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LA-SUB--95-49

Final Report

on

Mixed Waste Landfill Monitoring Prototype Test Design

for

Los Alamos National Laboratory

by

Eastman Cherrington Environmental
1640 Old Pecos Trail Suite H
Santa Fe, NM 87505

September 1994

Work performed under contract No. 3086L0014-34

Contract Technical Monitor: Robert Crowley, LANL
Principal Investigator: Carl Keller, ECE

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Table of Contents

I. Summary

The purpose of this contract is to design the prototype tests necessary for the verification of the measurement methods proposed for the Mixed Waste Disposal Facility. The design is limited to the hydrological performance of the measurement methods. It does not include the mechanical testing of the methods proposed. The test site is to be selected and when approved, construction drawings provided.

The contract also includes testing of vitrified clay pipe as the liner of choice for the passages under the landfill. The tests are to be done of both the hydrologic and the mechanical capability of the pipe. The test bed construction is to be supervised as it is being done by the construction contractor monitored by LANL. This contract does not include the logical subsequent work of performance of the measurements in the test bed.

Since this contract was received by September 15, with the work to be completed by September 30, only that work possible in the short time was performed. That included the design of the test bed, the purchase of the vitrified clay pipe and the mechanical tests of the pipe, and the purchase of the SEAMIST systems for testing in the clay pipe. None of those could be delivered in time for flow tests to be done on the clay pipe. The mechanical tests were done as part of the pipe purchase and are reported here. The contract was not extended beyond Sept. 30 for lack of funds. This report is therefore limited to the preliminary design of the test bed and to the specification of the orders for the materials. The hope is that funding will be restored to the program for the completion of the design and measurement effort.

II. Results

Task 1

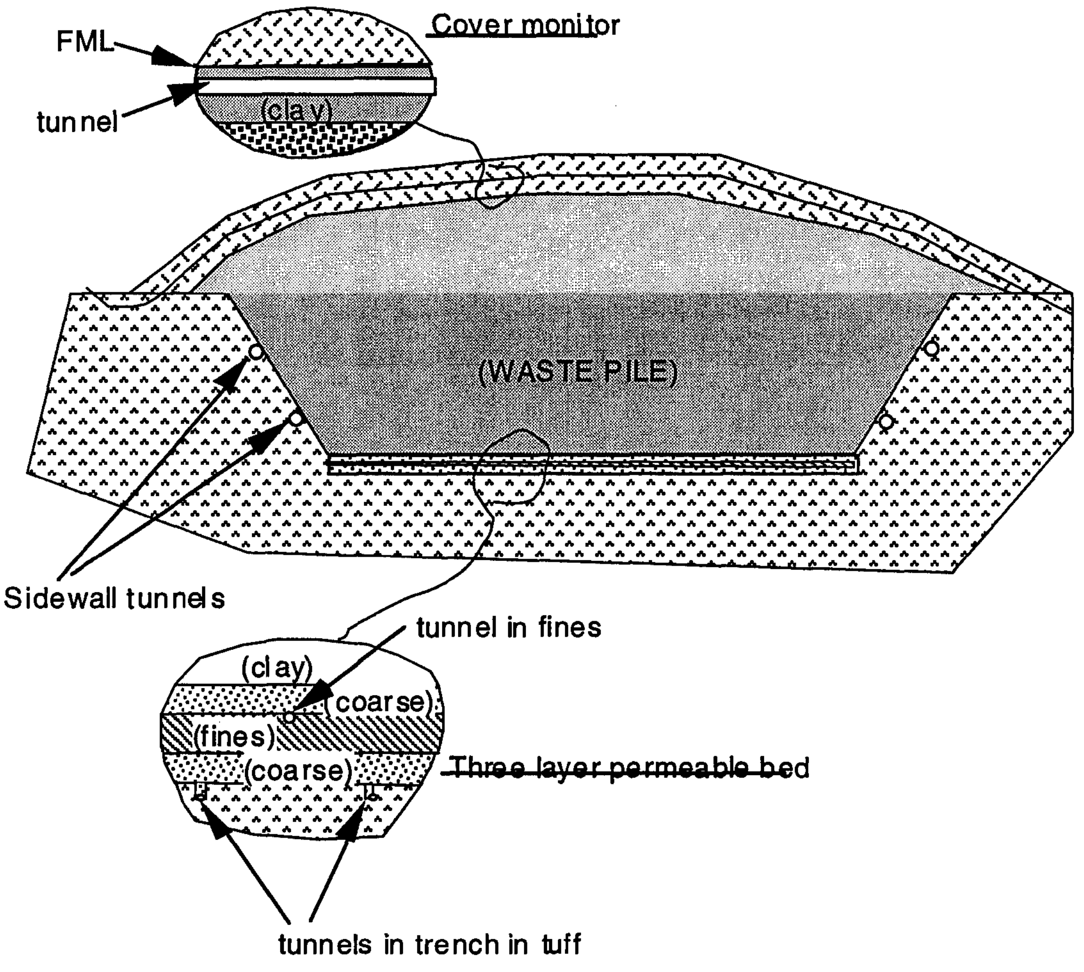
This task is described in the enclosed statement of work in Appendix A.

The work to be done included the design, coordination of the design with probable participants, and conceptual drawings. The work done was to provide the preliminary conceptual design drawings, the test plan, and the instrumentation description. Very little coordination with the participants could be done in the time available.

The design

The approach is to reproduce a section of the monitoring system shown in Figure 1 in a sufficiently small section as to minimize the cost and yet allow a valid test of the porous flow processes and measurement procedures to be used in the actual landfill. The monitoring design included three primary parts: the cover monitor, the sidewall monitors and the vadose zone monitoring bed beneath the containment liner of the landfill (hereafter called the permeable bed). The monitoring measurements which were described as interior to the containment system (Ref. 1) were not included, because they were not likely to be part of the final design (see the final report on the monitoring design, and the reliability assessment thereof, Ref. 2). Also, those measurements were more relevant to the landfill internal behavior than to a monitoring of the leakage from the containment system. That external monitoring is the focus of this design.

Figure 1. Cross section of landfill showing monitors



The sidewall monitoring was also not explicitly included in the prototype test except as the basic function is inherent in the lower tunnels of the permeable bed system. The permeable bed and the cover monitoring were included in the test bed in a manner to allow both to be constructed with the minimum cost yet provide a full reproduction of the hydrologic circumstances.

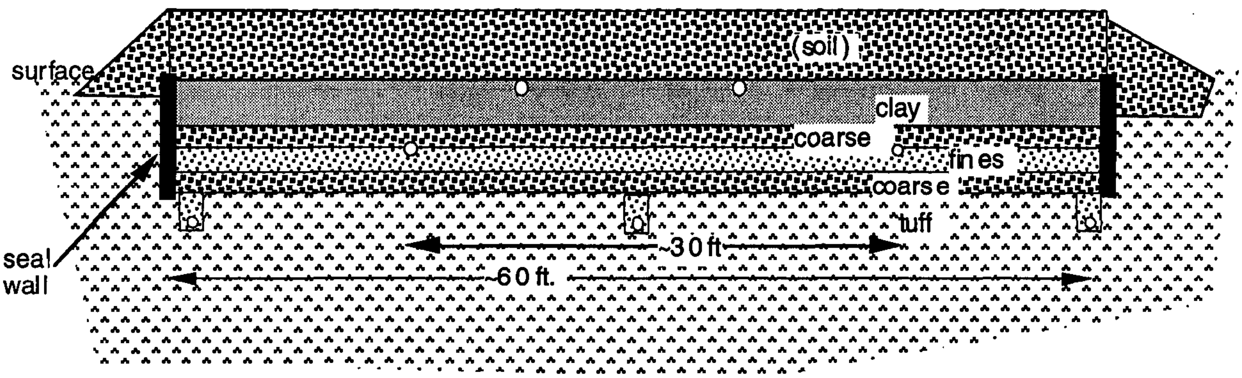
Generally, the term monitoring measurements is reserved for those measurements to be done in or via the tunnels (i.e., the measurements proposed as monitoring measurements in the landfill system.) The term in situ measurements refers to the measurements to be made internal to the test bed by gauges emplaced in the soil layers. Those are not included in the landfill monitoring design. They are the more traditional in situ measurements of the soil physics science.

General Construction

The design is shown in Figure 2. The permeable bed is built upon a tuff bed, trenched to provide the "tunnel" emplacement shown. The layered bed of coarse/fine/coarse material is laid down by the heavy equipment to be used in the actual construction of the landfill. The upper array of tunnels is shown half-buried in the fines material. The representative section was selected as 60 ft. by 60 ft. That includes the basic element of a 30 ft. tunnel spacing with good control of the boundary conditions as reflective boundaries. In the mixed waste landfill, the permeable bed is overlain by a clay layer (the lowest member of the containment system). The upper cover monitor is located in a clay layer. By combining the two clay layers for the prototype test, the two monitoring systems can be reproduced using a single clay layer. The clay is covered with a flexible membrane layer (FML) of HDPE. On top of the FML is piled enough soil to simulate the rest of the cover thickness. The result is that the cover monitor is correctly buried and the lower permeable bed is well buried, but much less than the 50 ft of cover expected.

The construction can be best done by scraping the tuff bare of soil at the actual landfill site. The trenches can be cut in the tuff surface, the layers and tunnels emplaced, and the soil removed can be piled on top of the FML. This should allow relatively simple construction of a testbed that simulates well the conditions of the cover and vadose zone monitor system.

The access to the tunnels is shown in Figure 3. The curved pipe is similar to that entering the tunnels in the permeable bed. The access to the cover tunnels is similar but at a more shallow angle. The pipe cap and manifold connections are realistic.



o tunnels

layer dimensions: one ft (each) of coarse, fines, coarse, 2 ft clay, ~4 ft soil. Bed is ~60 ft wide.

Figure 2. Dimensions of the prototype test bed

The sides of the pit are to be sealed to prevent flow of water or vapor in order to simulate the no flow boundary condition. The construction requires a wall that is about 6 ft. high and which can bear the construction loads of heavy equipment emplacing the several layers. It is expected that the soil will be excavated to the tuff surface (perhaps 4 ft. deep), the soil piled nearby, the 5 ft of layered material (i.e., coarse (1 ft), fine (1 ft), coarse (1 ft), clay (2 ft), the FML) placed and then the soil piled on top. The pit will be 4-5 ft deep with the side wall built of plywood backed by tamped dirt as the pit is filled. The plywood should be sheathed with heavy plastic on the inside surface to prevent moisture loss. Above the surface of the FML, the soil can be heaped across the top of the wall to a simple angle of repose. Figure 4 shows a possible geometry. Special care must be taken to assure that there is no infiltration of surface water into the test bed below the FML on the clay or through the side walls.

It should be noted that the "tunnels" may actually be clay pipe. That will depend upon the clay pipe tests to be done in Task 2. The original design calls for granite slabs covering the open trenches in the tuff. If the clay pipe is adequate, the pipe can be lain in the trenches also. If not, the tuff must be trenched according to the geometry shown in Figure 5. However, the clay pipe geometry may be either of those shown in Figure 5.

The SEAMIST access is likely to be via the geometry shown in Figure 6. There are no special requirements for the surface around the test bed except that it not be too muddy in the working areas near the manifolds and pipes. The surface of the soil pile should be covered with another FML to prevent infiltration of water. The reason is that we do not want rainwater to penetrate any potential leak in the FML above the clay layer to confuse the moisture injection tests planned.

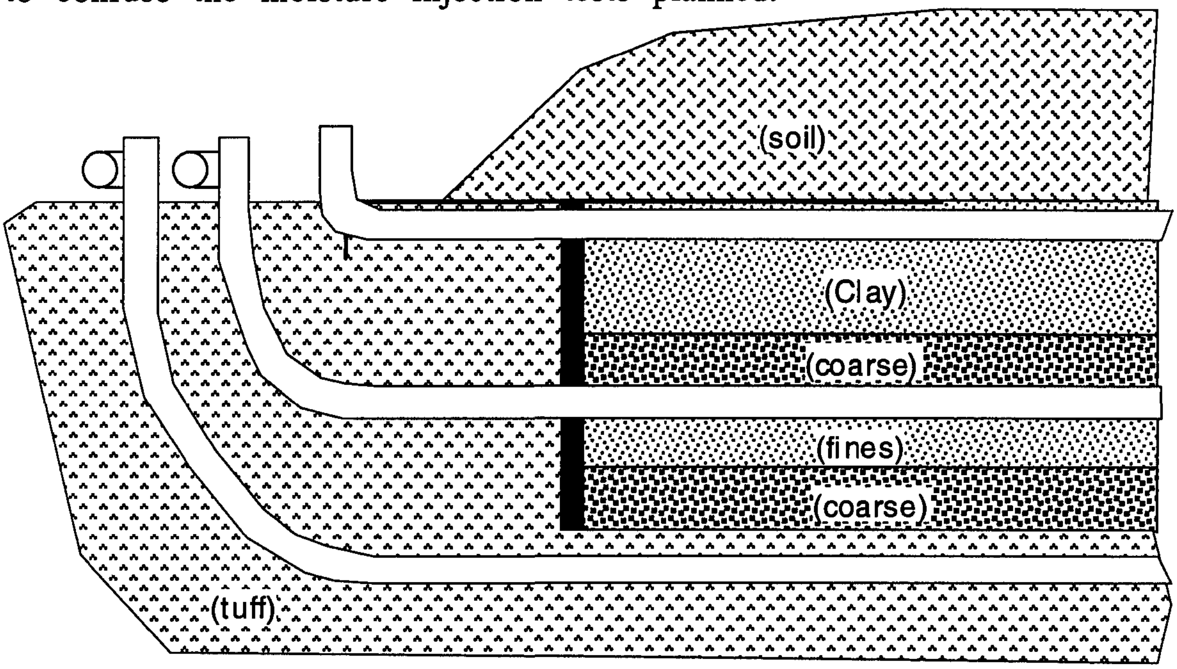


Figure 3. Access pipes to tunnels in testbed

Instrumentation plan

In general, the instruments emplaced are of two kinds: those for measurement of the conditions in the beds and those for performing the measurements of the monitoring design. The other apparatus embedded in the test bed is for the purpose of injecting leak simulants for the testing of the measurement capability. The yet incomplete part of the design is the measurement of the conditions of the bed prior to, and after, the leak injections. Those are heavily dependent upon the experience of EES-15 who has done those kinds of measurements in their cover performance experiments. The in situ condition measurements will require tubing and electrical cables to be emplaced in the test bed as it is being constructed. The expectation is that as the layers are individually completed, the instrumentation will be installed. The major concern is that the heavy equipment will damage the instrumentation. However, the clay pipe must also be protected by the construction procedure, so the same methods should allow the protection of the instruments.

The instruments for the monitoring measurements are all installed via the tunnels after construction. Only the access tunnels need to be protected.

Those may actually be cast in concrete where they transition from the layered medium, through the wall, to the surface.
The complete list of possible measurements considered for both the monitoring mode and the in situ measurements is provided in Appendix B. In the interest of economy, and reliability, certain measurements were selected for the test bed.

The in situ measurements are expected to include many the gauges shown in Table 1. The tensiometers and suction lysimeters will only be able to measure relatively wet conditions. The TDR measurements will need to be calibrated in the soils being measured. When the tests are done, or as needed, the soil in the layers may be cored from the surface for verification of the measurements, but that will damage the FML and can

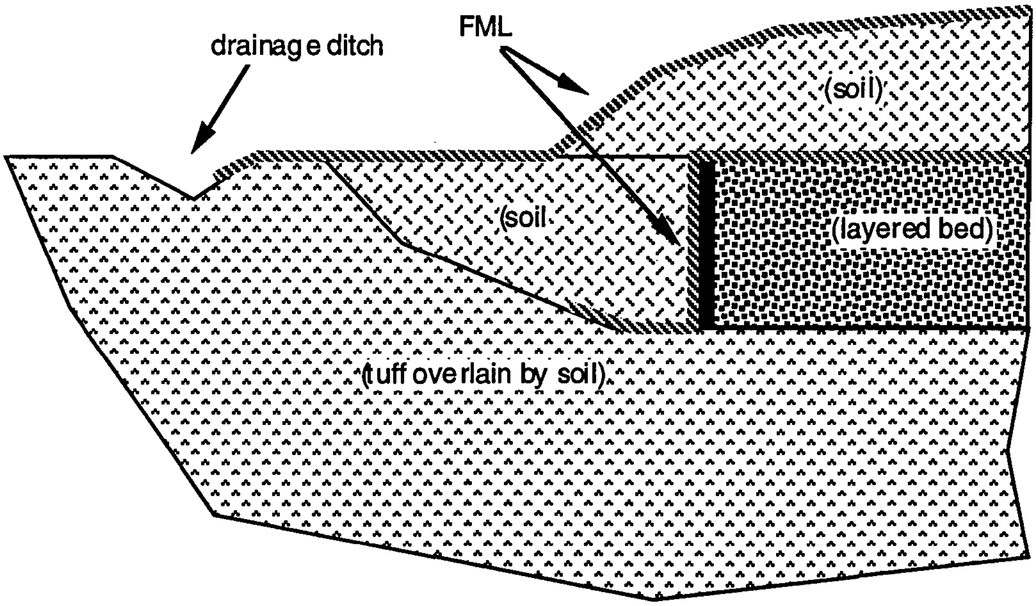


Figure 4. Wall and surface seal geometry of layered bed

not be done until the leak fluids have been injected. Some of the monitoring measurements will also serve to measure the in situ conditions. The neutron moisture measurements in the tunnels should be able to measure the moisture content of the bed for correlation with the absorber measurements and the vapor measurements. The temperature measurements are useful in the interpretation of the relative or absolute humidity measurements of vapor samples collected. Tubes emplaced in the medium can be used to extract small in situ soil gas samples for comparison with what is drawn from the tunnels.

Table 1.

Gauges considered for prototype tests

	para-meter	Gauge	Number (???)
Leak injection			
	fluid rate	liq. meter	1
Medium			
	Cap. tension	Therm. Psychrometer	10
	saturation	TDR	30
	liq.sat.& composi-tion	core and suction-lysimeter*	10/5*
	soil gas	tube	5
	cap. tension	tensiometer*	10*
	breakthru	wire grid	1(60'x60')
	resistance	wire pairs	10
Monitor-ing			
	absorber resistance	wire pair	10
	gas sample	SM w/ tubes	5/mem.
	liq. compo-sition	absorbers	30/mem
	radiation	rad. meter	1
	saturation	Neutron moist. log	1(in hand)
	saturation	absorbent covering	30 sec./mem.
	resistance	induction log. tool	1
	temperature	thermistors	6
Boundary conditions			
	temperature	thermistors	5
	rainfall	r. gauge	1
	press. in tuff	tube with transduce	3 depths
	baro. pressure	barometer	1

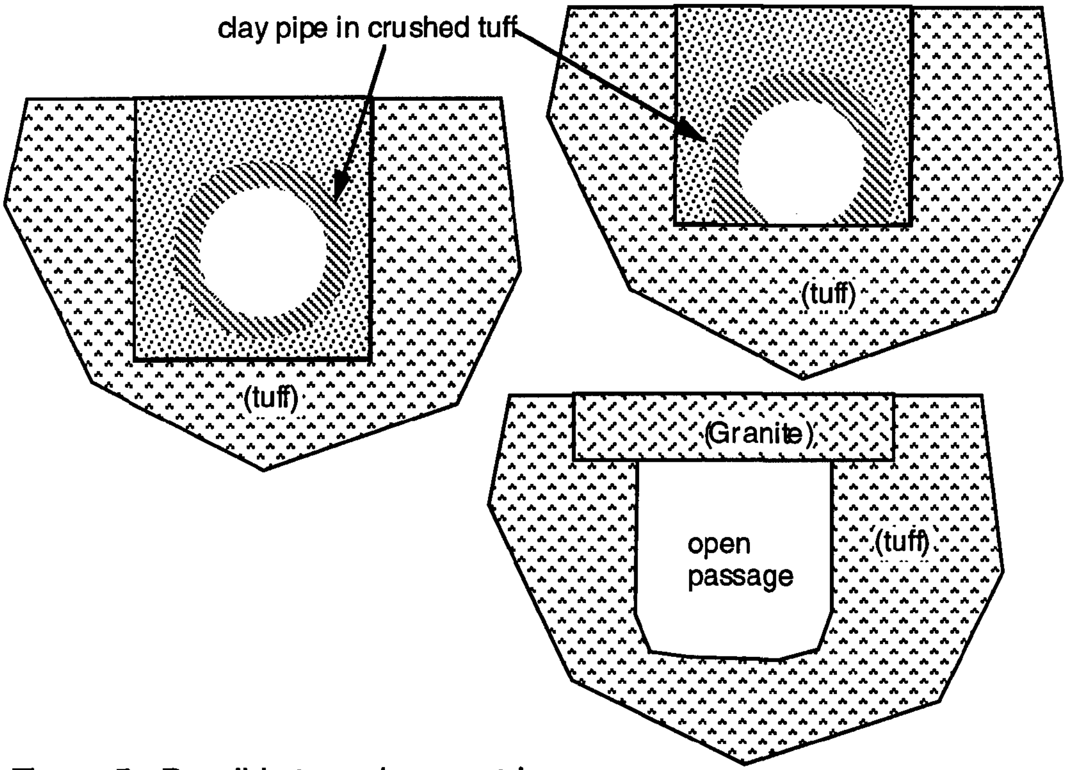


Figure 5. Possible tunnel geometries

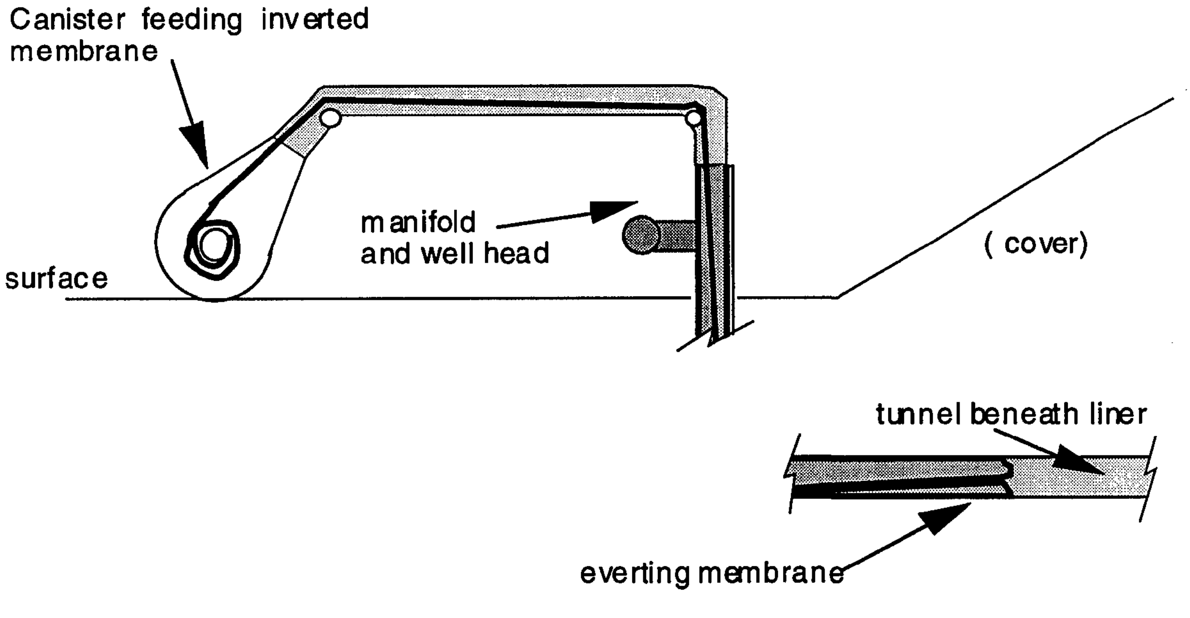


Figure 6. Geometry of the monitoring measurement installations

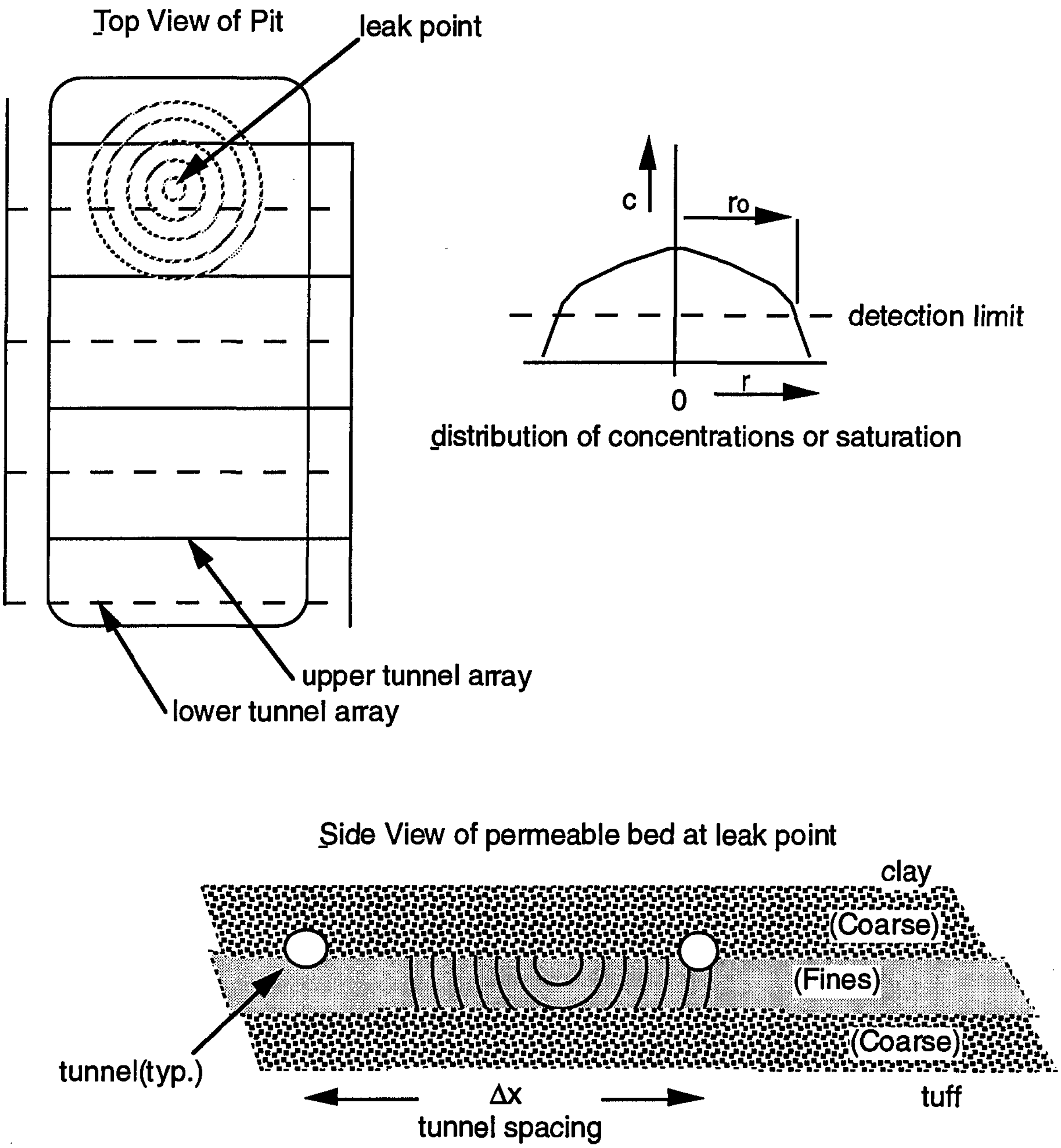
The instrumentation philosophy and design rationale

In the most simple test, the leaks can be injected at several different rates and the monitoring system can be exercised to see if the known leaks can be detected and under what leak rate and time scales. In fact, that is the main part of the prototype test. The requirements are that the leaks be injected in a realistic manner and that the monitoring measurements be done frequently. It is desirable to start with small leaks to test the limits of detection and work up to larger leaks. The problem with small leaks is that they take a long time to propagate. Yet, if the bed is wet with large leaks first, the small leaks are masked. The solution proposed is that the bed be divided by an impermeable barrier into the fast leak section and the slow leak section so that the tests can be conducted simultaneously. The best location for such a dividing wall is perpendicular to the tunnels across the midsection of the bed. The location is shown in Figure 2. The installations for monitoring can be done from the two ends independently. The tunnels must be blocked at the dividing wall to allow the vapor extraction measurements. Otherwise, a single pass of the SEAMIST system could measure both sections. Another attractive approach is to allow the tunnels to be blocked with a valve at the wall to allow one to sample both and then singly. If the tracers used for detection resolution can be separate in the two sections, the tunnels need not be blocked. The recommendation is that the tunnels be blocked by the wall <u>and</u> to use distinctly different tracers in the two sections. Since the cost of construction is increased by the dividing wall, it may be best to trench the layered bed after the beds are laid in place and to seal the trench with plastic sheeting and cement.

The in situ measurements have the large advantage of coupling the monitoring measurements with the traditional methods, and also with the predictive calculations used for developing the timing of the experiment. Because the frequency of monitoring and the size and rate of leak injections must be well done, the proposal is that the injections should be calculated for their expected propagation from the injection point to the intercepting tunnels. The predicted plot of a wet spot and the distribution of tracer concentrations and saturations, shown in Figure 7, is very helpful to the monitoring design. It is equally helpful to the prototype test design.

Calculations already done show that the wet spot from a 10 gal/day leak spreads quickly through the layered bed. Fortunately, it is more important to show that a large leak can be detected than it is to measure the smallest possible detection leak rate. The small leak detection may take more than a year.

Figure 7. Geometry of leak detection



With that in mind, the following discussion proposes a measurement procedure for the prototype test.

The matrix of measurements shown in Table 2 is based upon several assumptions:

- Vapor leak detection tests should be done first without significant liquid injection.

- The vapors injected should have partial pressures similar to solvents of concern and also similar to tritium (nearly that of water).
- The concentrations should be larger than the levels of concern for a small leak.

Otherwise, we could waste a lot of time looking for leaks too small to detect and too small to be a concern. The leak rates, location, and concentrations are a potentially controversial issue, but they should be reviewed by the performance assessment team, since they deal with the source term estimates.

Table 2. Prototype test measurements

Time	Purpose	Phase	In Situ	Monitoring
	Initial conds.			
1st wk.		vapor		vap. sample
		liquid	TDR	neut. log
			Suc. Lysimet.	resis. log
			resis. wires	absorbers
			core	
	Transport in permeable bed			
2nd. wk.		vapor		
		(daily meas.)	vap. source	vap. sample
3rd. -16th wk.		liquid & vap.		
		(weekly)	TDR	neut. and resis. logs
			suc. lysim.	absorbers
			resis wire	vap. samples
			suct. history	(other
			at inject. pt.	sensors ??)
	Transport in the cover bed			
1st wk.	Initial conds.	liquid		
			TDR	logging tools
3rd-15th wk.	point source injections	liquid/vapor (weekly)		
			TDR	logging tools vapor RH
16th wk.	planar source	liquid		
			TDR	logging tools

The time scale of the prototype test should not be more than four months, because to last longer costs more and allows time for propagation of the leaks injected into the less predictable long time scale. The provision for extension of the tests is allowed. The analysis of the chemical samples should be relatively quick, since the results may impact the subsequent measurements planned. For example, a null result for all absorbed samples may lead to the use of higher concentrations or larger volumes for the leak simulants. Since the results may be late, the plan is to progress from low to very large concentrations and volumes quickly. In the low leak side of the bed, the monitoring interval is of less concern than in the large leak side. If the monitoring interval is too long for a real landfill, the large leachate leak can lead to more serious problems. If the test is not run long enough, the small leak may not be detected. The recommended test interval is four months with actual tests run no less frequently than once a week. The vapor sampling during the second week should be done daily. It is not uncommon in flow tests to have tracers show up earlier than expected. First arrivals are an important test of the predictions.

The kinds of monitoring measurements are also shown in Table 2. They have been taken from the hierarchy of measurements in the preliminary design document, but they are conducted nearly simultaneously in this test. The only special care required is that the vapor sampling not be done in a manner so as to continually exhaust the vapor to be detected at less than detection concentrations. For that reason, different tracers are proposed for different leak volumes. One of the major disadvantages of the short time of this incomplete effort is that we were not able to consult with the analytical chemists on the best tracers to be used to simulate the hazardous materials. It is assumed unacceptable to inject hazardous materials into the test bed. If that requirement can be relaxed, the realism of the prototype test can be increased. It is realistic that the testbed can be excavated afterwards to observe the post test state of dyes and to sample for moisture and tracer content since the soil cover is so thin.

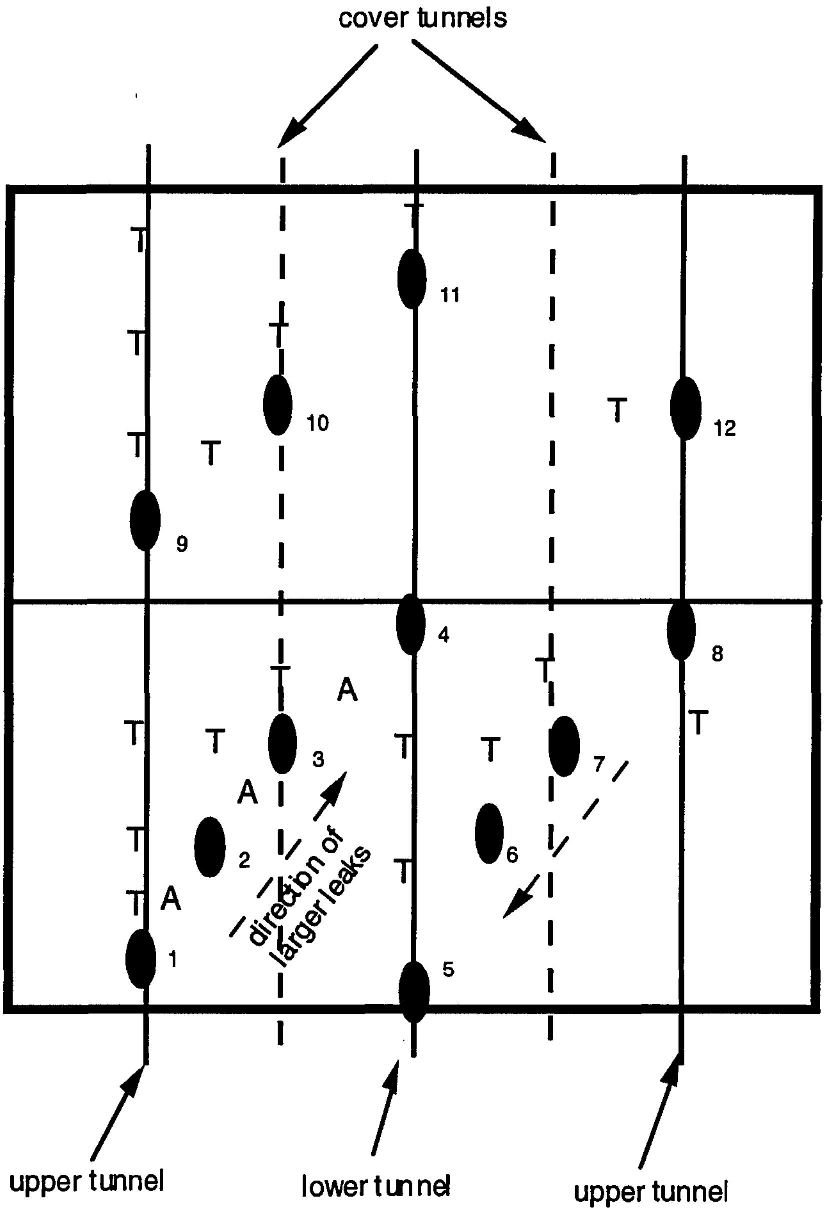
The test of a good experiment is that the factors which can perturb the process to be measured are realistic or insignificant. Time is the factor which is not well reproduced in this test. The leaks are expected to develop over times much longer than that of this test. For example, the leakage into the clay through the FML for the cover monitor is likely to occur very slowly or in association with a major failure of the FML due to settlement of the waste. That is not the case for this test. The test focuses on the ability to detect a wet spot in the clay by use of several methods. How does one develop a wet spot in the clay in time for this test, since the clay is relatively impermeable? The next section addresses the question of the specific leak injection geometries and the relationship to the test objective.

Leak Simulation

In the permeable bed

The leak injection strategy is difficult to define. A simple approach like starting all leaks at the same time with the same flow rate and stopping the flow later for the larger leaks is attractive. It gives a simple order to the approach. The smaller leaks are located nearer to the tunnel for better detection. Then the larger, more distant, leaks arrive later at the tunnels.

Figure 8a. Injection points in the permeable bed



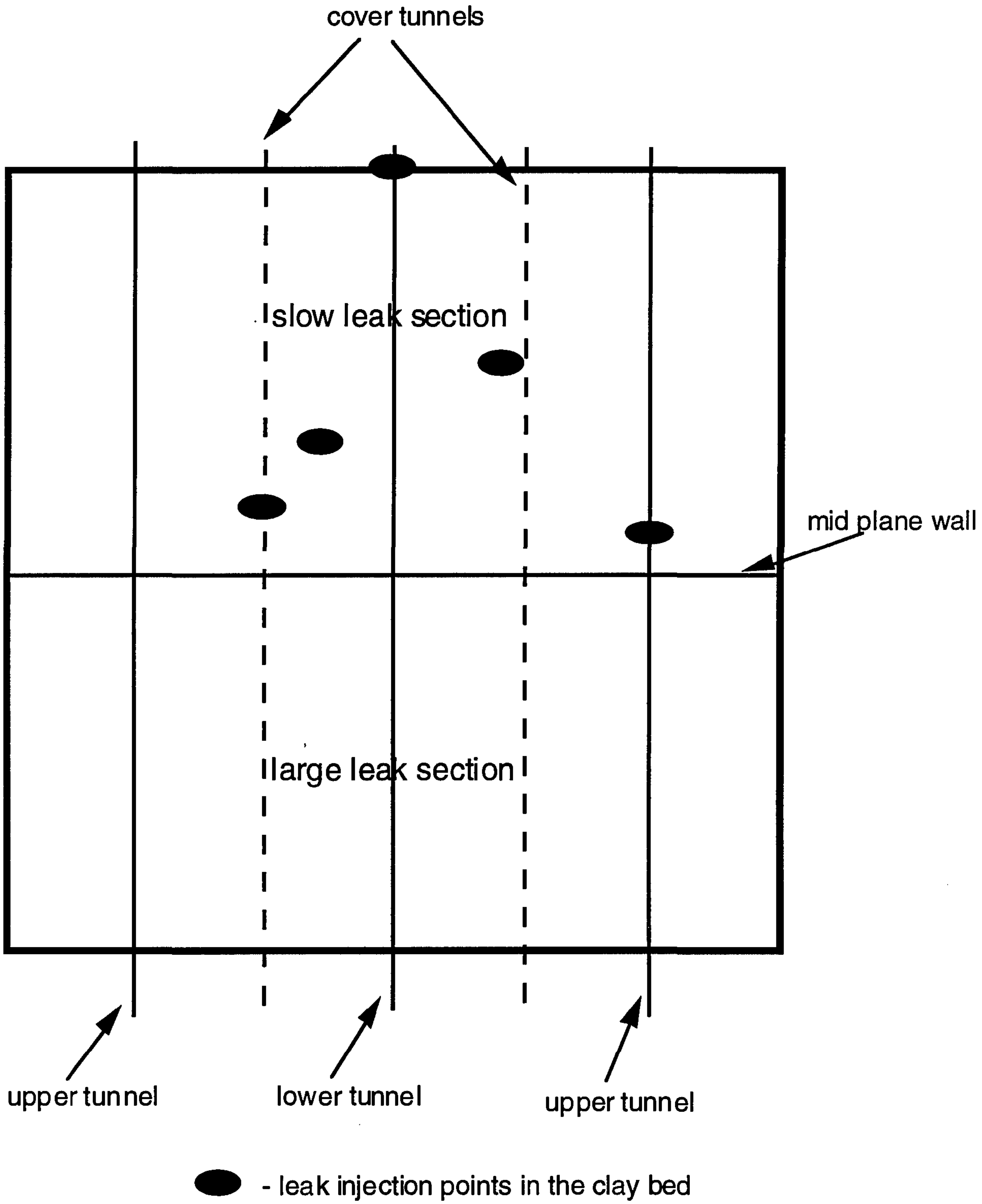
T- is a TDR measurment position in the fine layer

A- is a suction lysimeter in the fine layer

⬮ - is an injection point in the fine layer, except over the upper tunnel, where the injection point is at the top of the coarse layer.

It is important that the leaks are individually tagged with different tracers. The tracers must be conservative, if possible, and both dyes and dissolved salts are attractive. The absorption of a dyed liquid is especially easy to detect on a white absorber.

Figure 8b. The location of leaks in the clay cover layer.



Ideally, each leak would be propagating into the initial in situ soil condition. In some directions from the leak, that is possible for the geometry shown in Figure 8a. The larger leak section would have the smallest leak at no. 1, and the largest at no. 4. The wall effect next to no. 4 would be to double the effective leak rate. The arrival at the tunnel left of no. 4 would not see much perturbation from the other leaks if the leak rates are not too large. The leak rate and the leak time for each injection should be debated by the experimenters. Timing the leaks such that the first arrivals are from the small leaks assures that the larger leaks will not perturb, or be perturbed by, the small leak transport. The transport after the leak is stopped is likely to be slow compared to that while the injection is in progress, because of the common steep gradient at the wetting front. The absorbers should be equipped with resistance wires to measure the conductivity changes of the absorber to determine times of arrival and the general history of the absorption. Conductivity probes in the soil may also be useful for detecting arrivals and for comparison with the measurements in the absorbers. The simple filter paper mounted wire pairs described in Ref. 3 are an attractive addition. Figure 9 shows how the resistance probes might be spread over the test bed in a square array. The probes could be located at the bottom edge of the fines layer to measure the spread of a wet spot, and an array on the tuff surface could detect breakthrough.

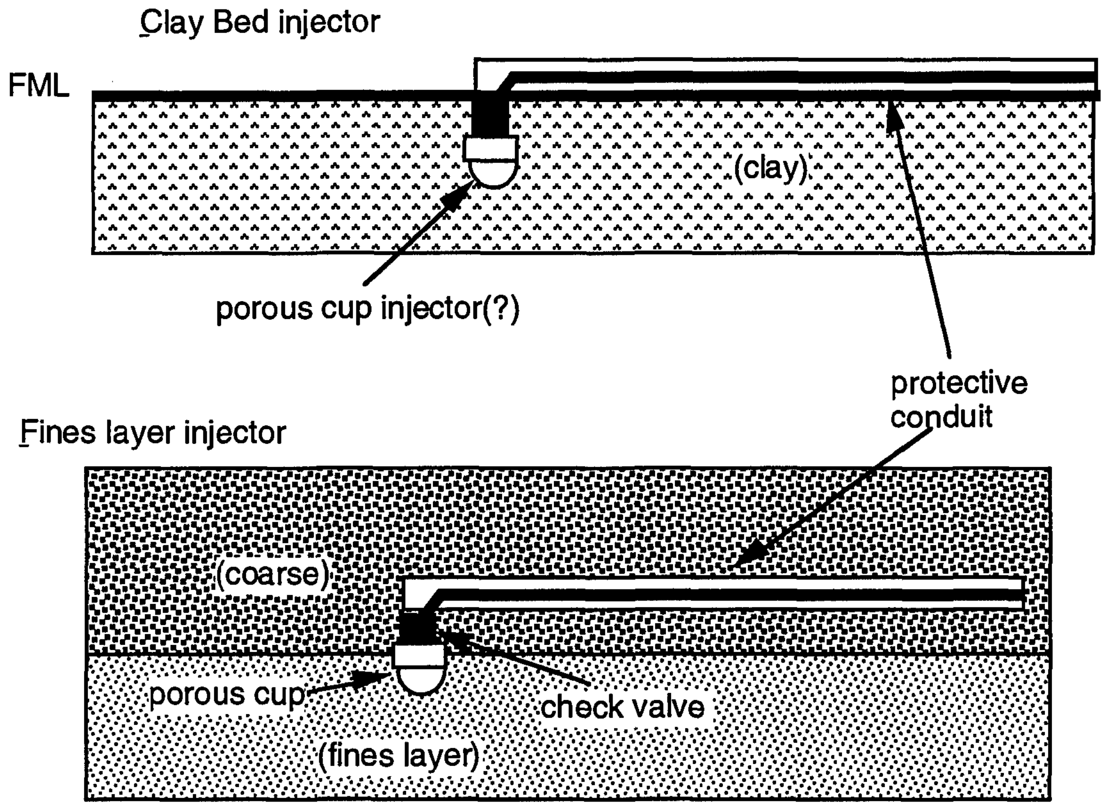


Figure 8c. Injection point geometry (all tubing lines parallel to the tunnels)

The same resistance measurements can be used for the wet spot propagation mapping in the clay layer. In that case, the probes can be located at the top of the clay layer, since the gravitational effects are likely to be small. The correlation of the resistance measurements with the TDR measurements should allow a measure of the relevance of the resistance measurements. The resistance measurements must be performed in a manner so as to not generate a masking potential offset. That usually requires the use of an AC voltage that generates a low current.

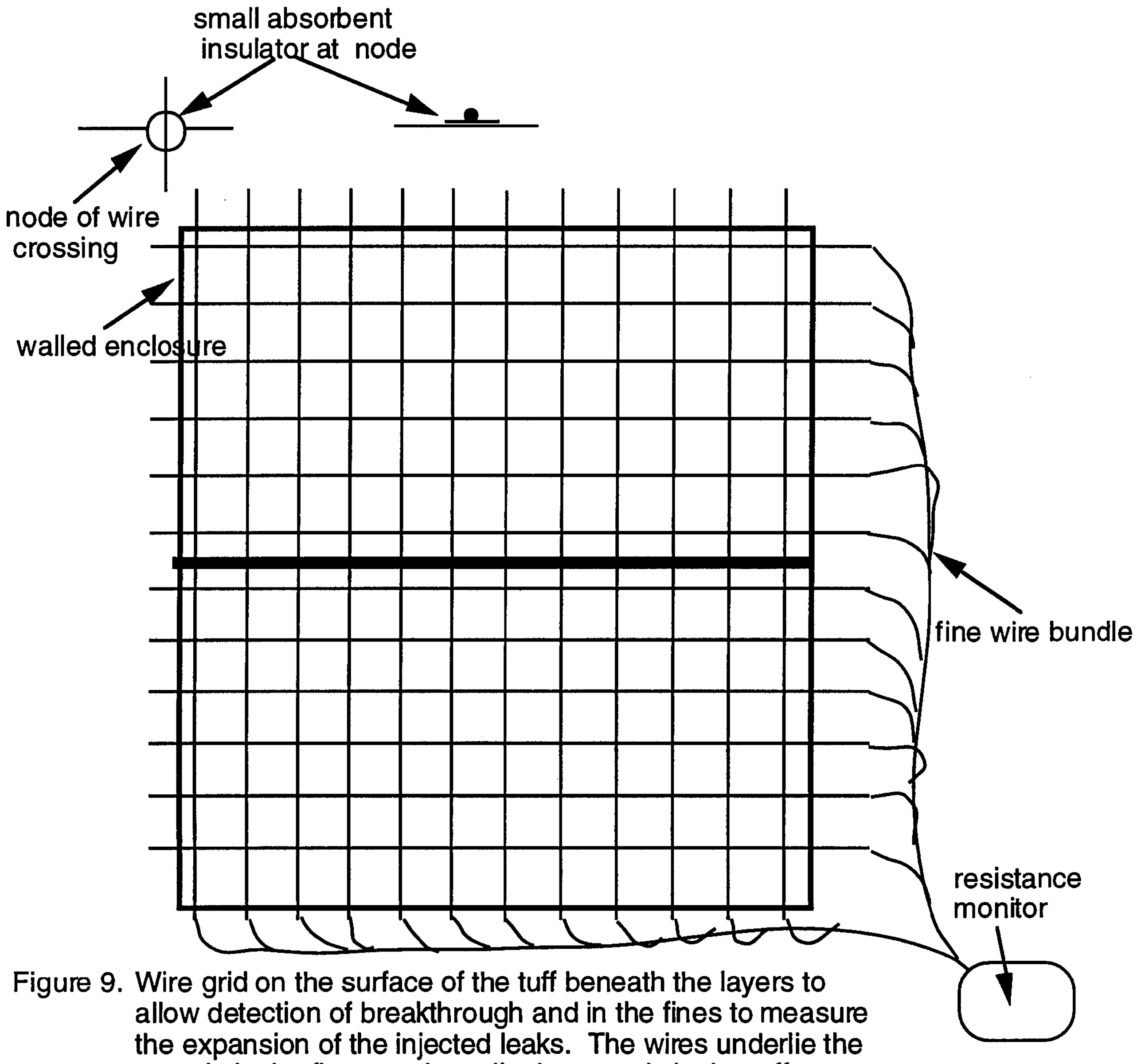


Figure 9. Wire grid on the surface of the tuff beneath the layers to allow detection of breakthrough and in the fines to measure the expansion of the injected leaks. The wires underlie the tunnels in the fines, and overlie the tunnels in the tuff.

The locations of TDR gauges are shown on Fig. 8a also. No tensiometers are shown since they would be "sucked dry" by the initial relatively dry conditions. However, at the end of each injection, if the injector tip screen could be a porous cup (Fig. 8c), the injection point could serve as a tensiometer to watch the capillary tension rise as the liquid diffuses.

Several suction lysimeters are shown in Fig. 8a to allow possible sample collections late in the injection sequence when the saturations may be high enough in some places to allow them to work. The largest leak could be timed to allow a large saturated region to develop in hope of seeing some evidence of break-through to the tuff below. It is for that reason also that the large source, no. 4, is locate directly above the lower tunnel.

The injection rates in the southern half of Figure 8 should be large enough to break through for sure. The injections in the northern half should be sized to allow break through of only the largest leak.

In the clay layer

The leak rates into the clay layer are certain to be controlled by the permeability of the clay. The only way to increase the injection rate is to pond water at a greater height above the injection point. That is a possibly real mechanism if the drainage layer should become clogged. The other possibility is to simulate a fissure in the clay as might occur with a large waste settlement. That would be an injection along a very permeable plane. The definition of this leak geometry would best be done after a debate of the most likely failure modes of the cover.

The failure modes that are the most likely are the following: waste settlement and the associated sink, root intrusion, tears during construction, slumping of the slope of the cover under saturated conditions, and drilling through the cover (long after the site is closed). Most of these failures, except the sink, are more of a problem if the drainage layer should also become plugged. There are several possibilities for the plugging to occur. The possibilities also depend heavily upon the water infiltration possible. If the landfill cover can be monitored, surface uses of the site may be more tolerated (with associated irrigation) than if the cover can not be monitored.

The injection points shown in the clay layer are relatively near the tunnels because more distant points would not be expected to be detectable in the time frame of the experiment. There may be experience that would allow a better selection of injection rates and positions. In the time of this effort, the literature could not be searched, nor could the experience of the EES-15 group be reviewed.

Task 2

The thrust of this task is to characterize the soil and the candidate clay pipe. The soil characterization tests were not done because of the long time for conducting the tests (estimated as 12 weeks by Dan B. Stephens and Associates). Those tests could not be started without the definition of the soil to be tested, the fines material. That has not been done, because of the late results of LANL calculations of the flows in the initial soil types defined for the calculations. However, the fines layer definition should not be difficult, since one can mix a wide variety of materials in the manner necessary to achieve the air flow and the tensions needed.

The clay pipe was ordered from Superior Clay Corporation according to the specifications shown in Appendix C. However, the laboratory characterization was not ordered for the same reasons that the soil tests were not done.

Task 3.

The SEAMIST systems were purchased, since the catalog price and the order constituted a commitment of the '94 funds. The systems purchased are those described in the proposal and Task 3:
Five membranes 80 ft long, with three of them blank for installation of absorbers and two of them with 5 equally spaced gas sampling ports for vapor sampling in the 60 ft test bed, were procured.

The clay pipe has been delivered and the mechanical tests have been performed by Superior per the industry procedures (ASTM C700) in a three line loading machine. The permeability tests on the pipe have not been done, because the pipe delivery was after the termination of this effort. The strength tests of the clay pipe are encouraging. The relative strengths of the pipe are shown in Table 3 as compared to the fully fired round perforated pipe (3625 lbs./ft vs. the industry minimum of 2000). The pipe dimensions are provided in Appendix C.

Table 3. Pipe strengths

no.	Pipe Description	Crush (lbs/4')	relative strength
1	thick wall plain; bisque fired	28,750	2.0
2	"	33,000	2.3
3	perf. thick plain, bisque fired	31,000	2.1
4	perf. and scratched, bisque fired	5300	0.36
5	perf., bisque fired	6500	0.45
6	"	5000	0.34
7	perf, full fired	14,000	1.0
8	perf. & slotted, full fired	11,700	0.81

9	"	10,800	0.81
10	perf & tunneled, full fired	7000	.48
11	"	6800	.47

The flow tests through the clay pipe were to measure to what degree the pipe was "transparent" to the flow of pore liquids to absorbers placed inside the pipe as a function of the surrounding soil characteristics. Because of the late start, that was not possible.

Task 4

The test bed has not been built, so the coordination was not done.

Deliverables

The deliverables in this report include the following:

1. Preliminary test designs and instrumentation descriptions.
2. Clay pipe purchase and strength test results
3. SEAMIST system purchases
4. Final report

Progress reports were not provided since the effort covered only a half month.

There were no interactions with the regulatory agencies during the course of this contract.

The problem with the schedule was noted on the signed contract.

This report is included in the ECE report library and the contract files are maintained by ECE. The untested clay pipe (about 3 tons) is stored at ECE's warehouse until further notice along with the SEAMIST systems fabricated for use in the test.

III. Conclusion

The results for the two week effort available are substantial. The equipment needed has been delivered, the preliminary design developed, and some test results are available. The major factor in the preliminary design is the lack of time for discussion of the design with the other participants. However, many of the potential problems have been addressed in the construction sequence and in the performance of meaningful measurements in the test bed.

The work that is started should be continued to determine whether the monitoring method meets expectations. In particular, the clay pipe tests should be done because of the dependence of the approach on an adequate construction of the tunnels for both hydrologic and mechanical requirements. The initial tests suggest that the clay pipe is strong enough. Does it allow the pore liquid to pass through sufficiently well? Probably.

References

1. R. Crowley and C. Keller, "Preliminary Design Document for the MWDF Monitoring & Alarm System (MAS)", Mixed Waste Disposal Facility (MWDF), LANL MWDF Project, Los Alamos National Laboratory, Los Alamos, NM, November 5, 1993.

2. C. Keller, "Final Report on Mixed Waste Landfill Monitoring Design", for Los Alamos National Laboratory Contract No. 9-xz3-2348K-1, ECE Technologies, Santa Fe, NM, September 1994.

3. C. Keller and B. Travis, "An Evaluation of the Potential Utility of Fluid Absorber Mapping of Contaminants", *Proceedings of the Seventh National Outdoor Action Conference and Exposition*, pp. 421-435, Las Vegas, NV, May 25-27, 1993.

Appendix A

STATEMENT OF WORK

July 14, 1994

Revised August 29, 1994

For Support of the LANL Environmental Monitoring Sensor Development Project

GENERAL: This Statement of Work is to provide for the development of sensors and monitoring methods for existing and future Low-Level Mixed Waste (LLMW) facilities at LANL and other DOE sites.

DESCRIPTION OF WORK:

Task 1: Develop construction design requirements for the hydraulic and chemical sensitivity tests for monitoring methods and sensors that are proposed for use in low-level mixed waste (LLMW) facilities at LANL and other DOE sites. These tests shall investigate the hydraulic and chemical characteristics of the proposed vadose zone monitoring system as proposed for the MWDF Monitoring and Alarm System (MAS) in the MAS Title I Preliminary Design Document. That test design support shall include the following:

A. The required overall test geometry and objectives (to be approved by the LANL project leader).

B. Predictions of expected behavior in terms of the driving pressures and retrieval tensions for the system.

C. Definitions of required measurements to validate the predictions of the related models.

D. Recommended construction sites.

E. Test procedures to be followed.

F. Construction guidelines.

G. When the site is selected, conceptual construction drawings will be provided. The drawings shall be sufficiently detailed to enable preparation of final drawings used in a construction bid package.

H. The Subcontractor shall coordinate with personnel from LANL EES-15 to incorporate measurement procedures and design requirements into the design of the proposed prototype tests that will be used to validate and verify new measurements proposed for these tests.

Task 2: The Subcontractor shall perform or subcontract and coordinate the testing of soils and construction materials purchased under Task 3. These subtasks shall consist of the following:

A. Porosity tests on various shapes of vitrified clay pipe (VCP) as specified by The Subcontractor.

B. Permeability tests on the VCP.

C. Determine moisture characteristic curves on various soils and material samples to determine properties as specified by The Subcontractor.

D. Conduct moisture detection tests on VCP using neutron a moisture logging tool.

Task 3:

A. Fabricate the SEAMIST™ systems to be tested. This consists of five approximately 60′ membranes (two for gas sampling and three for logging tool and absorber installation). Canisters shall be provided for the membrane installation.

B. Purchase sections of VCP as specified by The Subcontractor for the tests of Task 2.

C. Purchase of instrumentation needed for Tasks 2 through 5 shall be the responsibility of LANL DX-12. The EMSMDP PL shall coordinate this effort between the Subcontractor and DX-12.

Task 4: Coordinate the test bed construction to assure that the design requirements are being met.

DELIVERABLES:

1. For Task 1, the Subcontractor shall provide input for the Test Plans. This input shall include the following:

- Full descriptions of all prototype tests,
- Objectives of all tests,
- Required measurements,
- Requirements for interfaces with other organizations,
- Test procedures,
- Data Quality Objectives,
- Proposed test schedules,
- Conceptual construction drawings,

2. The Subcontractor shall provide a written record to the EMSMDP PL of interactions between the Subcontractor and other participants related to this project. These participants will include LANL, and A-E involved in design support, other vendors, and any regulatory agency contracted regarding this project.

3. The Subcontractor shall provide a monthly progress report that summarizes major accomplishments and reports contract costs for the month and the cumulative total. The report should also note any problems on technical matters, schedules, or budgets. The progress report shall be due by the end of the first week of each new month.

4. The Subcontractor shall notify the EMSMDP PL in writing of any potential technical or contractual problem identified in the course of the work related to this contract as soon as the problem is detected. It shall be the responsibility of the EMSMDP PL to provide guidance to the Subcontractor to resolve the problem and provide a written response to the Subcontractor.

5. The Subcontractor shall provide a project close-out report detailing work completed to the end of the project and providing a reference for location of the report of the data provided in this project.

Appendix B

List of Measurements Considered for the Design

Kinds of measurements:

1. Flow of liquids and vapors in the permeable beds
   a. saturation
   b. capillary tension
   c. concentration of tracer
   d. pressure

2. Flow of vapor in the tunnels (rates and kind)
   a. quantity of gas flow
   b. temperature
   c. composition

3. Monitoring measurements of conditions in the medium and tunnels
   a. relative humidity
   b. temperature
   c. capillary tension
   d. saturation
   e. stress ?
   f. tracer distributions
   g. homogeneity of the medium
   h. Permeability of the medium
   i. resistivity of embedded wires in absorbers
   j. logging tool outputs

4. Mechanical function of the SM system
   a. pressure
   b. tension
   c. position

5. Condition of the tunnels as affected by the monitoring procedure
   a. how they look- a camera run
   b. have they been dilated by SM?
6. Analysis of samples collected
   a. absorber composition
   b. gas sample analysis

7. Confirmation of the logging tool measurements

8. Measurement of the injection of tracers and leak simulants.
   a. rates
   b. times of injection and rate changes.

9. Boundary conditions of the tests
   a. air temp.
   b. rainfall
   c. relative humidity
   d. barometric pressure
   e. pressure in the tuff below the bed.
   f. gas or liquid flux from the tuff

The measurements are of two kinds, the actual conditions and the conditions as determined by the monitoring procedures.

Who should do what?

The measurements of the conditions in the medium (e.g., the transport of the injected leak simulants) should not be done by ECE.

Some gauges such as that for RH meas. may be fielded by LANL and the digital recording of all sensors should be done by LANL staff, even if the transducers are supplied by other people.

Note: Gore has discontinued its LEAK LEARN line of sensitive cable due to insufficient sales. This is a concern with all the proposed "instruments".

Where should the measurements be made?

The measurements should be located such that the distribution of fluid seen in Figure B1 is well documented at all times for comparison with the predictions and with the monitoring measurements made.

The actual locations should be selected after the predictive calcs. are done. However, the list of measurements can be made in tabular form to define the number and kind of transducers and recorded histories needed. That table is Table B1.

What are the traditional measurements to be made for comparison with the predictions and the monitoring results?

The traditional measurements are:
1. Tensiometers*

2. Suction lysimeters*
3. TDR
4. Cores of the soil
5. Soil gas extractions
6. gypsum block
7. Water balance calculations from interflow measurements

* Note: There has been little success with these techniques at LANL, per Jack Nyhan, because the diurnal temperature effects dominate the response.

Table B1.

Gauges needed for prototype tests

	para-meter	Gauge	Brand	Number (???)	
Leak injection					
	fluid rate	liq. meter		1	
Medium					
	Cap. tension	Therm. Psychrom		10	
	saturation	TDR		30	
	liq.sat.& composi-tion	core and suction-lysimeter *		10/5*	
	soil gas	tube		5	
	cap. tension	tensio-meter*		10*	
	breakthru	wire grid		1(60'x60')	
	resistance	wire pairs		10	
Monitor-ing					
	absorber resistance	wire pair		10	
	gas sample	SM w/ tubes		5/mem.	
	liq. compo-sition	absorbers		30/mem	

	radiation	rad. meter		1	
	saturation	Neutron moist. log		1(in hand)	
	saturation	absorbent covering		30 sec./mem.	
	resistance	induction log. tool		1	
	temper- ature	ther- mistors		6	
Boundary conditions					
	temper- ature	ther- mistors		5	
	rainfall	r. gauge		1	
	press. in tuff	tube with transduce		3 depths	
	baro. pressure	baromete r		1	

Appendix C Specifications of the Pipe Order from Superior Clay

The clay pipe sections needed are for the following tests:

1. Round pipe, standard strength tests of 4' sections at the pipe manufacture's site (two tests each)
   a. normal pipe (perforated)
   b. slotted pipe (2 kinds of slots, both with perforations)
   c. bisque fired (round with perforations)
   d. 2' thick walled round pipe, bisque fired

2. Pipe permeability tests
   a. normal pipe in fines and in clay with water (2 4' sections)
   b. bisque pipe in "fines" and in clay with water (" " ")
   c. 2" wall thickness pipe in the same media (" " ")
   d. best of the above with dissolved chemicals of interest.

3. Fabrication and function test of the curved sections to be used in the bottom of the pit.
   a. test of the ability to produce smooth curved pipe of about 5' radius.
   b. test of the allowable tension on the tether against the membrane in the curved section(surface roughness is an important factor).

Total of 2 curved sections

The task for Superior Clay is to:'
fabricate:

1. Standard 6" diam x 4' long straight pipe without any bell.	4 pieces
2. Same as above, but bisque fired.	4 pieces
3. Standard pipe (as item 1), but slotted	4 each of 2 kinds
4. Standard pipe, but curved on nominal 5 ft. radius.	2 pieces
5. 2" thick wall, 6" inside diam. pipe, bisque fired	4 pieces

The two slot designs are shown in the attached drawings.

The perforations needed in all of the pipe sections are shown in the attached Figure 4. The bisque firing is to increase the permeability of the pipe. If the skin formed upon pipe extrusion is a barrier, perhaps it could be removed, or scored, on the bisque fired pipes.

test:

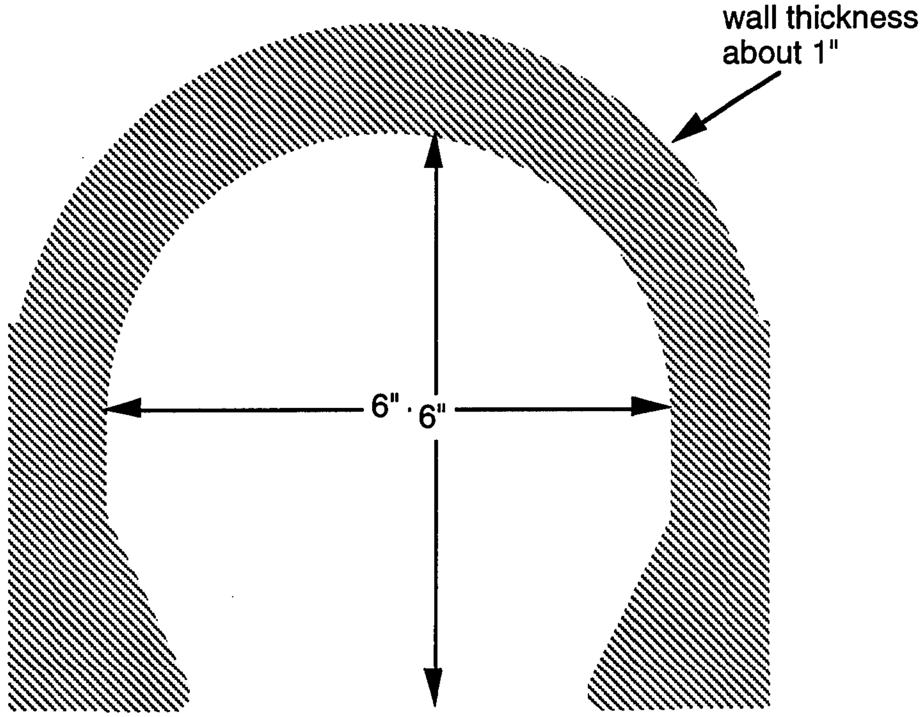
The items 1-4 are to be tested to failure (two samples of each kind) for strength comparisons. The tests are to be done in the standard manner in your three line loading machine. Please provide us with the failure loads of each test.

ship:

Two remaining pieces of each kind of pipe are to be delivered to our office in Santa Fe, NM for porous flow testing.

Also ship to us the broken fragments from the strength tests, so that we can have them tested for other hydraulic properties such as porosity, permeability and capillary tension. Please box the broken pieces separately for each pipe, and label as to the type of pipe tested.

Figure 1. Horseshoe tunnel



Dimensions approx., Made from standard pipe section as convenient and to allow for testing on the three line loading machine. Normal firing.

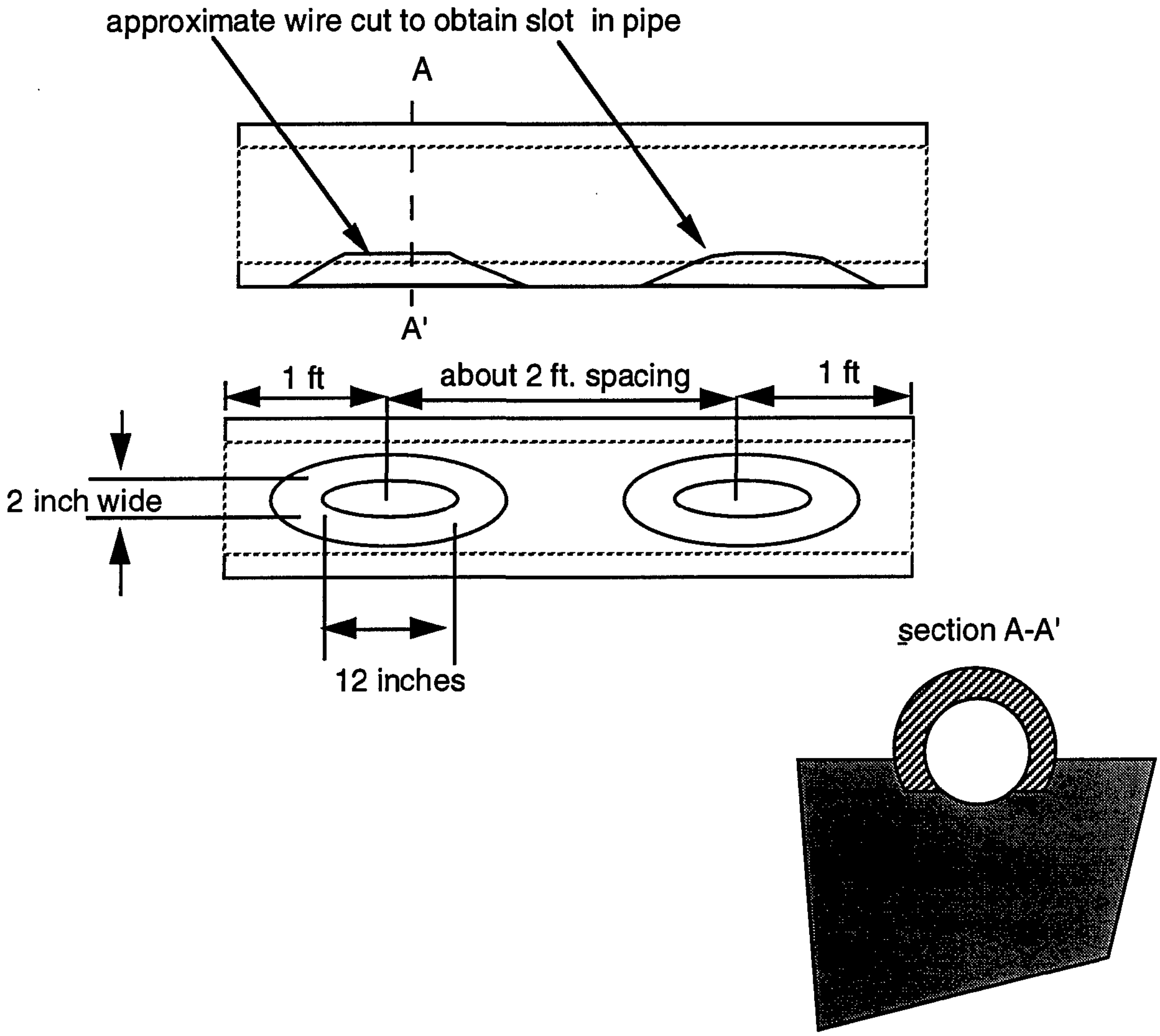
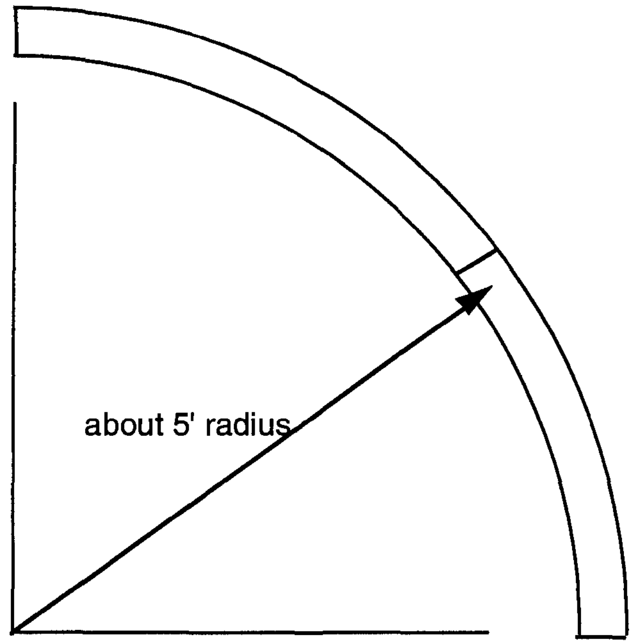


Figure 2. The slotted pipe tunnel



Convenient handling requires a pipe section about 4 ft. long which would lead to about a 45 degree turn of each section. The pipe i.d. should be about the same as standard pipe. Section connections can be of other materials supplied later.

Figure 3. Curved pipe geometry

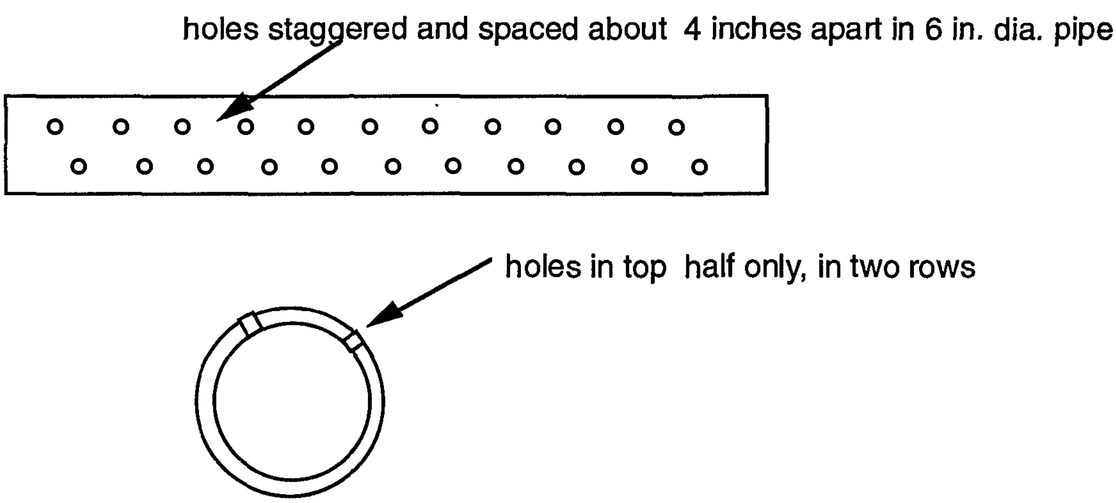


Figure 4. Perforation geometry. Holes are to be of about 0.25 in. diameter with minimum sharp projection on the inside.

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