Chevron

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December 6, 2016

Alameda County Health Care Services Agency
Environmental Health Services
Environmental Protection
1131 Harbor Bay Parkway, Suite 250
Alameda, California 94502-6577

RECEIVED
By Alameda County Environmental Health 11:06 am, Jan 09, 2017

Re: 76 Station No. 1156 (351645)
Basis of Design Report
4276 MacArthur Boulevard, Oakland, California
Fuel Leak Case No.: RO0000409

I have reviewed the attached report dated November 7, 2016.

I agree with the conclusions and recommendations presented in the referenced report. The information in this report is accurate to the best of my knowledge and all local Agency/Regional Board guidelines have been followed. This report was prepared by Carlin Environmental Consulting, Inc., upon whose assistance and advice I have relied.

This letter is submitted pursuant to the requirements of California Water Code Section 13257(b)(1) and the regulating implementation entitled Appendix A pertaining thereto.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge.

Sincerely,

James P. Kiernan, P.E.
Project Manager

Attachment: Basis of Design letter by Carlin Environmental Consulting, Inc.

Carlin Environmental Consulting, Inc.

Assessment > Remediation > Mitigation Design

November 7th, 2016

Prepared for:
Raj Goswamy
(Submitted via email to:
rajgoswamy@sbcglobal.net)

AND

Alameda County Department Environmental Health
Attn: Kit Soo
1131 Harbor Bay Pkwy
Alameda, CA 94502

Subject: Basis of Design for Soil Vapor Mitigation Measures System to be installed at 4276 MacArthur Blvd, Oakland, CA

Introduction:

Carlin Environmental Consulting, Inc. (CEC) is pleased to prepare this Basis of Design letter for the Soil Vapor Mitigation Measures (SVMM) System to be implemented at 4276 MacArthur Blvd. Oakland, California. This letter will outline the purpose of the designed system and its components as well as a basic description of the theoretical physics behind the system. In general, we will describe and support the method of the design and will be providing literature material from Land Science Technologies, the company that supplies the components of the system (i.e. the impermeable membrane, Geo-seal and Retro-coat applications). This letter is being prepared at the request of the Alameda County Department Environmental Health (ACDEH).

It is important to distinguish, that since this project involves mitigating both a new portion of the building and an existing slab, there are two different systems being used. Both will be discussed within.

Basis Of Design Discussion:

For the portion of the building proposed to be built, there will be two components to the SVMM system: sub-slab venting system and vapor barrier system.

Sub-slab Venting System – is a permeable layer constructed beneath the slab and membrane and above the compacted soil. Land Science Technologies manufactures a product, Vapor Vent, which is a perforated 12-inch flat horizontal vapor collection pipe (See Attachment 3 – Vapor Vent Specification). This collection piping and associated joints and adaptors are embedded in a 2-inch thick gravel layer. The gravel layer is essential for giving the soil vapor space to move and be drawn to the perforated vapor collection piping. This drawing of the soil vapors is discussed below. Theoretically, once the soil vapor is drawn to the collection piping, it is pulled to solid PVC/cast iron pipes that transition to vent risers. These vent risers exit the membrane and through the slab and travel up through the structure to the roof. With the complete sub-slab system of gravel, perforated collection piping and solid pipe vent risers, the contaminated soil vapor is conveyed from the soil beneath the slab, through the vent risers and out into the atmosphere where it is diffused at low concentrations and at a level above human occupancy. Sub-slab venting is a crucial component to any soil vapor mitigation system because it gives the affected soil vapor a place to go rather than 1) accumulating beneath the slab or 2) leaking into the structure and accumulating inside.

This sub-slab venting system is a passive system, meaning that there are no fans to "pull and pump" the soil vapor form beneath the structure through the system and out the vent risers. A passive system is aided by naturally occurring circulation pattern aided by natural wind blowing across the tops of the open vent risers. This is the drawing affect discussed above. CEC does not recommend the use of wind driven turbines attached to the top of vent risers. The following is an excerpt from GeoKinetics, Inc. on the effectiveness of a passive venting system and not utilizing wind-driven turbines:

"Through extensive field measurements we have found that air will typically exhaust from some vent risers while flowing into others at the same time. This circulation pattern is normally effective in purging any accumulated gases or vapors from the system. Diurnal variations in the barometric pressure also assist in purging gases or vapors from the system. The addition of wind-driven turbines to the vent risers would disrupt this normal circulation pattern. Also, the turbines would only function during windy periods. It has been our experience that they are not necessary and provide no overall benefit." (See Attachment 7 – Geo-Seal Vapor Vent Flow Rates).

See Attachments 3 - Vapor Vent Specification and 7 - Geo-Seal Vapor Vent Flow Rates for this section.

Vapor Barrier System – the vapor barrier system includes a chemically compatible and essentially impermeable layer constructed between the sub-slab venting system and the slab. All penetrations from underground utilities and plumbing are sealed with the membrane barrier to create an essentially airtight system.

The vapor barrier system for this project is a product called Geo-Seal manufactured by Land Science Technologies. Geo-Seal is a three-part composite membrane system consisting of:

- Geo-Seal BASE - high-density polyethylene (HDPE) thermally bonded to a geotextile
- Geo-Seal CORE - 60-mil spray applied copolymer asphalt
- Geo-Seal BOND - high-density polyethylene (HDPE) thermally bonded to a geotextile

Attached is product literature from Land Science Technologies explaining the testing and characteristics of the Geo-Seal product. Among these items are product details, specifications, and permeation case studies.

Please refer to the following attachments for general product information, specifications and case studies on the Geo-Seal product. Attachment 1 - Geo-Seal Brochure, Attachment 4 - Geo-Seal Specification, Attachment 8 - Permeation Diffusion Geo-Seal, and Attachment 9 - Advances in Vapor Barriers Testing Compatibility and Science.

As discussed, there are two different vapor mitigation "systems" being utilized for this project. This section will discuss the system being applied to the existing building.

Similar to the new building portion, there will be two components of the SVMM in the existing portion of the structure: sub-slab venting system and a vapor intrusion coating system.

<u>Sub-Slab Venting System</u> – This system is essentially the same sub-slab venting system discussed in depth above, except it is being placed within an existing slab. The main components, which are the gravel layer, perforated vapor collection piping, and solid vent riser, are present in this version of the system. Since there is already a concrete slab present, the gravel layer will not be able to cover the entire pad and modifications to the system are made.

For existing slabs, trenches are cut where the venting system is determined to be placed. A trench, minimum 12-inches depth is cut and dug into the compacted subgrade the length and orientation of the desired vapor collection system. A permeable geo-fabric material is placed within the trench to provide support and prevent material erosion from the compacted subgrade. After the trench is lined with the permeable geo-vent, it is filled with gravel and the 12" perforated Vapor-Vent collection piping and accompanying joints and pipes to the vent risers (See Attachment 3 and 7 for Vapor Vent specifications and supporting information). The Vapor-Vent piping should be surrounding by gravel on top and bottom and on both sides. As noted above, the permeable gravel provides a pathway for soil vapor to travel and enter the collection piping. Once the piping and gravel are placed, the geo-fabric is folder over to encompass the venting system, gravel and piping within the trench. New slab is placed on top.

Vent risers are included in the version of the sub-slab venting system just as they are in the more traditional method discussed previously. The passive venting system will perform just as described above.

See attachments 3 - Vapor Vent Specification and 7 - Geo-Seal Vapor Vent Flow Rates

Vapor Intrusion Coating System – A Land Science Technologies product called Retro-Coat will be used as the essentially impermeable barrier to be applied to the slab of the existing structure. Retro-Coat is an odorless, no VOC, chemically compatible and 100% solids coating that is applied in two 10-mil coats of Retro-Coat on top of a typical 6-mil coat of Retro-Coat PRIMER. Prior to application of Retro-Coat PRIMER and Retro-Coat, applicators will use Retro-Coat CAULK around the base of all pipe penetrations and sealing any cracks and gaps in the slab.

The Retro-Coat system is laboratory tested and approved. Please refer to the following attachments for Retro-Coat product specifications and supporting information. See Attachment 2 - Retro-Coat Brochure, Attachment 5 - Retro-Coat Specification, and Attachment 10 - Chemical Resistance Retro-Coat Whitepaper case study.

Conclusion:

It is CEC's opinion that the two different types of soil vapor mitigations measures discussed herein and as illustrated on the Soil Vapor Mitigation drawings for this site will adequately protect future inhabitants of the existing and proposed structure. Adequate testing of the materials that will be used have been conducted by the materials manufacturer. Supporting documentation is attached as appendices to this letter. Harmful soil vapor which is reportedly residual contamination from historical site usage that migrates to the foundation of the structure will be redirected to the passive venting system and allowed to diffuse into the atmosphere at relatively low concentrations. Additionally, the two different types of membranes/impermeable barriers will preclude harmful concentrations of the soil vapor from entering the structure and into the breathing space of future occupants.

If there are any further questions or concerns, please contact us at (714) 508-1111.

Sincerely,
Carlin Environmental Consulting, Inc.

Gary T. Carlin
President

Justin Allen
Staff Environmental Scientist

James Coleman
GE 229

APPENDIX

Attachment 1 – Geo-Seal Brochure
Attachment 2 – Retro-Coat Brochure
Attachment 3 – Vapor Vent Specification
Attachment 4 – Geo-Seal Specification
Attachment 5 – Retro-Coat Specification
Attachment 6 – Geo-Seal and Retro-Coat Installation Guide
Attachment 7 – Geo-Seal Vapor Vent Flow Rates
Attachment 8 – Permeation Diffusion Geo-Seal
Attachment 9 – Advances in Vapor Barriers Testing Compatibility and Science
Attachment 10 – Chemical Resistance Retro-Coat Whitepaper case study

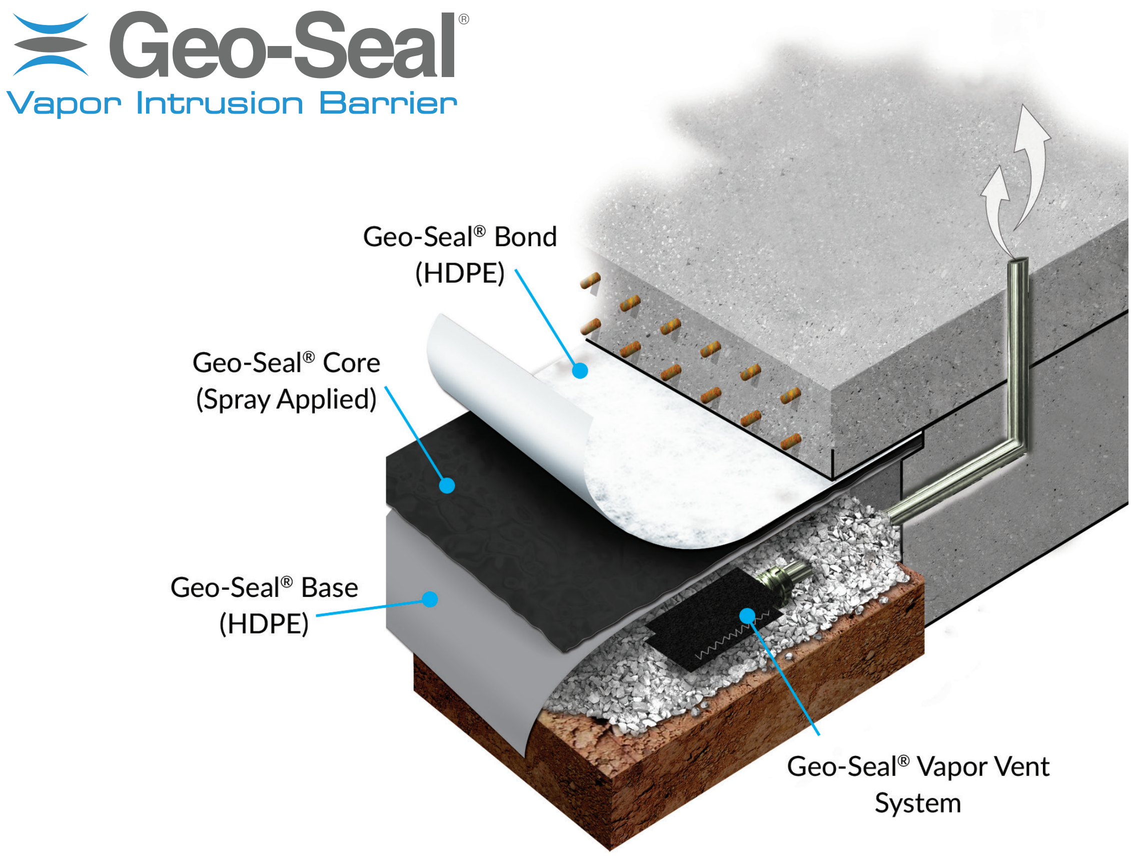
Geo-Seal®
Vapor Intrusion Barrier

Vapor Management **Technology**

Introduction

Geo-Seal® is a sub-slab vapor intrusion barrier system designed to eliminate vapor intrusion for brownfields or any type of environmentally-impaired site. Geo-Seal is a chemically-resistant material placed between the foundation of the building and the soil pad to eliminate vapor intrusion pathways and stop contaminant vapors from permeating through the slab. By deploying Geo-Seal, developers can ensure a healthy indoor environment while reducing the cost of site remediation and expediting site construction.

- Geo-Seal is a composite system that creates the ideal blend between constructability and chemical resistance by using both high density polyethylene (HDPE) and spray applied asphalt latex.
- Geo-Seal has been tested and proven to be highly effective against VOCs like chlorinated solvents and petroleum contaminants, and, methane.
- Geo-Seal is the 1st patented vapor intrusion barrier system in the US
- Geo-Seal has gained wide approval among various regulatory agencies across the country.



Geo-Seal BASE

The BASE layer is rolled out geotextile facing down, which allows Geo-Seal CORE to be applied directly to the high density polyethylene. The BASE layer provides the ultimate substrate and enables the spray layer to be free of shadowing and pinholes.

Geo-Seal CORE

The CORE is applied at 60 mils, is sprayed to the base layer, seals around penetrations and seals the seams of the BASE layer.

Geo-Seal BOND

A proprietary protection layer is placed over the CORE layer to enhance the curing of the membrane and increase puncture resistance.

Vapor-Vent

- Eliminates the need for trenching
- Cost-effective compared to pipe and gravel systems
- Eliminates long-term costs when configured as a passive system
- Allows for rapid installation
- When used with Geo-Seal provides maximumprotection against contaminated vapor

Geo-Seal Triple-Layer System
(2 Chemical Resistant Layers + 1 Spray Applied Core Layer)

Dual Chemical Resistant Layers

The BASE layer (bottom) and the BOND layer (top) are composed of a high-density polyethylene material bonded to a geo-textile on the out-facing side. High density polyethylene is known for chemical resistance, high tensile strength, excellent stress-crack resistance and for highly reliable subsurface containment. The geo-textile which is physically bonded to the chemical resistant layer accomplishes two goals; it allows the BOND layer to adhere to the slab, and provides a friction course between the BASE layer and the soil.

Spray Applied CORE Layer

The CORE layer is composed of a unique, elastic co-polymer modified asphaltic membrane which also provides additional protection against vapor transmission. This layer creates a highly-effective seal around slab penetrations and eliminates the need for mechanical fastening at termination points.

Chemical Resistance

The dual chemical resistant layers combined with the spray CORE form a barrier resistant to the most concentrated chemical pollutant vapors.

Enhanced Curing

Geo-Seal is “construction friendly” as the reduced curing time of the Geo-Seal CORE layer and the ability to apply it in cooler temperatures ensures quick installation and minimizes the impact on construction schedules.

Puncture Resistance

Geo-Seal forms a highly puncture resistant barrier that greatly reduces the chance of damage occurring after installation and prior to the placement of concrete.

Removing Contained Vapors

Vapor-Vent can be used in conjunction with Geo-Seal to alleviate the buildup of vapors beneath structures as a result of vapor barrier implementation. Vapor-Vent can be utilized as an active or passive ventilation system depending on the requirements of the design engineer.

Certified Applicator Network

The application of Geo-Seal and Vapor-Vent can be performed by any one of many certified applicators throughout the country.

Service and Support

Geo-Seal representatives are available to provide job and site specific assistance. A local representative can ensure Geo-Seal and Vapor-Vent is installed as per the specification.

World Class Clients

Environmental consultants, engineers, and real estate professionals trust Land Science to produce results knowing our expertise and industry knowledge has been proven time and again at the job site. Our world class clients include leaders in the food, banking, government, and housing industries.

Get Started Today

To recieve a custom vapor intrusion solution, please call 949.481.8118 or email info@landsciencetech.com

One of our Technical Solutions Managers will review your project details and provide you with a customized vapor intrusion solution designed to achieve your goals.

EXPERTS IN VAPOR INTRUSION MITIGATION

Land Science® develops vapor intrusion mitigation solutions that protect people and invigorate renewal of contaminated properties.

We leverage our industry expertise to assist clients in developing site specific solutions that are technically sound and cost-effective.

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1011 Calle Sombra, San Clemente CA 92673 T: 949.481.8118

Retro-Coat™

Vapor Intrusion Coating

Vapor Intrusion Coating System **for Existing Structures**

Product Description

The Retro-Coat™ Vapor Intrusion Coating System is a complete product line that consists of chemically resistant materials to properly protect existing structures from the threat of contaminant vapor intrusion without the need for additional concrete protection. Developed by the R&D team of Land Science®, the Retro-Coat system has been subjected to rigorous testing procedures to prove its ability to combat the most aggressive chemical vapors. The main component of the Retro-Coat system is the Retro-Coat coating which is a two part, odorless, no VOC, 100% solids coating.

Retro-Coat finishes to a high gloss, easy-to-clean surface that is impervious to vapor and moisture transmission. Available in a variety of colors, Retro-Coat can be applied on damp as well as dry concrete, concrete masonry units, tile, brick and metal. For enhanced slip resistance, a suitable aggregate can be added. In addition, other additives or materials can be utilized to achieve a desired performance or aesthetic look.

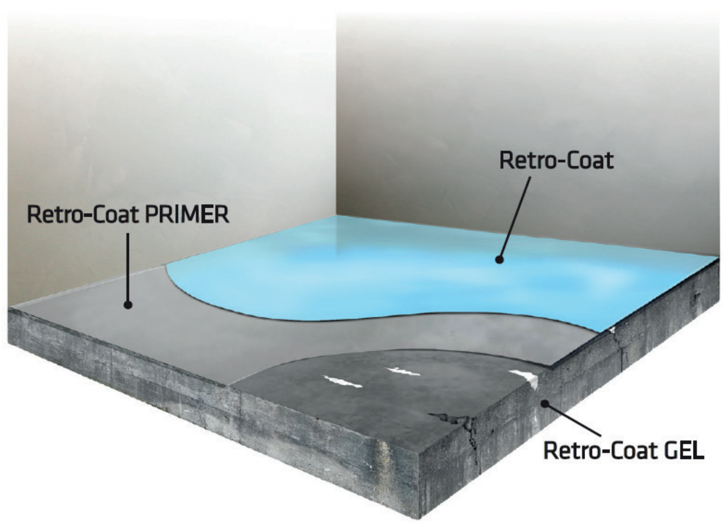
Typical Application

Retro-Coat is suitable as a barrier to block contaminated vapors from entering existing structures. Particular uses include coating the horizontal surfaces of existing structures where contamination under, or adjacent to, a structure can potentially migrate inside the structure and create a vapor encroachment condition. This condition is most commonly found when the existing structure was operated as a dry cleaner, gas station, manufacturing facility or located in close proximity to any structure where carcinogenic chemicals were utilized.

A typical application consists of a minimum 20 mil thick system; consisting of two 10 mil coats of Retro-Coat at 160 SF/gallon per coat and is recommended along with a 6 mil coat of Retro-Coat PRIMER. The typical 20 mil application can withstand forklift traffic, other machinery and even act as secondary containment. However, if Retro-Coat is exposed to harsh conditions over a longer period of time and/or used for a unique application, please consult with a LST representative to discuss options and a recommended approach.

Retro-Coat Advantages

Retro-Coat™
Vapor Intrusion Coating



- Our R&D team developed all of the Retro-Coat system components specifically for vapor intrusion protection in existing structures
- Retro-Coat is resistant to both TCE and PCE, the vast majority of coatings cringe at such aggressive chemicals
- Retro-Coat is a wearing surface, meaning no additional concrete protection is necessary
- No odor and fast cure time reduce building downtime
- Carpet, tile, linoleum or other floor coverings can be applied directly over Retro-Coat, if desired
- Eliminates the need to remove the existing slab and when combined with *in situ* treatment, lowers overall remediation cost
- Retro-Coat can increase the performance of an existing active sub-slab depressurization system
- Retro-Coat can aid in the retiring of existing active systems
- Available and installed by Land Science certified contractors

Installation

Particular care must be taken to follow those instructions precisely to assure proper installation. These instructions pertain to a standard 20 mil application; please contact us if the desired application is different.

1. New concrete should be allowed to cure a minimum of 28 days and/or be checked with a rubber mat or plastic sheet to ensure adequate curing time has occurred.
2. All surfaces to be covered should be power washed, shot blasted, acid etched, scarified or sanded to present a clean, sound substrate to which to bond to. The prepared surface should have a ph of 7.
3. Any bugholes and cracks wider than 1/8" should be filled with Retro-Coat PREP and allowed to dry before coating. More severely damaged concrete or other special conditions will require the proper Retro-Coat product.
4. When installing the standard 20 mil application of Retro-Coat, apply a 6 mil coat of Retro-Coat PRIMER and allow to dry prior to applying the initial coat of Retro-Coat. Priming may not be necessary when Retro-Coat is applied to a thickness greater than 20 mils. On new concrete or old concrete with an open porosity and on wood surfaces apply Retro-Coat PRIMER and allow to dry.
5. The two Retro-Coat ingredients should be mixed in the prescribed ratios, using a low speed "jiffy-style" mixer, (maximum 750 rpm). Mix Part A for about 1 minute then, add Part B and mix until uniform in color and consistency (at least one additional minute.)
6. Do not mix less than the prescribed amount of any ingredient or add any solvent to the mix.
7. Apply the mixed Retro-Coat material with a short nap roller, a squeegee or a brush. Apply approximately 160 SF per gallon per coat to achieve 10 mils of coating.
8. Apply a second coat while the first coat is still tacky if using spike shoes or dry enough to walk on, but before 7 hours at 75°F. If the first coat has set and is no longer tacky then the first coat should be sanded before recoating.
9. A suitable aggregate may be broadcast onto the surface after backrolling to provide more anti-slip profile to the finished surface. It is advisable to test various types and sizes of aggregate to achieve the desired finished profile.

Product Specification

The specified area shall receive an application of Retro-Coat as manufactured by Land Science. The material shall be installed by precisely following the manufacturer's published recommendations pertaining to surface preparation, mixing and application. The material shall be a low odor, two part, solvent free 100% solids, high gloss flexibilized system with good resilience to resist thermal and mechanical shock. It should be able to be roller applied at a minimum of 10 mils thickness per coat on vertical surfaces without sagging (at ambient conditions). The system must adhere to damp as well as dry concrete, wood, metal tile, terrazzo and sound existing epoxy and urethane coatings. It shall have tensile elongation of at least 6.0% when tested under ASTM-638. Its bond strength to quarry tile shall exceed 1000 psi when tested with an Elcometer pull test. Its hardness shall not exceed 83, as measured on the Shore D scale. The system shall be unaffected by oils and greases and shall withstand chemical attack for at least 72 hours against 98% sulfuric, 50% hydrofluoric acid, glacial acetic acid and acrylonitrile.

Precautions

1. This is a fast reacting product; immediately pour onto floor after mixing and spread with notched squeegee. Recoat window without sanding at 70°F: 8 hours
2. A severe skin and eye irritant; check MSDS before use
3. Do not apply below 50°F

Note: Failure to follow the above instruction, unless expressly authorized by a Land Science Representative, will void our material warranty.

Chemical Resistance

Retro-Coat™ is considered chemically resistant to neat concentrated acids, caustics and solvents. For permeation or diffusion coefficients please contact Land Science.

Physical Properties

Tensile Strength (ASTM D-638) : 9800 psi

Tensile Elongation (D-638) : 6.0%

Flexural Strength (D-790) : 7035 psi

Hardness, Shore D (D-2240) : 83

Gardner Impact Strength (D-2794) : 80 in. lbs.

Bond Strength to Quarry Tile : >1000 psi

Vapor Transmission Rate (E-96) : .027 perms

Water Absorption (D-570) : 0.2% in 24hrs.

Taber Abrasion (D-1044) : 86 mg loss.

60^{o} Gloss : 100

Physical Characteristics

Density, lbs/gal.	**Mixing Ratios**	**By Volume**	**By Weight**	
Pt. A : 11.0	Pt. A : Pt. B	2:1	2.3:1	
Pt. B : 8.9				
A&B Mixed : 9.3	**Curing Times @**	**50^{o} F**	**77^{o}F**	**90^{o}F**
Viscosity @ 77^{o}F, cps	Pot Life	35 min.	30 min.	20 min.
Pt. A : 18,400	Working Times	20 min.	20 min.	15 min.
Pt. B : 500	Hard, Foot Traffic	14 hrs.	7 hrs.	3 ½ hrs.
A&B Mixed : 4800	Maximum hardness and chemical resistance are achieved after 7 days at 77^{o}F			

Color Availability

Standard colors: beige, black, blue, dark gray, green, gray, red, white, yellow

Shelf Life: 1 Year at 77^{o}F in unopened containers

Packaging and Coverage Rates (for 20 mil coverage)

4 Gallon Kit : 320 SF

20 Gallon Kit : 1600 SF

100 Gallon Kit : 8,000 SF

World Class Clients

Environmental consultants, engineers, and real estate professionals trust Land Science to produce results knowing our expertise and industry knowledge has been proven time and again at the job site. Our world class clients include leaders in the food, banking, government, and housing industries.

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To recieve a custom vapor intrusion solution, please call 949.481.8118 or email info@landsciencetech.com

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EXPERTS IN VAPOR INTRUSION MITIGATION

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We leverage our industry expertise to assist clients in developing site specific solutions that are technically sound and cost-effective.

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1011 Calle Sombra, San Clemente CA 92673 T: 949.481.8118

Vapor-Vent™
SOIL GAS COLLECTION SYSTEM
Version 1.5

SECTION 02 56 19 – GAS CONTROL

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes the following:

1. Substrate preparation.
2. Vapor-Vent™ installation.
3. Vapor-Vent accessories.

B. Related Sections: The following Sections contain requirements that relate to this Section:

1. Division 2 Section “Earthwork”, “Pipe Materials”, “Sub-drainage systems”, ”Gas Control System”, “Fluid-Applied gas barrier”.
2. Division 3 Section “Cast-in-Place Concrete” for concrete placement, curing, and finishing.
3. Division 5 Section “Expansion Joint Cover Assemblies”, for expansion-joint covers assemblies and installation.

1.3 PERFORMANCE REQUIREMENTS

A. General: Provide a gas venting material that collects gas vapors and directs them to discharge or to collection points as specified in the gas vapor collection system drawings and complies with the physical requirements set forth by the manufacturer.

1.4 SUBMITTALS

A. Submit Product Data for each type of gas venting system specified, including manufacturer’s specifications.

B. Sample – Submit representative samples of the following for approval:

1. Gas venting, Vapor-Vent.
2. Vapor-Vent accessories.

1.5 QUALITY ASSURANCE

A. Installer Qualifications: Engage an experienced Installer who is certified in writing and approved by vapor intrusion barrier manufacturer Land Science Technologies for the installation of the Geo-Seal® vapor intrusion barrier system.

B. Manufacturer Qualification: Obtain gas venting, vapor intrusion barrier and system components from a single manufacturer Land Science Technologies

C. Pre-installation Conference: A pre-installation conference shall be held prior to installation of the venting system, vapor intrusion barrier and waterproofing system to assure proper site and installation conditions, to include contractor, applicator, architect/engineer and special inspector (if any).

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials to project site as specified by manufacturer labeled with manufacturer’s name, product brand name and type, date of manufacture, shelf life, and directions for handling.

B. Store materials as specified by the manufacturer in a clean, dry, protected location and within the temperature range required by manufacturer. Protect stored materials from direct sunlight.

C. Remove and replace material that is damaged.

PART 2 – PRODUCTS

2.1 MANUFACTURER

A. Land Science Technologies, San Clemente, CA. (949) 481-8118

1. Vapor-Vent™

2.2 GAS VENT MATERIALS

A. Vapor-Vent – Vapor-Vent is a low profile, trenchless, flexible, sub slab vapor collection system used in lieu or in conjunction with perforated piping. Vapor-Vent is offered with two different core materials, Vapor-Vent POLY is recommended for sites with inert methane gas and Vapor-Vent is recommended for sites with aggressive chlorinated volatile organic or petroleum vapors. Manufactured by Land Science Technologies

B. Vapor-Vent physical properties

VENT PROPERTIES	**TEST METHOD**	**VAPOR-VENT POLY**	**VAPOR-VENT**
Material		Polystyrene	HDPE
Comprehensive Strength	ASTM D-1621	9,000 lbs / ft^2	11,400 lbs / ft^2
In-plane flow (Hydraulic gradient-0.1)	ASTM D-4716	30 gpm / ft of width	30 gpm / ft of width
Chemical Resistance		N/A	Excellent
FABRIC PROPERTIES	**TEST METHOD**	**VAPOR-VENT POLY**	**VAPOR-VENT**
Grab Tensile Strength	ASTM D-4632	100 lbs.	110 lbs.
Puncture Strength	ASTM D-4833	65 lbs.	30 lbs.
Mullen Burst Strength	ASTM D-3786	N/A	90 PSI
AOS	ASTM D-4751	70 U.S. Sieve	50 U.S. Sieve
Flow Rate	ASTM D-4491	140 gpm / ft^2	95 gpm / ft^2
UV Stability (500 hours)	ASTM D-4355	N/A	70% Retained
DIMENSIONAL DATA			
Thickness		1”	1”
Standard Widths		12”	12”
Roll Length		165 ft	165 ft
Roll Weight		65 lbs	68 lbs

2.3 AUXILIARY MATERIALS

A. Vapor-Vent End Out

B. Reinforced Tape.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions under which gas vent system will be installed, with installer present, for compliance with requirements. Do not proceed with installation until unsatisfactory conditions have been corrected.

3.2 SUBSTRATE PREPARATION

A. Verify substrate is prepared according to project requirements.

3.3 PREPARATION FOR STRIP COMPOSITE

A. Mark the layout of strip geocomposite per layout design developed by engineer.

3.4 STRIP GEOCOMPOSITE INSTALLATION

A. Install Vapor-Vent over substrate material where designated on drawings with the flat base of the core placed down and shall be overlapped in accordance with manufacturer's recommendations.

B. At areas where Vapor-Vent strips intersect cut and fold back fabric to expose the dimpled core. Arrange the strips so that the top strip interconnects into the bottom strip. Unfold fabric to cover the core and use reinforcing tape, as approved by the manufacturer, to seal the connection to prevent sand or gravel from entering the core.

C. When crossing Vapor-Vent over footings or grade beams, **consult with the specifying environmental engineer and structural engineer for appropriate use and placement of solid pipe materials**. Place solid pipe over or through concrete surface and attach a Vapor-Vent End Out at both ends of the pipe before connecting the Vapor-Vent to the pipe reducer. Seal the Vapor-Vent to the Vapor-Vent End Out using fabric reinforcement tape. Refer to Vapor-Vent detail provided by Land Science Technologies.

D. Place vent risers per specifying engineer's project specifications. Connect Vapor-Vent to Vapor-Vent End Out and seal with fabric reinforced tape. Use Vapor-Vent End Out with the specified diameter piping as shown on system drawings.

3.5 PLACEMENT OF OVERLYING AND ADJACENT MATERIALS

A. All overlying and adjacent material shall be placed or installed using approved procedures and guidelines to prevent damage to the strip geocomposite.

B. Equipment shall not be directly driven over and stakes or any other materials may not be driven through the strip geocomposite.

Geo-Seal® Vapor Intrusion Barrier
02 56 19.13
Fluid-Applied Gas Barrier
Version 1.30

Note: If membrane will be subjected to hydrostatic pressure, please contact Land Science Technologies™ for proper recommendations.

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the contract, including general and supplementary conditions and Division 1 specification sections, apply to this section.

1.2 SUMMARY

A. This section includes the following:

1. Substrate preparation:
2. Vapor intrusion barrier components:
3. Seam sealer and accessories.

B. Related Sections: The following sections contain requirements that relate to this section:

1. Division 2 Section “Earthwork”, “Pipe Materials”, “Sub-drainage Systems”, “Gas Collection Systems”:
2. Division 3 Section “Cast-in-Place Concrete” for concrete placement, curing, and finishing:
3. Division 5 Section “Expansion Joint Cover Assemblies”, for expansion-joint covers assemblies and installation.

1.3 PERFORMANCE REQUIREMENTS

A. General: Provide a vapor intrusion barrier system that prevents the passage of methane gas and/or volatile organic compound vapors and complies with physical requirements as demonstrated by testing performed by an independent testing agency of manufacturer’s current vapor intrusion barrier formulations and system design.

1.4 SUBMITTALS

A. Submit product data for each type of vapor intrusion barrier, including manufacturer’s printed instructions for evaluating and preparing the substrate, technical data, and tested physical and performance properties.

B. Project Data - Submit shop drawings showing extent of vapor intrusion barrier, including details for overlaps, flashing, penetrations, and other termination conditions.

C. Samples – Submit representative samples of the following for approval:

1. Vapor intrusion barrier components.

D. Certified Installer Certificates – Submit certificates signed by manufacturer certifying that installers comply with requirements under the “Quality Assurance” article.

1.5 QUALITY ASSURANCE

A. Installer Qualifications: Engage an experienced installer who has been trained and certified in writing by the membrane manufacturer, Land Science Technologies™ for the installation of the Geo-Seal® System.

B. Manufacturer Qualification: Obtain vapor intrusion barrier materials and system components from a single manufacturer source Land Science Technologies.

C. Field Sample: Apply vapor intrusion barrier system field sample to 100 ft^2 (9.3 m^2) of field area demonstrate application, detailing, thickness, texture, and standard of workmanship.

1. Notify engineer or special inspector one week in advance of the dates and times when field sample will be prepared.

2. If engineer or special inspector determines that field sample, does not meet requirements, reapply field sample until field sample is approved.

3. Retain and maintain approved field sample during construction in an undisturbed condition as a standard for judging the completed methane and vapor intrusion barrier. An undamaged field sample may become part of the completed work.

D. Pre-installation Conference: A pre-installation conference shall be held prior to application of the vapor intrusion barrier system to assure proper site and installation conditions, to include contractor, applicator, architect/engineer, other trades influenced by vapor intrusion barrier installation and special inspector (if any).

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials to project site as specified by manufacturer labeled with manufacturer's name, product brand name and type, date of manufacture, shelf life, and directions for storing and mixing with other components.

B. Store materials as specified by the manufacturer in a clean, dry, protected location and within the temperature range required by manufacturer. Protect stored materials from direct sunlight. If freezing temperatures are expected, necessary steps should be taken to prevent the freezing of the Geo-Seal CORE and Geo-Seal CORE Detail components.

C. Remove and replace material that cannot be applied within its stated shelf life.

1.7 PROJECT CONDITIONS

A. Protect all adjacent areas not to be installed on. Where necessary, apply masking to prevent staining of surfaces to remain exposed wherever membrane abuts to other finish surfaces.

B. Perform work only when existing and forecasted weather conditions are within manufacturer's recommendations for the material and application method used.

C. Minimum clearance of 24 inches is required for application of product. For areas with less than 24-inch clearance, the membrane may be applied by hand using Geo-Seal CORE Detail.

D. Ambient temperature shall be within manufacturer's specifications. (Greater than +45ºF/+7ºC.) Consult manufacturer for the proper requirements when desiring to apply Geo-Seal CORE below 45ºF/7ºC.

E. All plumbing, electrical, mechanical and structural items to be under or passing through the vapor intrusion barrier system shall be positively secured in their proper positions and appropriately protected prior to membrane application.

F. Vapor intrusion barrier shall be installed before placement of fill material and reinforcing steel. When not possible, all exposed reinforcing steel shall be masked by general contractor prior to membrane application.

G. Stakes used to secure the concrete forms **shall not penetrate** the vapor intrusion barrier system after it has been installed. If stakes need to puncture the vapor intrusion barrier system after it has been installed, the necessary repairs need to be made by a certified Geo-Seal applicator. To confirm the staking procedure is in agreement with the manufactures recommendation, contact Land Science Technologies.

1.8 WARRANTY

A. General Warranty: The special warranty specified in this article shall not deprive the owner of other rights the owner may have under other provisions of the contract documents, and shall be in addition to, and run concurrent with, other warranties made by the contractor under requirements of the contract documents.

B. Special Warranty: Submit a written warranty signed by vapor intrusion barrier manufacturer agreeing to repair or replace vapor intrusion barrier that does not meet requirements or that does not remain methane gas and/or volatile organic compound vapor tight within the specified warranty period. Warranty does not include failure of vapor intrusion barrier due to failure of substrate prepared and treated according to requirements or formation of new joints and cracks in the attached to structures that exceed 1/16 inch (1.58 mm) in width.

   1. Warranty Period: 1 year after date of substantial completion. Longer warranty periods are available upon request to the manufacturer.

C. Labor and material warranties are available upon request to the manufacturer.

PART 2 – PRODUCTS

2.1 MANUFACTURERS

A. Geo-Seal; Land Science Technologies™, San Clemente, CA. (949) 481-8118

   1. Geo-Seal BASE sheet layer
   2. Geo-Seal CORE spray layer and Geo-Seal CORE Detail
   3. Geo-Seal BOND protection layer

2.2 VAPOR INTRUSION BARRIER SPRAY MATERIALS

A. Fluid applied vapor intrusion barrier system – Geo-Seal CORE; a single course, high build, polymer modified, asphalt emulsion. Waterborne and spray applied at ambient temperatures. A nominal thickness of 60 dry mils, unless specified otherwise. Non-toxic and odorless. Geo-Seal CORE Detail has similar properties with greater viscosity and is roller or brush applied. Manufactured by Land Science Technologies.

B. Fluid applied vapor intrusion barrier physical properties.

Geo-Seal CORE – TYPICAL CURED PROPERTIES

Properties	Test Method	Results
Tensile Strength - CORE only	ASTM 412	32 psi
Tensile Strength - Geo-Seal System	ASTM 412	662 psi
Elongation	ASTM 412	4140%
Resistance to Decay	ASTM E 154 Section 13	4% Perm Loss
Accelerated Aging	ASTM G 23	No Effect
Moisture Vapor Transmission	ASTM E 96	.026 g/ft^2/hr
Hydrostatic Water Pressure	ASTM D 751	26 psi
Perm rating	ASTM E 96 (US Perms)	0.21
Methane transmission rate	ASTM D 1434	Passed
Adhesion to Concrete & Masonry	ASTM C 836 & ASTM C 704	11 lbf./inch
Hardness	ASTM C 836	80
Crack Bridging	ASTM C 836	No Cracking
Heat Aging	ASTM D 4068	Passed
Environmental Stress Cracking	ASTM D 1693	Passed
Oil Resistance	ASTM D543	Passed
Soil Burial	ASTM D 4068	Passed
Low Temp. Flexibility	ASTM C 836-00	No Cracking at –20°C
Resistance to Acids:		
Acetic		30%
Sulfuric and Hydrochloric		13%
Temperature Effect:		
Stable		248°F
Flexible		13°F

Geo-Seal CORE Detail – TYPICAL CURED PROPERTIES

Properties	Test Method	Results
Tensile Strength	ASTM 412	32 psi
Elongation	ASTM 412	3860%
Resistance to Decay	ASTM E 154 Section 13	9% Perm Loss
Accelerated Aging	ASTM G 23	No Effect
Moisture Vapor Transmission	ASTM E 96	.026 g/ft^2/hr
Hydrostatic Water Pressure	ASTM D 751	28 psi
Perm rating (US Perms)	ASTM E 96	0.17
Methane transmission rate	ASTM D 1434	Passed
Adhesion to Concrete & Masonry	ASTM C 836	7 lbf./inch
Hardness	ASTM C 836	85
Crack Bridging	ASTM C 836	No Cracking
Low Temp. Flexibility	ASTM C 836-00	No Cracking at –20ºC
Resistance to Acids:		
Acetic		30%
Sulfuric and Hydrochloric		13%
Temperature Effect:		
Stable		248°F
Flexible		13°F

2.3 VAPOR INTRUSION BARRIER SHEET MATERIALS

A. The Geo-Seal BASE layer and Geo-Seal BOND layer are chemically resistant sheets comprised of a 5 mil high density polyethylene sheet thermally bonded to a 3 ounce non woven geotextile.

B. Sheet Course Usage

1. As foundation base layer, use Geo-Seal BASE course and/or other base sheet as required or approved by the manufacturer.

2. As top protective layer, use Geo-Seal BOND layer and/or other protection as required or approved by the manufacturer.

C. Geo-Seal BOND and Geo-Seal BASE physical properties.

Properties	Test Method	Results
Film Thickness		5 mil
Composite Thickness		18 mil
Water Vapor Permeability	ASTM E 96	0.214
Adhesion to Concrete	ASTM D 1970	9.2 lbs/inch^2
Dart Impact	ASTM D 1790	>1070 gms, method A
		594 gms, method B
Puncture Properties Tear	ASTM B 2582 MD	11,290 gms
	ASTM B 2582 TD	13,150 gms

2.4 AXILLARY MATERIALS

A. Sheet Flashing: 60-mil reinforced modified asphalt sheet good with double-sided adhesive.

B. Reinforcing Strip: Manufacturer's recommended polypropylene and polyester fabric.

C. Gas Venting Materials: Geo-Seal Vapor-Vent HD or Geo-Seal Vapor-Vent Poly, and associated fittings.

D. Seam Detailing Sealant Mastic: Geo-Seal CORE Detail, a high or medium viscosity polymer modified water based asphalt material.

1. Back Rod: Closed-cell polyethylene foam.

PART 3 – EXECUTION

3.1 AUXILIARY MATERIALS

A. Examine substrates, areas, and conditions under which vapor intrusion barrier will be applied, with installer present, for compliance with requirements. Do not proceed with installation until unsatisfactory conditions have been corrected.

3.2 SUBGRADE SURFACE PREPARATION

A. Verify substrate is prepared according to manufacturer's recommendations. On a horizontal surface, the substrate should be free from material that can potentially puncture the vapor intrusion barrier. Additional protection or cushion layers might be required if the earth or gravel substrate contains too many jagged points and edges that could puncture one or more of the system components. Contact manufacturer to confirm substrate is within manufactures recommendations.

B. Geo-Seal can accommodate a wide range of substrates, including but not limited to compacted earth, sand, aggregate, and mudslabs.

1. Compacted Earth: Remove pieces of debris, gravel and/or any other material that can potentially puncture the Geo-Seal BASE. Remove any debris from substrate that can potentially puncture the Geo-Seal system prior to application.

2. Sand: A sand subgrade requires no additional preparation, provided any material that can potentially puncture the Geo-Seal BASE layer is not present.

3. Aggregate: Contact the manufacturer to ensure the aggregate layer will not be detrimental to the membrane. **The gravel layer must be compacted and rolled flat.** Ideally a ¾" minus gravel layer with rounded edges should be specified; however the Geo-Seal system can accommodate a wide variety of different substrates. Contact Land Science Technologies if there are questions regarding the compatibility of Geo-Seal and the utilized substrate. Exercise caution when specifying pea gravel under the membrane, if not compacted properly, pea gravel can become an unstable substrate.

4. Mudslabs: The use of a mubslab under the Geo-Seal system is acceptable, contact Land Science Technologies for job specific requirements.

C. Mask off adjoining surface not receiving the vapor intrusion barrier system to prevent the spillage or over spray affecting other construction.

D. Earth, sand or gravel subgrades should be prepared and compacted to local building code requirements.

3.3 CONCRETE SURFACE PREPARATION

A. Clean and prepare concrete surface to manufacturer's recommendations. In general, only apply the Geo-Seal CORE material to dry, clean and uniform substrates. Concrete surfaces must be a light trowel, light broom or equivalent finish. Remove fins, ridges and other projections and fill honeycomb, aggregate pockets, grout joints and tie holes, and other voids with hydraulic cement or rapid-set grout. It is the applicator's responsibility to point out unacceptable substrate conditions to the general contractor and ensure the proper repairs are made.

B. When applying the Geo-Seal CORE or Geo-Seal CORE Detail material to concrete it is important to not apply the product over standing water. Applying over standing water will result in the membrane not setting up properly on the substrate

C. Surfaces may need to be wiped down or cleaned prior to application. This includes, but is not limited to, the removal of forming oils, concrete curing agents, dirt accumulation, and other debris. Contact form release agent manufacturer or concrete curing agent manufacturer for VOC content and proper methods for removing the respective agent.

D. Applying the Geo-Seal CORE to "green" concrete is acceptable and can be advantageous in creating a superior bond to the concrete surface. To help reduce blistering, apply a primer coat of only the asphalt component of the Geo-Seal CORE system. Some blistering of the membrane will occur and may be more severe on walls exposed to direct sunlight. Blistering is normal and will subside over time. Using a needle nose depth gauge confirm that the specified mil thickness has been applied.

3.4 PREPARATIONS AND TREATMENT OF TERMINATIONS

A. Prepare the substrate surface in accordance with Section 3.3 of this document. Concrete surfaces that are not a light trowel, light broom or equivalent finish, will need to be repaired.

B. Terminations on horizontal and vertical surfaces should extend 6" onto the termination surface. Job specific conditions may prevent a 6" termination. In these conditions, contact manufacturer for recommendations.

C. Apply 30 mils of Geo-Seal CORE to the terminating surface and then embed the Geo-Seal BASE layer by pressing it firmly into the Geo-Seal CORE layer. Next, apply 60 mils of Geo-Seal CORE to the BASE layer. When complete, apply the Geo-Seal BOND layer. After the placement of the Geo-Seal BOND layer is complete, apply a final 30 mil seal of the Geo-Seal CORE layer over the edge of the termination. For further clarification, refer to the termination detail provided by manufacturer.

D. The stated termination process is appropriate for terminating the membrane onto exterior footings, pile caps, interior footings and grade beams. When terminating the membrane to stem walls or vertical surfaces the same process should be used.

3.5 PREPARATIONS AND TREATMENT OF PENETRATIONS

A. All pipe penetrations should be securely in place prior to the installation of the Geo-Seal system. Any loose penetrations should be secured prior to Geo-Seal application, as loose penetrations could potentially exert pressure on the membrane and damage the membrane after installation.

B. To properly seal around penetrations, cut a piece of the Geo-Seal BASE layer that will extend 6" beyond the outside perimeter of the penetration. Cut a hole in the Geo-Seal BASE layer just big enough to slide over the penetration, ensuring the Geo-Seal BASE layer fits snug against the penetration, this can be done by cutting an "X" no larger than the inside diameter of the penetration. There should not be a gap larger than a 1/8" between the Geo-Seal BASE layer and the penetration. Other methods can also be utilized, provided, there is not a gap larger than 1/8" between the Geo-Seal BASE layer and the penetration.

C. Seal the Geo-Seal BASE layer using Geo-Seal CORE or Geo-Seal CORE Detail to the underlying Geo-Seal BASE layer.

D. Apply one coat of Geo-Seal CORE Detail or Geo-Seal CORE spray to the Geo-Seal BASE layer and around the penetration at a thickness of 30 mils. Penetrations should be treated in a 6-inch radius around penetration and 3 inches onto penetrating object.

E. Embed a fabric reinforcing strip after the first application of the Geo-Seal CORE spray or Geo-Seal CORE Detail material and then apply a second 30 mil coat over the embedded joint reinforcing strip ensuring its complete saturation of the embedded strip and tight seal around the penetration.

F. After the placement of the Geo-Seal BOND layer, a cable tie should then be placed around the finished penetration. The cable tie should be snug, but not overly tight so as to slice into the finished seal.

OPTION: A final application of Geo-Seal CORE may be used to provide a finishing seal after the Geo-Seal BOND layer has been installed.

NOTE: Metal or other slick penetration surfaces may require treatment in order to achieve proper adhesion. For plastic pipes, sand paper may be used to achieve a profile, an emery cloth is more appropriate for metal surfaces. An emery cloth should also be used to remove any rust on metal surfaces.

3.6 GEO-SEAL BASE LAYER INSTALLATION

A. Install the Geo-Seal BASE layer over substrate material in one direction with six-inch overlaps and the geotextile (fabric side) facing down.

B. Secure the Geo-Seal BASE seams by applying 60 mils of Geo-Seal CORE between the 6" overlapped sheets with the geotextile side down.

C. Visually verify there are no gaps/fish-mouths in seams.

D. For best results, install an equal amount of Geo-Seal BASE and Geo-Seal CORE in one day. Leaving unsprayed Geo-Seal BASE overnight might allow excess moisture to collect on the Geo-Seal BASE. If excess moisture collects, it needs to be removed.

NOTE: In windy conditions it might be necessary to encapsulate the seam by spraying the Geo-Seal CORE layer over the completed Geo-Seal BASE seam.

3.7 GEO-SEAL CORE APPLICATION

A. Set up spray equipment according to manufacturer's instructions.

B. Mix and prepare materials according to manufacturer's instructions.

C. The two catalyst nozzles (8001) should be adjusted to cross at about 18" from the end of the wand. This apex of catalyst and emulsion spray should then be less than 24" but greater than 12" from the desired surface when spraying. When properly sprayed the fan pattern of the catalyst should range between 65° and 80°.

D. Adjust the amount of catalyst used based on the ambient air temperature and surface temperature of the substrate receiving the membrane. In hot weather use less catalyst as hot conditions will quickly "break" the emulsion and facilitate the curing of the membrane. In cold conditions and on vertical surfaces use more catalyst to "break" the emulsion quicker to expedite curing and set up time in cold conditions.

E. To spray the Geo-Seal CORE layer, pull the trigger on the gun. A 42° fan pattern should form when properly sprayed. Apply one spray coat of Geo-Seal CORE to obtain a seamless membrane free from pinholes or shadows, with an average dry film thickness of 60 mils (1.52 mm).

F. Apply the Geo-Seal CORE layer in a spray pattern that is perpendicular to the application surface. The concern when spraying at an angle is that an area might be missed. Using a perpendicular spray pattern will limit voids and thin spots, and will also create a uniform and consistent membrane.

G. Verify film thickness of vapor intrusion barrier every 500 ft^2. (46.45 m^2), for information regarding Geo-Seal quality control measures, refer to the quality control procedures in Section 3.9 of this specification.

H. The membrane will generally cure in 24 to 48 hours. As a rule, when temperature decreases or humidity increases, the curing of the membrane will be prolonged. The membrane does not need to be fully cured prior the placement of the Geo-Seal BOND layer, provided mil thickness has been verified and a smoke test will be conducted.

I. **Do not penetrate** membrane after it has been installed. If membrane is penetrated after the membrane is installed, it is the responsibility of the general contractor to notify the certified installer to make repairs.

J. If applying to a vertical concrete wall, apply Geo-Seal CORE directly to concrete surface and use manufacturer's recommended protection material based on site specific conditions. If applying Geo-Seal against shoring, contact manufacturer for site specific installation instructions.

NOTE: Care should be taken to not trap moisture between the layers of the membrane. Trapping moisture may occur from applying a second coat prior to the membrane curing. Repairs and detailing may be done over the Geo-Seal CORE layer when not fully cured.

3.8 GEO-SEAL BOND PROTECTION COURSE INSTALLATION

A. Install Geo-Seal BOND protection course perpendicular to the direction of the Geo-Seal BASE course with overlapped seams over nominally cured membrane no later than recommended by manufacturer and before starting subsequent construction operations.

B. Sweep off any water that has collected on the surface of the Geo-Seal CORE layer, prior to the placement of the Geo-Seal BOND layer.

C. Overlap and seam the Geo-Seal BOND layer in the same manner as the Geo-Seal BASE layer.

D. To expedite the construction process, the Geo-Seal BOND layer can be placed over the Geo-Seal CORE immediately after the spray application is complete, provided the Geo-Seal CORE mil thickness has been verified.

3.9 QUALITY ASSURANCE

A. The Geo-Seal system must be installed by a trained and certified installer approved by Land Science Technologies.

B. For projects that will require a material or labor material warranty, Land Science Technologies will require a manufacturer's representative or certified 3rd party inspector to inspect and verify that the membrane has been installed per the manufacturer's recommendations.

The certified installer is responsible for contacting the inspector for inspection. Prior to application of the membrane, a notice period for inspection should be agreed upon between the applicator and inspector.

C. The measurement tools listed below will help verity the thickness of the Geo-Seal CORE layer. As measurement verification experience is gained, these tools will help confirm thickness measurements that can be obtained by pressing one's fingers into the Geo-Seal CORE membrane.

To verify the mil thickness of the Geo-Seal CORE, the following measurement devices are required.

1. Mil reading caliper: Calipers are used to measure the thickness of coupon samples. To measure coupon samples correctly, the thickness of the Geo-Seal sheet layers (18 mils each) must be taken into account. Mark sample area for repair.

2. Wet mil thickness gauge: A wet mil thickness gauge may be used to quickly measure the mil thickness of the Geo-Seal CORE layer. The thickness of the Geo-Seal sheet layers do not factor into the mil thickness reading.

   NOTE: When first using a wet mil thickness gauge on a project, collect coupon samples to verify the wet mil gauge thickness readings.

3. Needle nose digital depth gauge: A needle nose depth gauge should be used when measuring the Geo-Seal CORE thickness on vertical walls or in field measurements. Mark measurement area for repair.

To obtain a proper wet mil thickness reading, take into account the 5 to 10 percent shrinkage that will occur as the membrane fully cures. Not taking into account the thickness of the sheet layers, a freshly sprayed membrane should have a minimum wet thickness of 63 (5%) to 66 (10%) mils.

Methods on how to properly conduct Geo-Seal CORE thickness sampling can be obtained by reviewing literature prepared by Land Science Technologies.

D. It should be noted that taking too many destructive samples can be detrimental to the membrane. Areas where coupon samples have been removed need to be marked for repair.

E. Smoke Testing is highly recommended and is the ideal way to test the seal created around penetrations and terminations. Smoke Testing is conducted by pumping non-toxic smoke underneath the Geo-Seal vapor intrusion barrier and then repairing the areas where smoke appears. Refer to smoke testing protocol provided by Land Science Technologies. For projects that will require a material or labor material warranty, Land Science Technologies will require a smoke test.

F. Visual inspections prior to placement of concrete, but after the installation of concrete reinforcing, is recommended to identify any punctures that may have occurred during the installation of rebar, post tension cables, etc. Punctures in the Geo-Seal system should be easy to indentify due to the color contrasting layers of the system.

Land Science Technologies
Specifications for Retro-Coat™
Version 1.0

Part 1 – Scope

1.1 Product and Application

This specification describes the application of the Retro-Coat™ System. The minimum thickness of the system is between 25-30 mils, including a 20 mil minimum application of Retro-Coat.

1.2 Acceptable Manufacturers

A. Retro-Coat as manufactured by Land Science Technologies San Clemente, CA.

1.3 Performance Criteria

A. Retro-Coat as manufactured by Land Science Technologies San Clemente, CA.

1. Diffusion Coefficient (Columbia Labs)
   PCE: 7.6×10^{-14} m^2/s
   TCE: 8.2×10^{-14} m^2/s

2. Tensile Elongation (ASTM D-638)
   Minimum: 6000 psi

3. Tensile Elongation (ASTM D-638)
   Minimum: 6 %

4. Flexural Strength (ASTM D-790)
   Minimum: 7000 psi

5. Hardness, Shore D (ASTM D-2240)
   Maximum: 85

6. Gardner Impact (ASTM D-2794)
   Minimum: 80 inch-pounds

7. Bond Strength to Quarry Tile
   Minimum: 1000 psi

8. Vapor Transmission Rate (ASTM E-96)
   Maximum: .07 perms

9. Water Absorption (ASTM D-570)
   Maximum: .02% in 24 hours

10. 60° Gloss
    Minimum: 100.

1.4 Materials

A. Retro-Coat “A” shall be a modified epoxy containing special flexibilizers and specially formulated resins for superior chemical resistance and enhanced resilience. No solvents are allowed.

B. Retro-Coat “B” shall be customized blend of hardeners specifically formulated to maximize chemical resistance. No solvents are allowed.

1.5 Applicator

A. Applicator must be a certified contractor of Land Science Technologies.

Part 2 – Application

2.1 Surface Preparation

A. All existing surfaces that will be covered with the systems specified herein should be mechanically ground, shot blasted or sand blasted to yield a minimum 60 grit surface texture. All loosely adhered coatings will be removed. Any grease and other contaminants found on the concrete must also be removed.

B. All open cracks 1/2” and greater should be v-notched to a 3/4” width by 1/2” depth and cleaned of any debris. Such cracks should be filled with Retro-Coat Gel and struck off flush with the surrounding surface.

C. Cut back and/or remove any expansion joint backing or filler strips to a minimum of 1 ½” deep. Insert disposable filler in the joints to prevent filling with the overlayment materials and to allow for accurate location of final saw cuts in the overlayment.

2.2 Material Application

A. Retro-Coat CAULK

1. Apply Retro-Coat CAULK around the base of all pipe penetrations making sure to fill any gap between the penetration and concrete slab

2. Apply Retro-Coat CAULK to the joint created between horizontal and vertical transitions. The caulking material should be applied and pressed into the joint filling any gaps that might be present.

B. Retro-Coat PRIMER

1. Apply Retro-Coat PRIMER to all areas at a thickness of 6 mil and allow to dry tack free. In areas where the concrete surface is in need of slight repair or needs to be leveled, a slurry form of Retro-Coat PRIMER called Retro-Coat PRIMER-S can be applied with a flat squeegee. Retro-Coat PRIMER-S is self priming and does not need to be primed again.

C. Retro-Coat

1. Mix Retro-Coat, Part A with a low-speed (<750 rpm) jiffy-style mixer for about 30 seconds, or until uniform in color, then mix in Retro-Coat Coating, Part B for another 30-60 seconds.

2. Dump contents onto floor in a ribbon pattern, squeegee, and then back roll at a coverage rate of 160 SF/gallon to achieve a film thickness of 10 mils.

3. Apply second coat 10 mil coat to achieve a total thickness of 20 mils. Repeat as necessary to achieve specified thickness.

4. If a flooring material will be placed over Retro-Coat after it is applied, or appearance is not a priority, (1) 20 mil coat can be applied.

2.3 Protection of Finished Work

A. Prohibit foot traffic on floor for 24 hours after laying (at 70ºF). At 50ºF,this time should be extended to 48 hours.

B. Rinse off any chemicals that may come in contact within 7 days of installation with the freshly laid floor immediately.

2.4 Cleanup

A. Properly dispose of all unused and waste materials.

B. Tools can be washed in warm, soapy water when wet, but after drying, can only be cleaned by grinding or with a paint stripper.

C. Unused resin can be set off with proper amount of hardener and disposed of in regular trash bins.

Part 3 – Quality Control

3.1 Warranty

A. Installer shall provide a one year warranty against delamination, chemical attack and normal wear and tear.

B. Manufacturer will provide a one year material warranty.

3.2 Quality Control

A. Installer shall use a notched squeegee to apply Retro-Coat to the specified mil thickness and calculations shall be done to determine if the correct amount of material has been applied. Retro-Coat contains 100% solids at the time of application; therefore no material shrinkage will occur during the curing process. One gallon will cover 80 square feet.

B. A wet mil film gauge can be used to spot check the Retro-Coat thickness to make certain the minimum 20 mil thickness has been applied, though some discretion should be used because high points or low points on the underlying surface can adversely affect the thickness measurements.

3.3 Floor Care

A. The standard smooth surface of Retro-Coat should be cleaned on a regular basis by damp mopping the floor with conventional commercial cleaners. It is important to first remove any grease or oils by a suitable cleaner, preferably a citrus based cleaner. Rinse with clear water to help eliminate film buildup and then allow to dry. Never use abrasive powder cleaners like Ajax or Comet as they tend to scratch the floor.

B. Additional steps can also be taken to prolong the look and life of a seamless floor:

1. Protect the floor during transference of heavy equipment
2. Educate the drivers inside the building the importance of avoiding “jack-rabbit” starts and stops, as well as keeping the metal forks lifted
3. Regular cleaning should take place as to not allow the buildup of abrasive material, such as sand or dirt, on the coating
4. Eliminate all metal wheels
5. Change over to light-colored polyurethane wheels
6. Do not slide heavy metal totes, drums or bins across the floor
7. Immediately hose down chemical spills, especially on newly laid floors.

Geo-Seal®

Vapor Intrusion Barrier

1. Vapor-Vent should be installed in a permeable subgrade to maximize vapor collection ability

2. Geo-Seal BASE is a composite sheet material comprised of HDPE and non-woven geotextile

3. Geo-Seal CORE is spray applied to increase the systems tensile strength and provide a seamless membrane

4. Penetrations are sealed individually

5. Geo-Seal BOND is applied over the Geo-Seal CORE to provide additional protection

6. Concrete is placed directly onto the completed Geo-Seal system

Retro-Coat™

Vapor Intrusion Coating

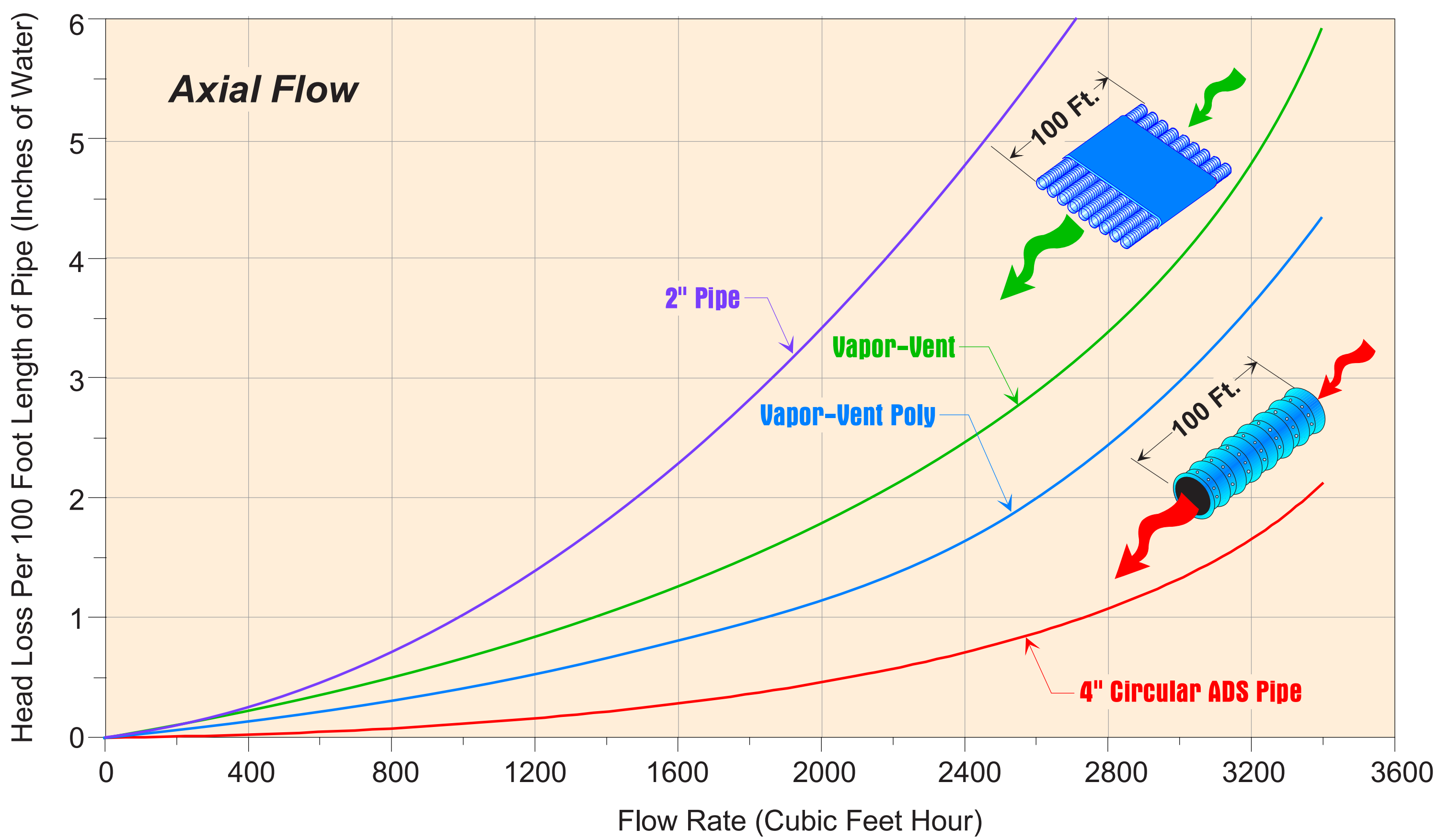
1. Existing concrete slab is first cleaned and then abraded

2. Retro-Coat Gel and fillers are used to repair concrete cracks and other imperfections

3. Retro-Coat PRIMER is applied to the concrete surface as final preparation. This increases adhesion between the concrete slab and the Retro-Coat, as well as address moisture vapor transmission.

4. Retro-Coat is applied to a nominal thickness of 20 dry mils

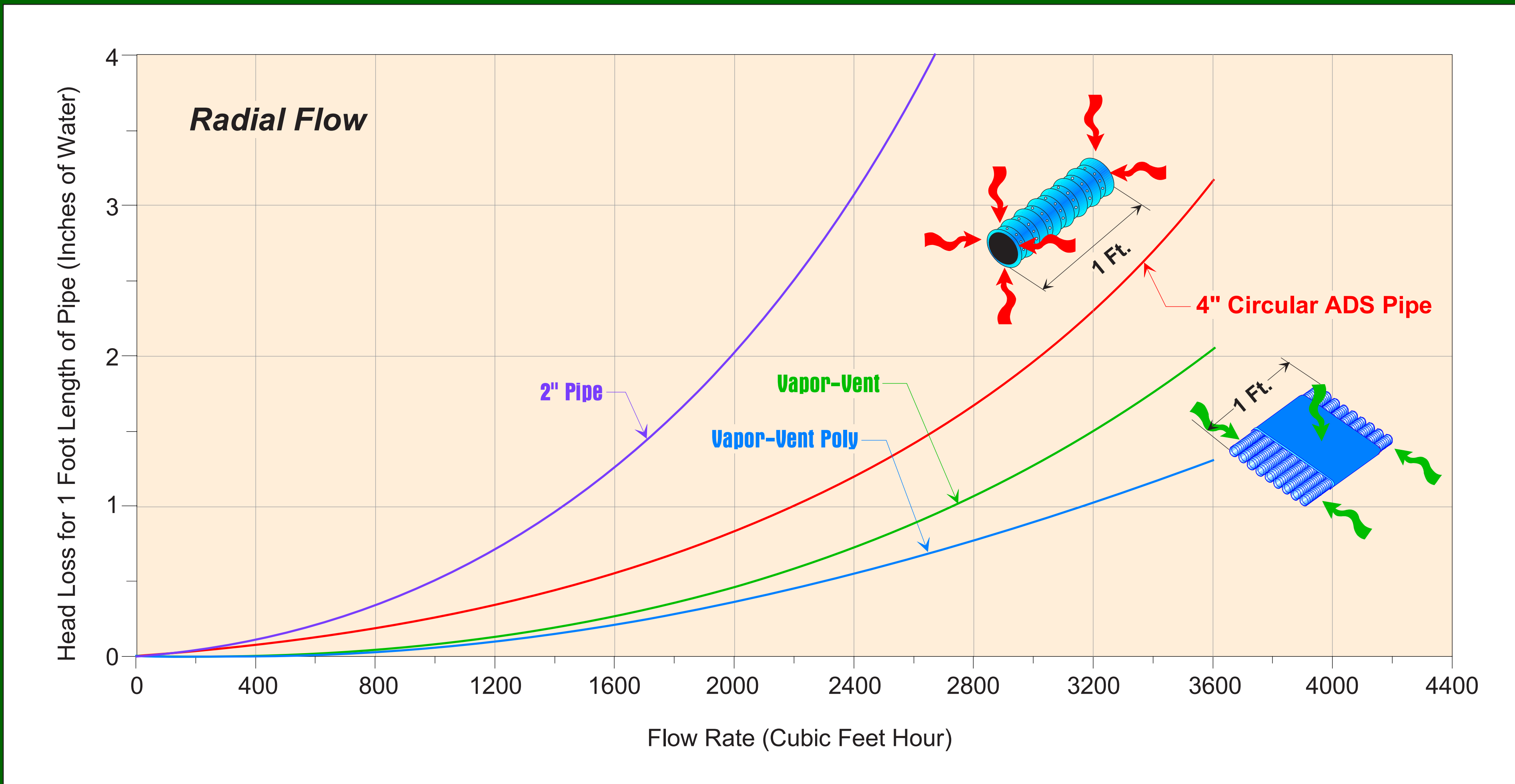
Axial Flow Characteristics for Vent Piping



GeoKinetics
Geotechnical & Environmental Engineers

Land Science Technologies

Radial Flow Characteristics for Vent Piping



GeoKinetics
Geotechnical & Environmental Engineers

Land Science Technologies

VI Modeling Methods

1. Rely on the Ficks's law of diffusion
2. Developed to help predict the migration of sub surface vapor contamination
3. Soil type and thickness way heavily on results

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Incorporating VI Barriers into VI Models

Barrier needs to have a low enough rate to make a difference

OR

Assumptions need to be made to overcome soil thickness

Diffusion/Permeation Methods

1. Methods can dictate results
2. Methods have not been validated
3. Use of numbers in models can be one line of evidence

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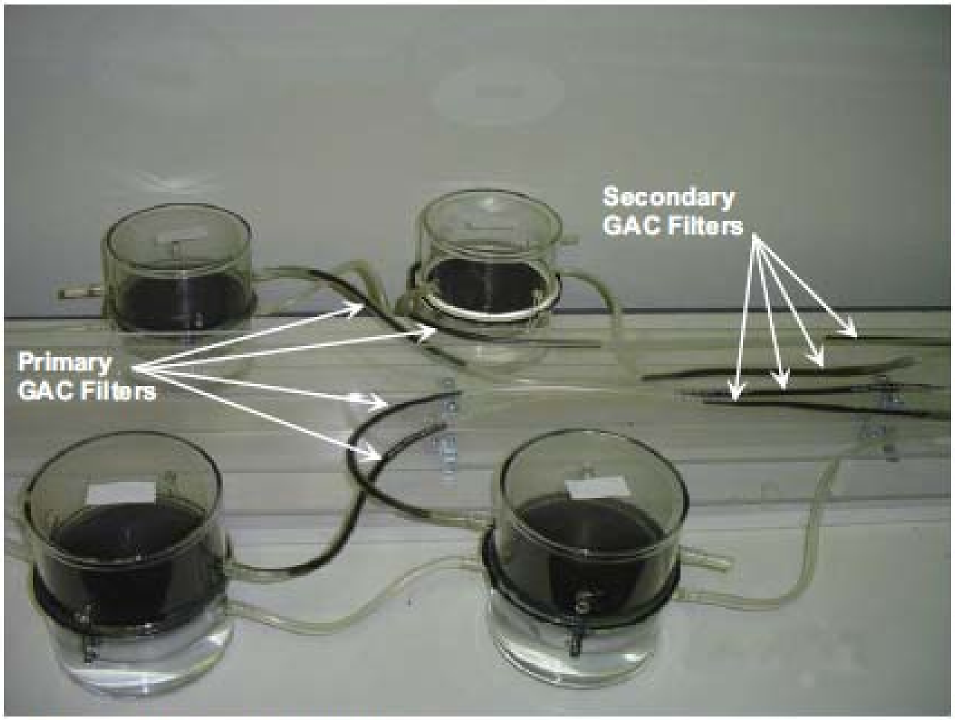
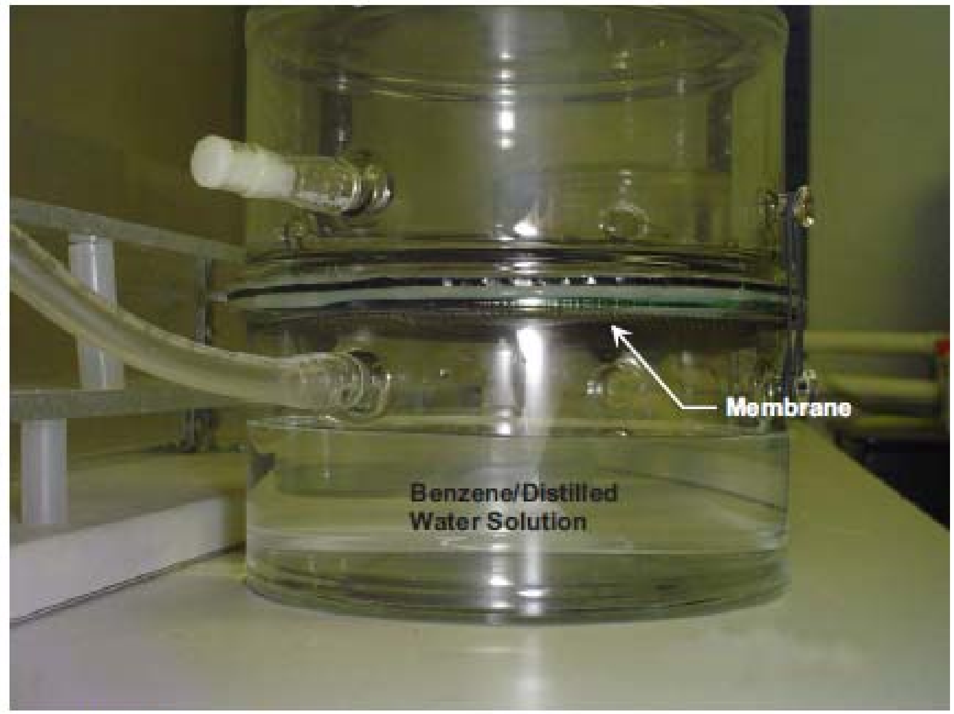
GeoKinetics



Overview of Diffusion Test Chambers



Close-Up of Diffusion Test Chamber

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LST/Columbia

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GeoKinetics Method

Product	Contaminant	Test Concentration	Result
Geo-Seal	Benzene	125,500 ppm	6.9×10^{-16} m^2/sec
Geo-Seal	PCE	90,000 mg/m^3	4.0×10^{-17} m^2/sec

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Comparison of Methods

	Diffusion Coefficient (GeoKinetics Method)	Permeation (LST Method)
Geo-Seal	4.0×10^{-17} m^2/s	2.2×10^{-10} m^2/s

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Brownfield Vapor Barriers:
Chemical Compatibility, Testing, and Advances in Materials Science

Scott Wilson (swilson@regenesis.com), Benjamin Mork, Ph.D. (Land Science Technologies, a division of Regenesis, San Clemente, CA)

ABSTRACT: A new composite membrane system, Geo-Seal™, has been developed that offers exceptional chemical resistance for use as a vapor barrier at brownfield sites. Data generated in controlled laboratory conditions indicate the composite membrane to have < 0.2X the volatile organic compound partitioning when compared to spray applied latex/asphalt vapor barriers. More importantly, data generated under both liquid and gas permeability tests indicate that the new composite membrane system limits the transmission of volatile organic vapors. Data indicated the Geo-Seal membrane to resist contaminant permeation breakthrough for a period 18X longer than that of simple asphalt/latex membranes and to allow for < 0.16X the rate of VOC permeance of the asphalt/latex membranes.

INTRODUCTION

Brownfield site development often requires the use of a contaminant vapor barrier to inhibit volatile organic contaminants remaining on-site from migrating into the newly constructed buildings, potentially impacting indoor air quality.

Historically plastic sheet materials such as high density polyethylene, known for chemical resistance, have been applied as contaminant vapor barriers. The use of these materials, however, requires labor-intensive cutting and seaming to ensure a continuous and cohesive barrier to vapor migration. This installation process can be intensive, difficult, and costly when applied to construction foundations with multiple penetrations (e.g. piping, electrical conduits).

In recent years "spray applied" latex/asphalt membrane-type waterproofing materials have been widely promoted for brownfield vapor barrier use. While easy to apply and proven to retard water migration through concrete, the use of these latex/asphalt materials for repelling volatile organic constituents (VOCs) such as benzene and chlorinated solvents may be complicated by the affinity of latex/asphalt for VOCs. It is widely recognized that asphalt/latex-based products are, in fact, highly susceptible to partitioning by VOCs, particularly chlorinated dry cleaning- type solvents.

BACKGROUND

Spray Applied Asphalt/Latex Membranes. Asphalt/latex membranes are chemically described as bitumen/polystyrene emulsions that are spray-applied in the presence of calcium chloride salt solutions. Simply put, the salt solution "breaks the emulsion" upon mixing when applied forming a continuous layer of bitumen-styrene as the material dries upon a surface. Depending on the exact formulation, the emulsion material may also have clay or calcium carbonate added as a "filler" or "builder" which allows for varying of key characteristics such as viscosity, flexibility, etc.

Proceedings of the **Sixth International Conference on Remediation of Chlorinated and Recalcitrant Compounds**, Barriers to VOC Intrusion into Buildings. 2008.Monterey, California, USA. Battelle Press, Columbus, Ohio, USA. *In Press*.

Geo-Seal™ Composition. Geo-Seal™ (Land Science Technologies, San Clemente, CA, USA) is a unique composite membrane (patent pending) that incorporates the ease of application associated with spray applied asphalt/latex membranes with the chemical resistance, low chemical permeability, and mechanical strength of high density polyethylene (HDPE). The Geo-Seal membrane incorporates all the positive aspects of 60 mil asphalt/latex membranes plus the two outer layers of proprietary HDPE.

Hydrophobic vs Lipophilic. All asphalt/latex membrane materials are hydrophobic (water repelling) due to the petroleum (bitumen) content. This is why these materials tend to have both low adsorptivity toward water (water does not partition into the membrane itself) and low permeance with regard to water vapors (very little water vapor moves through the membrane). Asphalt/latex membranes make for excellent water-proofing and damp-proofing materials.

Conversely, asphalt/latex membrane materials are lipophilic (oil attracting, or non-polar). When contacted with oils they absorb the oil. In the same fashion, non-polar VOCs like benzene or perchloroethene (PCE) tend to partition into the membrane itself. This is very well documented. In fact, this is why the "dry cleaning" industry has adopted the use of PCE to remove bitumen from clothes…the PCE partitions into the bitumen and extracts it from the fabric. Likewise gasoline is commonly used as a cleaner to remove tar.

SOLVENT EXPOSURE TESTING

Any solvent exposure testing relevant to the use of materials for under-slab VOC contaminant vapor barriers should test or model the true long term exposure of the barrier material to the specific contaminant of concern. In the case of testing latex/asphalt contaminant vapor barrier material for exposure to volatile organic contaminants (e.g. benzene, PCE, trichloroethene (TCE), etc.) the most important factor to consider is the long term adsorption of the contaminant into the membrane itself.

Over time the lipophilic membrane material will continue to absorb contaminant until some point in the future when it reaches equilibrium and/or becomes "saturated". The period of time required to reach saturation is dependent upon the contaminant type, its concentration in the soil pore gas, temperature, pressure, and its specific partitioning coefficient toward the specific asphalt/latex membrane under testing.

The standard analytical method for solvent exposure testing is generally considered to be ASTM D-543 (ASTM D-543-06). In this test the specific membrane material (latex/asphalt) is exposed to the specific contaminant of concern (e.g. PCE) within the specific medium of concern (air) for a period of 7 days. The amount of weight gained by the membrane is a direct measure of the absorption of the contaminant by the membrane material. When little absorption occurs it can be said that there is little reactivity or change of the membrane with exposure. This test however, will only indicate the absorption (partitioning) which occurs within the 7 day period when the membrane is subjected to the contaminant at the specific concentration tested. It does not indicate the total potential absorption (partitioning) that may occur over the lifespan of the membrane in an actual field application.

In order to understand the long term effects of a membrane's exposure to solvents one has to either 1) test the membrane under low volatile organic vapor (VOC) concentrations for an extended period of time- until the partitioning equilibrates (this could be many years depending on how low the vapor concentration is) or 2) run the test at very high concentrations to ensure saturation within the test period. At the point of saturation with VOCs, asphalt/latex membranes show very different characteristics, particularly with regard to VOC permeation, weight, dimensions, and tensile strength.

It is widely known that unprotected asphalt/latex membranes absorb significant contaminant vapors as the VOC partitions into the bitumen fraction of the membrane itself. Eventually this leads to saturation of the membrane, membrane swelling, softness, etc.

General Asphalt/Latex Solvent Exposure Testing. In work conducted by an independent laboratory experienced in asphalt/latex membrane formulation, ASTM D-543 was conducted on varying formulations in the presence of hexane vapors. Specific formulations and test results are presented below in Table 1. It is appropriate to note that in all of the varying formulations a weight gain of greater than 10% was observed indicating that asphalt/latex membranes by their very chemical makeup absorb (partition) VOC vapors when properly exposed to the VOC.

TABLE 1. VOC Solvent Exposure Testing of Various Asphalt/Latex Membranes By ASTM D-543 Employing Hexane Vapors*

Ingredient			(%)	
Bitumen	72.2	71.7	72.2	66.2
Polystyrene Latex	18.1	17.9	18.1	16.6
$CaCl_2$	0.7	1.4	0.7	0.7
$CaCO_3$	9.0	9.0	0.0	16.6
Bentonite	0.0	0.0	9.0	0.0
% Weight Gain	15.0	12.5	14.1	10.9

*Applied Power Concepts Laboratory, Anaheim, CA 2004, USA.

Comparative Solvent Exposure Testing. In an effort to confirm that in fact commercially available spray-applied asphalt/latex membranes behave just as other asphalt/latex membranes, a third party laboratory conducted testing upon a sample (60 mil thickness) of a commercially available spray applied asphalt/latex vapor barrier (Liquid Boot®, Santa Ana, California, USA) obtained directly from a manufacturer-certified applicator.. The identical test was conducted employing a sample of the Geo-Seal composite membrane. The method employed was a modified ASTM D-543 using PCE vapors on one side of the membrane and ambient air on the other. Results indicated

2.1% weight gain for Geo-Seal, compared to 10.8% weight gain of the commercially available asphalt/latex membrane sample. Data derived from this testing is presented in Table 2 below.

TABLE 2. Solvent Exposure Testing – Modified ASTM D-543*			
	Pre-Test Weight (g)	Post-Test Weight (g)	Weight Gain
Asphalt/Latex+	4.24	4.70	10.8%
Geo-Seal™	3.87	3.95	2.1%

*Intertek Laboratories, Foxboro Mass. 2008
+Liquid Boot ®, Santa Ana, CA, USA

These data clearly indicate that commercially available asphalt/latex is subject to the same weakness as other simple spray applied asphalt/latex membranes- they do not repel VOC vapors. Instead they tend to absorb (partition) vapors. The Geo-Seal composite membrane, on the other hand, incorporates two layers of the very chemical resistant high density polyethylene in addition to the 60 mil spray applied copolymer modified bitumen/polystyrene core layer. These HDPE layers serve to limit exposure of the core layer to VOCs and to ensure mechanical integrity of the membrane.

PERMEATION TESTING

Permeation testing measures the rates of transport across membranes. Traditionally this has been conducted by simply placing the challenge gas or liquid on one side of the membrane and, after sealing, measuring the amount of the gas that emerges from the opposing side of the membrane over time. This method is the basis for several standard analytical techniques used in the testing of materials for waterproofing applications. However, this basic approach is flawed in testing VOC permeation through lipophilic membranes such as simple asphalt/latex membranes.

VOC Partitioning, Break-through and Permeation. Permeation of VOCs through a lipophilic membrane can be viewed as a three phase process where: 1) VOCs move into the membrane through absorption (partition) with only a fraction passing completely through, 2) partitioning of the VOCs into the membrane continues to the point of equilibrium saturation where break-through of higher concentrations occur, and 3) post saturation where VOCs are moving out of the membrane at significantly increased rates. This process is depicted in Figure 1, below.

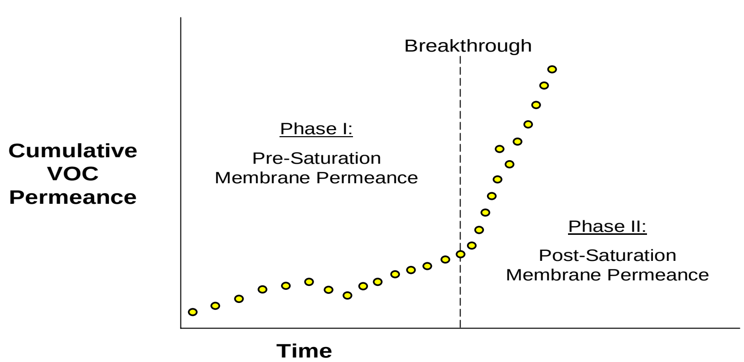

FIGURE 1. Permeation of VOCs through a Lipophilic Membrane

Asphalt/Latex Membrane Permeation Testing. When testing asphalt/latex membranes against VOCs one should not simply measure the flux of low concentrations of VOCs across the membrane as this approach does not take into account the concentration of VOCs absorbed (partitioned) by the membrane itself.

In the ASTM publication "Determination of Volatile Organic Compound Permeation Through Geomembranes" (Park, 1996) the authors state, in reference to the general testing method employed by vendors of asphalt/latex membranes:

> "The permeation rate was estimated solely on the amount of VOC that passed through the geomembrane surface area in a unit time. This estimation is incorrect for it does not account for partition and diffusion and assumes a constant concentration above the geomembrane".

In the permeation testing conducted by a vendor of asphalt/latex membranes (Cetco Liquid Boot, 2008), which was then used to generate a diffusion coefficient, the physical partitioning of the VOCs into the membrane was not taken into account. As noted by Park, et. al. (1996), this method is in error. The membrane in this testing was almost certainly <u>not</u> at the point of saturation after less than one year's time in contact with vapors from aqueous dissolved VOC. Thus, the testing was conducted under conditions where much of the VOCs were being partitioned into the membrane. Over time, however this lipophilic membrane would become saturated and the rate of VOC permeation would significantly increase.

Testing Permeation upon Pre-Saturation. An approach to understanding the capacity of a membrane to act as a long term barrier to VOC permeation is to first saturate the membrane with VOC. Once saturated, the membrane can then be subjected to the VOC in specific concentrations and the associated permeation rate can be measured. In this case, the impact of the VOC absorbance (partitioning) on the measurement of permeation is minimized if not eliminated altogether.

A series of tests were conducted by a third party laboratory in order to gain an understanding of the relative long term performance of the Geo-Seal composite membrane and the commercially available asphalt/latex membrane against VOC permeation.

Comparative Liquid VOC Challenge Post-Saturation. In order to understand the chemical permeation of VOCs through the two membrane systems a standard method ASTM F-739 was employed utilizing an open loop system permeation test cell (ASTM F739-07). The membranes were subjected to liquid VOC for 24 hours to ensure saturation followed by an 8 hour test of the materials toward VOC permeation from direct liquid VOC contact.

Results of this test represent "worst case" permeation rates, as it assumes maximum VOC concentration challenge after membrane saturation. Thus, the absolute VOC permeation rate numbers are very high. This test however serves to indicate the relative capacity for the two membranes to block permeation from the specific VOCs under identical controlled conditions. All tests were performed in triplicate under controlled laboratory conditions.

TABLE 3. Results of Comparative Permeation Testing under Liquid VOC Challenge*			
Barrier Material	VOC Contaminant	Breakthrough Time (minutes)†	Steady-State Perm Rate ($\mu g/cm^2/min$)
Asphalt/Latex+	PCE	15	12.9
Geo-Seal™	PCE	270	2

*Intertek Laboratories, Foxboro MA, USA. 2008
+Liquid Boot®, Santa Ana, CA, USA
† Time when permeation rate reached 1.0 $\mu g/cm^2/min$

As can be seen from the results presented in Table 3, the Geo-Seal barrier after saturation was much more resistant to permeation than the asphalt/latex membrane . Geo-Seal held up breakthrough permeation for an 18X longer period when compared to Liquid Boot. Additionally, once steady state permeation was reached, Liquid Boot allowed for 6.45X the rate of permeation when compared to Geo-Seal. This is not surprising when considering the HDPE composite composition of Geo-Seal compared to the simple commercially available asphalt/latex membrane.

Comparative VOC Vapor Challenge Post-Saturation. In order to compare the relative performance of Geo-Seal and commercially available asphalt/latex membranes to act as a long term barrier to VOC vapor permeation, a series of test were conducted by a third party laboratory employing a double compartment apparatus in a modified ASTM-F739 test protocol (see Figure 2). Under this test the membranes were first subjected to the VOC for 24 hours to reach saturation then placed into the apparatus which subjected the membrane to VOC vapors for a period of 8 hours.

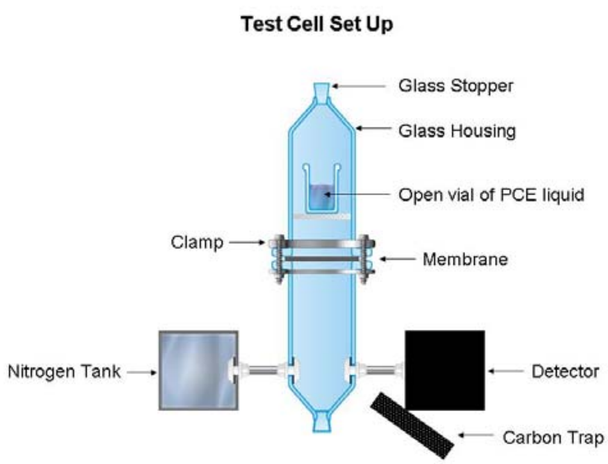

FIGURE 2. Double Compartment Apparatus

As can be seen from the results presented in Table 4, Geo-Seal did not break-through or allow detectable permeation of the VOC vapors within the testing period even after being saturated with the VOC prior to testing. The simple asphalt/latex membrane however, under the same conditions, reached break-through after 450 minutes and had reached a steady state permeation rate of 5 μg/cm^2/min.

TABLE 4. Results of Comparative Permeation Testing under VOC Vapor Challenge*			
Barrier Material	VOC Contaminant	Breakthrough Time (minutes)	Steady-State Perm Rate (μg/cm^2/min)
Asphalt/Latex+	PCE	450	5
Geo-Seal™	PCE	No Breakthrough	< 0.01

+Liquid Boot ®, Santa Ana, CA, USA

SUMMARY

Membrane materials for use as sub-slab contaminant vapor barriers are evolving. It is now becoming recognized that traditional waterproofing materials such as asphalt/latex membranes, while low in cost and easy to apply, are limited in their ability to block the permeation of volatile organic contaminants. Through recent advancements in membrane science a composite membrane (Geo-Seal™) is now available which encapsulates a spray applied asphalt/latex membrane with chemically resistant high density polyethylene. This technology is shown to have superior characteristics as a vapor barrier to VOC contamination when compared to traditional asphalt/latex membranes.

REFERENCES

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ASTM F739-07: American Society for Testing and Materials method ASTM F 739, “Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact” www.astm.org

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Park, J.K., J.P. Sakti, and J.A. Hoopes. 1996. “Determination of Volatile Organic Compound Permeation Through Geomembranes”. *Volatile Organic Compounds in the Environment, ASTM STP 126, W. Wang. J. Schoor, and J. Doi, Eds.*, American Society for Testing and Materials, 1996, pp. 245-258.

A New Methodology for Chemical Resistance Testing of a Retrofit Vapor Intrusion Barrier

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Abstract

Chemical resistance of the Retro-Coat™ barrier system was tested against the VOCs perchloroethene (PCE), and trichloroethene (TCE). A custom apparatus and testing methodology were developed to mimic conditions that are directly relevant to vapor intrusion. The testing was run for approximately 150 days and permeation rates were determined for each contaminant at challenge concentrations of approximately 25, 125, 250, and 500 ppmV. The VI-specific barrier was determined to be highly chemically resistant to these VOCs, exhibiting diffusion coefficients of $7.6 \times 10^{-14} m^2/s$ *and* $8.2 \times 10^{-14} m^2/s$ *for PCE and TCE respectively, thus validating efficacy of the Retro-Coat barrier as a preventative measure against vapor intrusion for existing structures on contaminated land.*

Introduction

Vapor Intrusion (VI) is the process by which toxic vapors from contaminated soil and groundwater can migrate into the indoor air of a building, thus presenting a risk to the health of building occupants. The risks of VI to human health can be significant in structures built upon sites contaminated with volatile organic chemicals (VOCs) such as perchloroethene (PCE) or benzene. For new structures built on contaminated land, there are a variety of strategies and technologies available to mitigate future vapor intrusion into structures. For example, the Geo-Seal® membrane is a multi-ply chemically resistant barrier that is installed prior to pouring the concrete slab foundation. Active and passive ventilation systems are also widely used to mitigate vapor intrusion beneath buidings and are usually installed during construction.

There are many VI mitigation options that can be incorporated into the construction phase of a new building, however there are limited options available for existing structures that have a vapor intrusion problem or a potential risk of vapor intrusion. For the countless existing “sick” or at-risk structures in need of a vapor intrusion mitigation solution, Land Science Technologies, Inc. (San Clemente, CA) has developed a VI-specific floor coating system called Retro-Coat™. This material has been explicitly developed and tested for its ability to seal concrete-slab floors in existing structures against VOCs, thus significantly lowering the risk of VI to the indoor air quality.

Although there are existing standardized test methods to quantify the transport of water vapors through barriers (e.g., ASTM E-96), these methods are inaccurate for estimation of VOC vapor transmission at levels relevant to vapor intrusion mitigation (e.g. ppmV levels). In order to demonstrate the efficacy of this new floor coating system, a new method and testing apparatus were developed. This is the only method to date that closely models the condition of contaminant vapor intrusion. The practice of active sampling, the chamber design, and the constant clean-air exchange above the barrier sample ensure that a conservative and accurate measure of contaminant diffusion through the barrier is obtained. In consideration of reported diffusion coefficients from this and other studies, it is very important that these criteria are addressed correctly in the experimental design and procedure.

An extensive five month study was performed to quantify the chemical resistance of Retro-Coat toward two toxic and volatile chemicals that are commonly encountered as soil and groundwater contaminants: perchloroethene (PCE) and trichloroethene (TCE). Historically, these chlorinated solvents have been widely used as dry-cleaning and degreasing agents, respectively. The study design involved testing multiple contaminant concentrations, starting from a high level (500 ppmV) and sequentially testing lower concentrations in order to establish a relationship between concentration and permeation rate. This "high to low" methodology is a conservative approach that ensures the permeation of contaminant is at a steady-state condition and that diffusion rates will not be underestimated. An overview of the new, custom-developed testing methodology is reported in this paper, along with the resulting chemical resistance data and contaminant diffusion coefficients determined for the Retro-Coat barrier material.

Experimental

<u>Chemical Resistance Testing Apparatus:</u> A labeled photograph of the custom-made vapor transmission testing apparatus is shown in Figure 1. The lower chamber is constructed from a 5 L glass round-bottom flask, and the top section consists of a 3-necked glass chamber. Both top and bottom chambers are open-ended to interface with an approximately 6" diameter circular sample of vapor barrier to be tested. The two chambers are separated by the tested barrier material and the system is secured and sealed by a ring clamp that compresses and seals the barrier between chambers with adjustable screws. Two independent chamber studies were run in parallel: one for each contaminant tested (PCE and TCE). All vapor experiments were run by Columbia Analytical Services (Simi Valley, CA)

<u>Sample Preparation</u>: A 20 mil (0.020 inch) thick sheet of the Retro-Coat barrier was prepared by layering 2 10-mil coatings on a 22"x42" glass surface with a 10-mil notched squeegee. After the material cured for one day, the barrier was

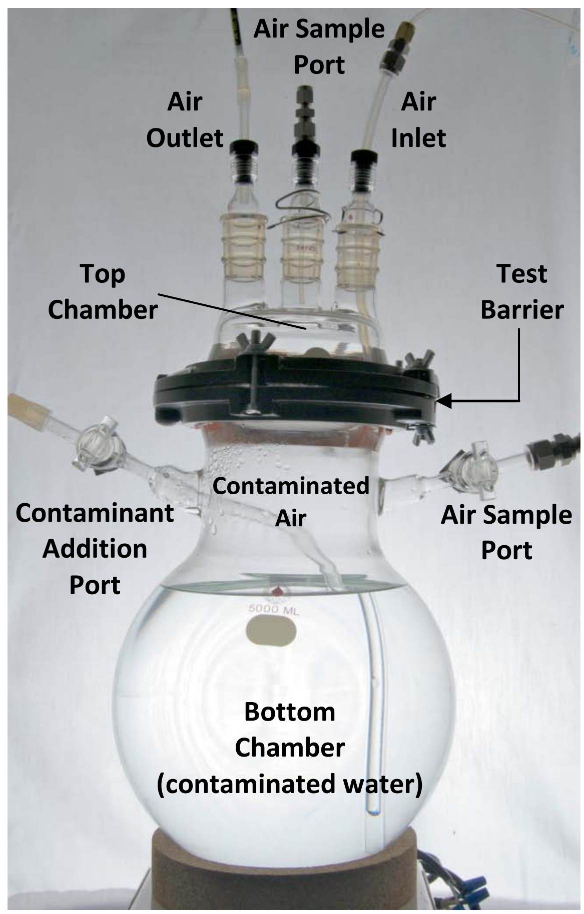

Figure 1. Chemical Resistance Testing Apparatus

carefully lifted off the glass. Six inch diameter circular samples of Retro-Coat were cut from the sheet. The thickness of each of the samples was tested at 13 points in a grid pattern. Two samples, one for each chamber, were selected with a target thickness of 20 mil.

<u>Chemical Permeation Experiments</u>: This experimental methodology establishes a contaminant vapor concentration in the lower chamber, then measures the transmission rate of that contaminant through the test sample into the upper chamber air, which is constantly exchanged at a fixed flow rate of 2.5 mL/min. This constant air exchange approximates the indoor air of a building being exchanged by an HVAC system. The permeation testing was run at a series of four target challenge concentrations for each contaminant: 500 ppmV, 250 ppmV, 125 ppmV, and 25 ppmV in the gas phase of the lower chambers. The vapor concentrations were established by spiking the water in the lower chamber with appropriate doses of contaminant followed by the natural equilibration of liquid and vapor phases. The sequence of tested concentrations was run in decreasing order from highest to lowest in order to ensure that for the final 3 concentrations the permeation rates started high and equilibrated down to their steady-state values. This is a conservative approach that ensures permeation and diffusion are not underestimated in the study results.

The bottom chambers were kept sealed for the duration of the experiments, in order to maintain desired contaminant levels for long durations. In order to emulate indoor air exchange as created by HVAC systems in typical buildings, the top chamber was continuously purged with high purity humidified air. The top chamber has a void volume of 400 mL. Humidified zero-air (HZA) was controlled by a mass flow controller (MFC) and continuously delivered to the upper chamber inlet port at 2.5 mL/min. The outlet port was vented to a chemical fume hood.

<u>Analytical Measurements</u>: Through the course of these studies, gas phase contaminant measurements were taken twice per day from both chambers for five days each week. The gas samples were taken by syringe and quantified by direct injection on an Agilent 5890 GC-ECD system.

Results and Discussion

Chemical resistance testing was carried out over four challenge concentration phases for each contaminant. A range of contaminant vapor concentrations from 500 ppmV down to 25 ppmV was targeted. Within each phase of the experiment after the challenge concentration stabilized near its target value, the top chamber vapor was monitored for four to eight weeks until its contaminant concentration had also stabilized. The total duration of these experiments was approximately 150 days, ensuring the data are representative of long term performance of the barrier. Actual challenge concentrations varied from the theoretical targets, but in general were very stable. Table 1 lists the targeted and actual vapor challenge concentrations for PCE and TCE for the individual test phases. Although in general the actual concentrations were slightly lower than targeted, the values were relatively stable over time and allowed for accurate calculation of permeation and diffusion rates.

Table 1. Targeted and actual challenge contaminant concentrations in lower chamber vapors

	Target [PCE] (ppmV)	Actual [PCE] (ppmV)	Target [TCE] (ppmV)	Actual [TCE] (ppmV)
Phase A	500	**444**	500	**446**
Phase B	250	**237**	250	**248**
Phase C	125	**95**	125	**103**
Phase D	25	**26**	25	**29**

Each testing phase was monitored until the permeating contaminant concentration in the upper chamber had stabilized for a 3-week period, at which time it was deemed to be at a steady-state condition. At that time, the next phase was initiated and the next challenge concentration was established in the lower chamber. As needed, contaminant was introduced to the water of the lower chamber by spiking (PCE or TCE in methanol) through the contaminant addition port (Figure 1) to establish close to target challenge concentrations.

Each contaminant data set resulted in time-averaged, steady-state contaminant concentrations for the lower chamber and the top chamber gases. The averaged contaminant concentrations for all phases of both experiments are listed in Table 2. Using these data and experimental apparatus parameters the chemical permeation rate, *J*, for each phase was calculated and also listed below.

Table 2. Contaminant data and calculated permeation rates for each phase in PCE and TCE experiments

	Challenge Concentration (ppmV)	Top Chamber Concentration (ppbV)	Permeation Rate ($\mu g\ cm^{-2}\ s^{-1}$)
	PCE		
Phase A	444	12.8	4.64E-08
Phase B	237	6.61	1.96E-08
Phase C	95.2	1.86	6.43E-09
Phase D	26.3	0.536	1.83E-09
	TCE		
Phase A	446	16.4	4.41E-08
Phase B	248	4.00	9.95E-09
Phase C	104	3.76	1.07E-08
Phase D	29.1	1.90	5.29E-09

Using the data in Table 2, a plot of permeation rate vs. challenge concentration was constructed for each contaminant. These plots are shown in Figures 2 and 3.

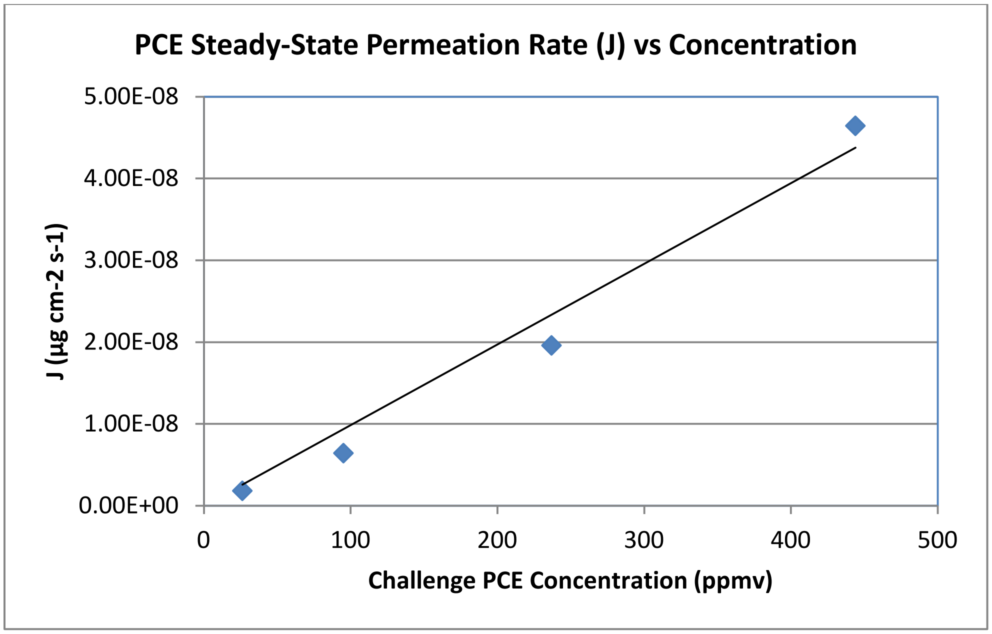

Figure 2. PCE permeation rate, *J*, vs. challenge concentration

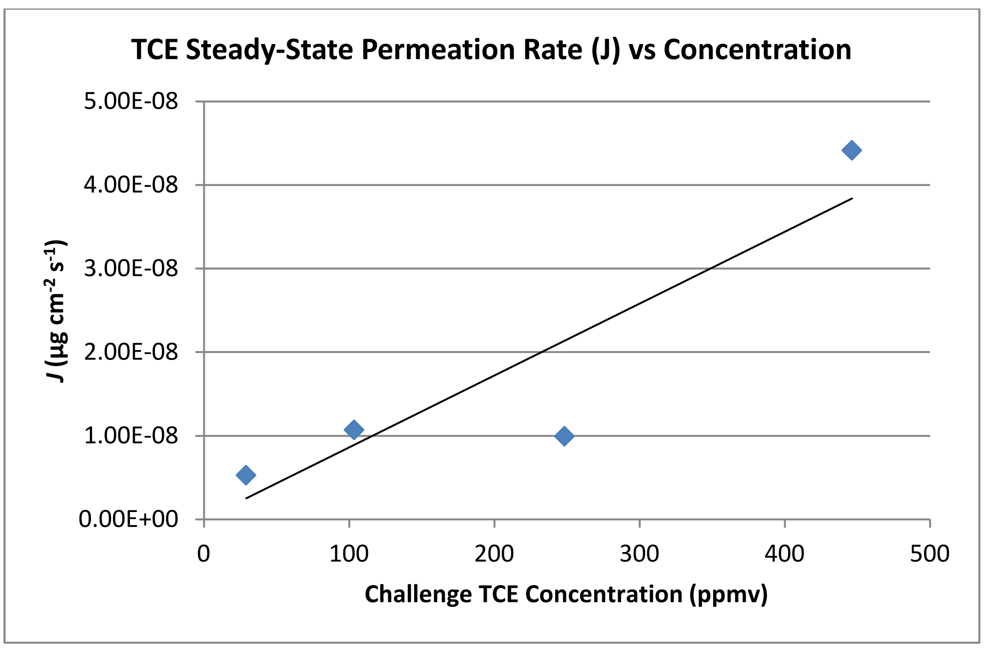

Figure 3. TCE permeation rate, J, vs. challenge concentration

Diffusion coefficients for each contaminant were calculated using the data in Table 2. and Fick's first law, which relates the chemical permeation rate (or diffusion flux), *J*, to the difference in contaminant concentration across the barrier (dC) and thickness of the barrier (dx, equation 1). For these calculations, dx = 20 mil, and dC is the difference in contaminant concentration across the membrane (challenge – permeate).

$$J = -D(dC/dx) \quad (1)$$

The experimentally-derived diffusion coefficients (D) for PCE and TCE in the Retro-Coat VI barrier are displayed in Table 3. These numbers indicate a very high degree of chemical resistance toward the tested VOCs. For comparison, Luber et. al reported diffusion coefficients of PCE and TCE in HDPE (high density polyethylene), material commonly used to line hazardous waste landfills, to be 7.8×10^{-11} m^2/s and 7.3×10^{-11} m^2/s respectively.[1,2] While these numbers were obtained using a different methodology (contaminated water rather than vapor) they are, nonetheless, three orders of magnitude larger than the diffusion coefficients determined for the Retro-Coat vapor intrusion barrier in this study.

Table 3. Sample thickness and diffusion coefficients

Contaminant	Retro-Coat Sample thickness in mil	Diffusion Coefficient (m^2/s)
PCE	20.48 ±3.06	**7.6×10^{-14}**
TCE	20.22 ±3.11	**8.2×10^{-14}**

Conclusions

New equipment and state of the art methods have been developed to test the chemical resistance of vapor intrusion barriers. The Retro-Coat vapor barrier was tested against the chemically aggressive chlorinated solvents PCE and TCE under a wide range of concentrations and found to be extremely chemically resistant. Diffusion coefficients of 7.6×10^{-14} and 8.2×10^{-14} m^2/s for PCE and TCE, respectively verify that this floor coating is very effective for blocking the flow of VOCs from contaminated sites into the building indoor air. This amount of protection corresponds to the coating providing a reduction factor of greater than one million fold for indoor air contamination compared with soil gas VOC levels.

This retrofit floor coating technology is the first of its type to be developed specifically for vapor intrusion mitigation. Its efficacy has been proven explicitly by technically rigorous vapor-phase contaminant diffusion studies that relate directly to common vapor intrusion scenarios. The test results reported here are conservative and very accurate, and should only be compared with diffusion coefficients derived under equally rigorous conditions. Future work in this area will include the study of other VOCs that are highly relevant to vapor intrusion problems, most notably benzene.

References

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2. Rowe, R.K., Hrapovic, L. and Kosaric, N., 1995, "Diffusion of Chloride and Dichloromethane Through an HDPE Geomembrane", *Geosynthetics International*, Vol. 2, No. 3, pp. 507-536.