
8	"			"	3-8
9	"			"	3-9
10	"			"	3-10
11	"			"	3-11
12	4.6	6"	1 1/2"	"	3-12
			Total wt	205.0	w/o collar

WF Riemath
Inspector's Signature

7-18-88
Date

Checklist for Tube Lysimeter 4

Treatment Number RUBBERIZED ASPHALT IV

1. LYSIMETER INSPECTION

   a. Drainage fittings, tube and valve (clamp) installed correctly x WFR

   b. Acceptable fit with lifting collar x WFR

   c. Acceptable fit with gas exchange chamber collar ______

   d. Lysimeter I.D. No. inscribed correctly x WFR

______________________________ ____________
Inspector's Signature Date

2. LEAK TEST

		Weight	Date/Time
			6/27 - 2:30
-	Tarewt of dry lysimeter	21.8 kg	
a.	Wt. of water added to the lysimeter	96.7 kg	5/27/88 1610
	Tare Wt. with Liting collar	32.9 Kg	
b.	Lysimeter top covered correctly	x	
w/LC c.	Initial wt. of water-filled lysimeter	129.6 kg	5/27/88 1610
d.	Lysimeter wt. after 24 hours	129.6 kg	5/31/88 1155
(dry w/LC 32.9) e.	Wt. of water drained	96.7 kg	5/31/88 1155

   f. Visible evidence of leaks yes______ no x 5/31/88 (small dri repaired) 3/31 1155 initiall

   g. Scale used (calibration #) 815-66-01-001 (expires 3/16/89)

   h. Scale calibration data located in LRB______________

s/WF Riemath 5/31/88
Inspector's Signature Date

Checklist for Tube Lysimeter #4

3. LOWER BARRIER CONSTRUCTION

a. Screen placed over drain hole 6/30/88 x

Date		Layer	Size	Lift No.	Weight (kg)	Distance from top (cm)
6/30/88	b.	Gravel	+1/4"X-1"	1	21.4	58"
6/30/88	c.	Sand	Course	2	6.7	56"
6/30/88 7/5/88	d.	Asphalt ~~Sand~~ ~~xxxxx~~	Rubberized ~~added over edge of cloth~~	3	905 gm ~~91 gm~~	55 1/2" ok total wt. asphalt 996 gm

e. Geotextile cut and installed correctly 6-30-88 x

e(1) 3' H_2O leak test of asphalt 7-6-88 ~~ok WFR~~

f. Sand and gravel layers wetted to field capacity ______

g. Scale used ______________________

h. Scale calibration data located in LRB ____________

______________________ ____________
Inspector's Signature Date

Checklist for Tube Lysimeter #4

4. LYSIMETER SOIL BACKFILL DATA (scale calibration in LRB_____)

Lift No.	Lift Wt. (kg)	Ht. From Top (cm)	Lift Ht. (cm)	Density (g/cm^3)	Moisture Sample No.
4	18.5	49 1/2"	6"	1.7	4-4
5	"			"	4-5
6	"			"	4-6
7	"			"	4-7
8	"			"	4-8
9	"			"	4-9
10	"			"	4-10
11	"			"	4-11
12	4.6	6"	1 1/2	"	4-12
			Total wt 205.1 kg w/o	collar	

s/WF Riemath — Inspector's Signature

7-18-88 — Date

Checklist for Tube Lysimeter 5

Treatment Number ADMIX V

1. LYSIMETER INSPECTION

a. Drainage fittings, tube and valve (clamp) installed correctly x WFR

b. Acceptable fit with lifting collar x WFR

c. Acceptable fit with gas exchange chamber collar ______

d. Lysimeter I.D. No. inscribed correctly x WFR

______________________ ______
Inspector's Signature Date

2. LEAK TEST

			Date/Time
			5/27 - 2:30
-	Tare wt of dry lysimeter	21.5 kg	
a.	Wt. of water added to the lysimeter	100.0 kg	5/27/88 1500
	Tare Wt. withLifting Collar	32.4 Kg	
b.	Lysimeter top covered correctly	x	
c.	Initial wt. of water-filled lysimeter	132.4 kg	5/27/88 - 3 pm
d.	Lysimeter wt. after 24 hours	132.5 kg	5/31/88 11:15
e.	Wt. of water drained	100.1 kg	5/31/88 1200 noon

dry w/LC w/LC
32.4

Error of balance

f. Visible evidence of leaks yes______ no x 3-32 (initial dri repaired) 5/31/88 noon

g. Scale used Calibration # 815-66-01-001 (expires 5/16/88)

h. Scale calibration data located in LRB____________

s/WF Riemath 5/31/88
Inspector's Signature Date

Checklist for Tube Lysimeter 5

3. LOWER BARRIER CONSTRUCTION

a. Screen placed over drain hole x

		Layer	Size	Lift No.	Weight (kg)	Distance from top (cm)
	b.	Gravel	~~1~~/4" x-1"	1	21.5 kg	58"
73.9	c.	Sand	Course	2	7.4 kg	55 3/4" (1.9 kg H_2O)
Starting at 50.5 kg 23.4	d.	Admix ~~Sand~~	4 fills in one See Log BNW 52133	3	23.4 kg after evap & drain	48 3/4 start & ~~stop~~ (25.3 kg wet)

e. Geotextile cut and installed correctly x

f. Sand and gravel layers wetted to field capacity ______

g. Scale used ______

h. Scale calibration data located in LRB ______

______ Inspector's Signature ______ Date

Checklist for Tube Lysimeter #5

4. LYSIMETER SOIL BACKFILL DATA (scale calibration in LRB_____)

Lift No.	Lift Wt. (kg)	Ht. From Top (cm)	Lift Ht. (cm)	Density (g/cm3)	Moisture Sample No.
4	18.5	42 3/4"	6"	1.7	5-4
5	"	36 3/4"		"	5-5
6		30 3/4"		"	5-6
7		24 3/4"		"	5-7
8		18 3/4"		"	5-8
9		12 3/4"		"	5-9
10	20.8	6"	6 3/4"	"	5-10
		Total wt	207.1 kg	w/o collar	

WF Riemath — Inspector's Signature

7-18-88 — Date

Checklist for Tube Lysimeter 6

Treatment Number ADMIX VI

1. LYSIMETER INSPECTION

a. Drainage fittings, tube and valve (clamp) installed correctly x WFR

b. Acceptable fit with lifting collar x WFR

c. Acceptable fit with gas exchange chamber collar ____

d. Lysimeter I.D. No. inscribed correctly x WFR

Inspector's Signature ____ Date ____

2. LEAK TEST

			Date/Time
			5/27 - 2:30
	- Tare wt of dry lysimeter	21.4 kg	
a.	Wt. of water added to the lysimeter	95.9 kg	6/3/88
	Tare Wt. with Lifting Collar	32.2Kg	
b.	Lysimeter top covered correctly	xWFR	
c.	Initial wt. of water-filled lysimeter	128.1 kg	6/3/88
d.	Lysimeter wt. after 24 hours	128.1 kg	6/7/88/10:28
e.	Wt. of water drained	95.9 kg	6/7/88/10:28
f.	Visible evidence of leaks	yes ____	no 6/7/88 10:30

g. Scale used (Calibration #) 815-66-01-001 (expires 5/16/89)

h. Scale calibration data located in LRB ____

s/WF Riemath — Inspector's Signature

6/7/88 — Date

Checklist for Tube Lysimeter 6

3. LOWER BARRIER CONSTRUCTION

a. Screen placed over drain hole x

	Layer	Size	Lift No.	Weight (kg)	Distance from top (cm)	
b.	Gravel	+1/4" x-1"	1	21.5	58"	
c.	Sand	Course	2	6.5	56"	
d.	Admix ~~Sand~~	4 lifts in one	3	23.3 Evap & drain	Start & 49½ After Tamp	(2 kg H_2O) 25.3 wet

Starting wt. Tare 49.6 (72.9)

See Log BNW 52133

e. Geotextile cut and installed correctly x

f. Sand and gravel layers wetted to field capacity ______

g. Scale used ______

h. Scale calibration data located in LRB ______

______ Inspector's Signature

______ Date

Checklist for Tube Lysimeter 6

4. LYSIMETER SOIL BACKFILL DATA (scale calibration in LRB_____)

Lift No.	Lift Wt. (kg)	Ht. From Top (cm)	Lift Ht. (cm)	Density (g/cm3)	Moisture Sample No.
4	18.5	43¼	6"	1.7	6-4
5	"	37¼	6"		6-5
6	"	31¼	6"		6-6
7	"	25¼	6"		6-7
8	"	19¼	6"		6-8
9	"	13¼	6"		6-9
10	"	7¼	6"		6-10
11		6	6¼		6-11
			Total wt 206.6 kg w/ocollar		

s/WF Riemath — Inspector's Signature

7-18-88 — Date

Checklist for Tube Lysimeter 7

Treatment Number ADMIX VII

1. LYSIMETER INSPECTION

   a. Drainage fittings, tube and valve (clamp) installed correctly x WFR

   b. Acceptable fit with lifting collar x WFR

   c. Acceptable fit with gas exchange chamber collar ______

   d. Lysimeter I.D. No. inscribed correctly x WFR

______________________ ______
Inspector's Signature Date

31.9

2. LEAK TEST 5/27/88 2:30 Date/Time

   - Tare wt of dry lysimeter 21.1 kg

   a. Wt. of water added to the lysimeter 97.9 kg 6/3/88

   Tare Wt. with Lifting Collar 31.9Kg

   b. Lysimeter top covered correctly x WFR

   c. Initial wt. of water-filled lysimeter 129.8 kg 6/3/88

   d. Lysimeter wt. after 24 hours 129.8 kg 6/7/88 10:51

   e. Wt. of water drained 97.9 kg 6/7/88/10:51

   f. Visible evidence of leaks yes______ no 4/7/88/10:50

   g. Scale used (Dalibration #) 815-66-01-001 (expires 5/16/89)

   h. Scale calibration data located in LRB______

s/WF Riemath 6/7/88
Inspector's Signature Date

Checklist for Tube Lysimeter 7

3. LOWER BARRIER CONSTRUCTION

a. Screen placed over drain hole x

Date		Layer	Size	Lift No.	Weight (kg)	Distance from top (cm)
7-6-88	b.	Gravel	+¼"x-1"	1	21.5	58"
7-7-88	c.	Sand	Course	2	6.6	56" (2.8 kg H_2O)
Starting at Tare 49.5 kg (72.2)	d.	Admix 4 lifts in one ~~Sand~~ See Log BNW 52133		3	22.7	49¼" start ~~end~~ 25.5 kg wet

e. Geotextile cut and installed correctly xWFR

f. Sand and gravel layers wetted to field capacity ______

g. Scale used ______

h. Scale calibration data located in LRB ______

______ Inspector's Signature

______ Date

Checklist for Tube Lysimeter #7

4. LYSIMETER SOIL BACKFILL DATA (scale calibration in LRB____)

Lift No.	Lift Wt. (kg)	Ht. From Top (cm)	Lift Ht. (cm)	Density (g/cm³)	Moisture Sample No.
4	18.5	43¼"	6"		7-4
5	"	37¼	"		7-5
6	"	31¼	"		7-6
7	"	25¼	"		7-7
8	"	19¼	"		7-8
9	"	13¼	"		7-9
10	"	7¼	"		7-10
11	39	6"	1¼		7-11
			Total wt 206.3 kg w/o collar		

s/WF Riemath — Inspector's Signature

7-18-88 — Date

Checklist for Tube Lysimeter 8

Treatment Number 8 ADMIX VIII

1. LYSIMETER INSPECTION

   a. Drainage fittings, tube and valve (clamp) installed correctly — x WFR

   b. Acceptable fit with lifting collar — x WFR

   c. Acceptable fit with gas exchange chamber collar — ______

   d. Lysimeter I.D. No. inscribed correctly — xWFR

______________________ Inspector's Signature ______ Date

2. LEAK TEST

			Date/Time
-	Tare wt of dry lysimeter	22.1 kg	
a.	Wt. of water added to the lysimeter	97.3 kg	6/7/88/15:47
	Tare Wt. with Lifting Collar	33.0 Kg	
b.	Lysimeter top covered correctly	x WFR	
c.	Initial wt. of water-filled lysimeter	130.3 kg	6/7/88/15:47
d.	Lysimeter wt. after 24 hours	130.3 kg	6/14/88 08:37
e.	Wt. of water drained	97.3 kg	6/14/88 08:37
f.	Visible evidence of leaks	yes ______	no 6/14/88 08:37

   g. Scale used (calibration #) 815-66-01-001 (expires 5/16/88)

   h. Scale calibration data located in LRB ______

s/ WF Riemath — Inspector's Signature

6/14/88 — Date

Checklist for Tube Lysimeter #8

4. LYSIMETER SOIL BACKFILL DATA (scale calibration in LRB_____)

Lift No.	Lift Wt. (kg)	Ht. From Top (cm)	Lift Ht. (cm)	Density (g/cm³)	Moisture Sample No.
4	18.5	43"	6"	1.7	8-4
5	"	37"	6"	"	8-5
6	"	31	6"	"	8-6
7	"	25	"	"	8-7
8	"	19	"	"	8-8
9	"	13	"	"	8-9
10	"	7	"	"	8-10
11	3.1 kg	6	1	"	8-11
			Total wt fall	206.6 kg	w/o collar

s/WF Riemath — Inspector's Signature

7-18-88 — Date

Checklist for Tube Lysimeter 8

3. LOWER BARRIER CONSTRUCTION

a. Screen placed over drain hole ______

	Layer	Size	Lift No.	Weight (kg)	Distance from top (cm)	
b.	Gravel	+¼x-1"	1	21.5	58"	
c.	Sand	Course	2	6.7	56"	
d.	Admix xxxxx Sand	4 UFTs in one	3	23.1	49" start stop	25.3 kg wet 2 kg H_2O

Starting wt tare 50.4 kg (73.5)

See Log BNW 52133

e. Geotextile cut and installed correctly ______

f. Sand and gravel layers wetted to field capacity ______

g. Scale used ______________________

h. Scale calibration data located in LRB ____________

______________________ Inspector's Signature

__________ Date

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