# PROTECTING SEVERE WASTEWATER STRUCTURES

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**SGA Coating Consultants**

**Tnemec Company, Inc.**

TNEMEC

# The Problem:

Deterioration of wastewater infrastructure. Traditional protective coatings not offering necessary protection.

# VAPOR PHASE ATTACK

Collection: manholes

biogenic sulfide corrosion

# VAPOR PHASE ATTACK

Collection: lift stations

biogenic sulfide corrosion

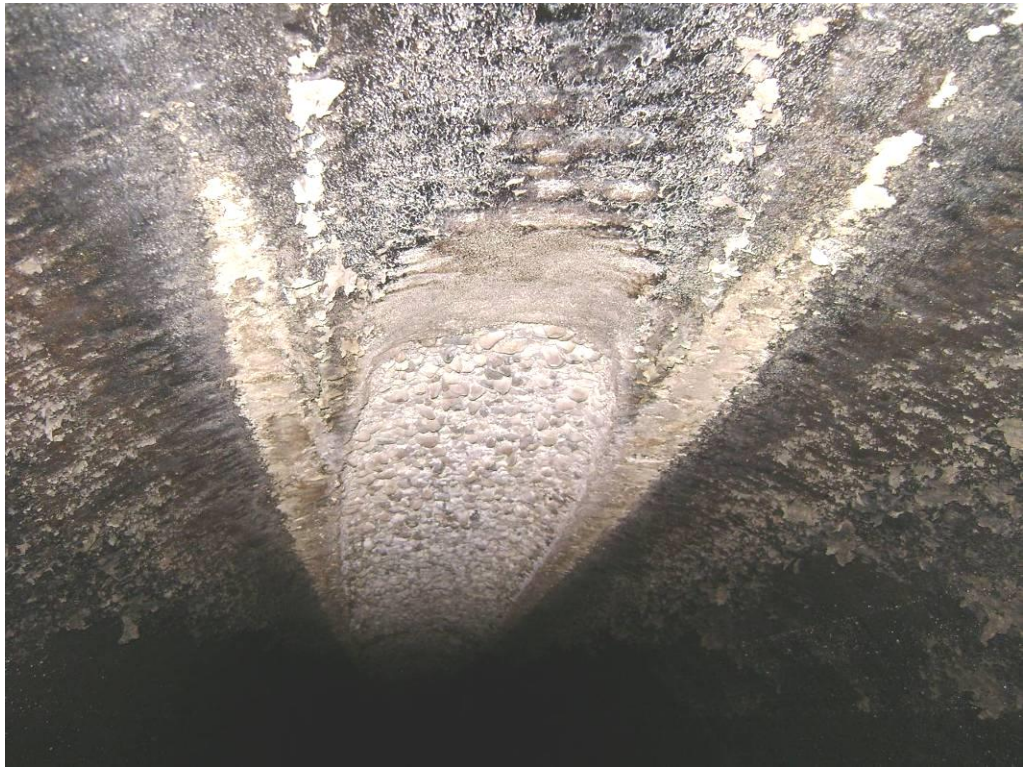
# VAPOR PHASE ATTACK

Collection: lift stations

biogenic sulfide corrosion

# VAPOR PHASE ATTACK

Collection: interceptors



biogenic sulfide corrosion

# VAPOR PHASE ATTACK

Treatment: influent channels


biogenic sulfide corrosion

# VAPOR PHASE ATTACK

Treatment: junction boxes

biogenic sulfide corrosion

# LIQUID PHASE ATTACK

Treatment: primary

aluminum sulfate exposure

# LIQUID PHASE ATTACK

Treatment: primary

ferric chloride exposure

# LIQUID PHASE ATTACK

Treatment: primary

chloride induced corrosion

# LIQUID PHASE ATTACK

*Example:* Brewery process wastewater

# LIQIUD PHASE ATTACK

*Example:* Secondary Containment (acid) Exposure

# LIQUID PHASE ATTACK

*Example:* Secondary Containment (acid) Exposure

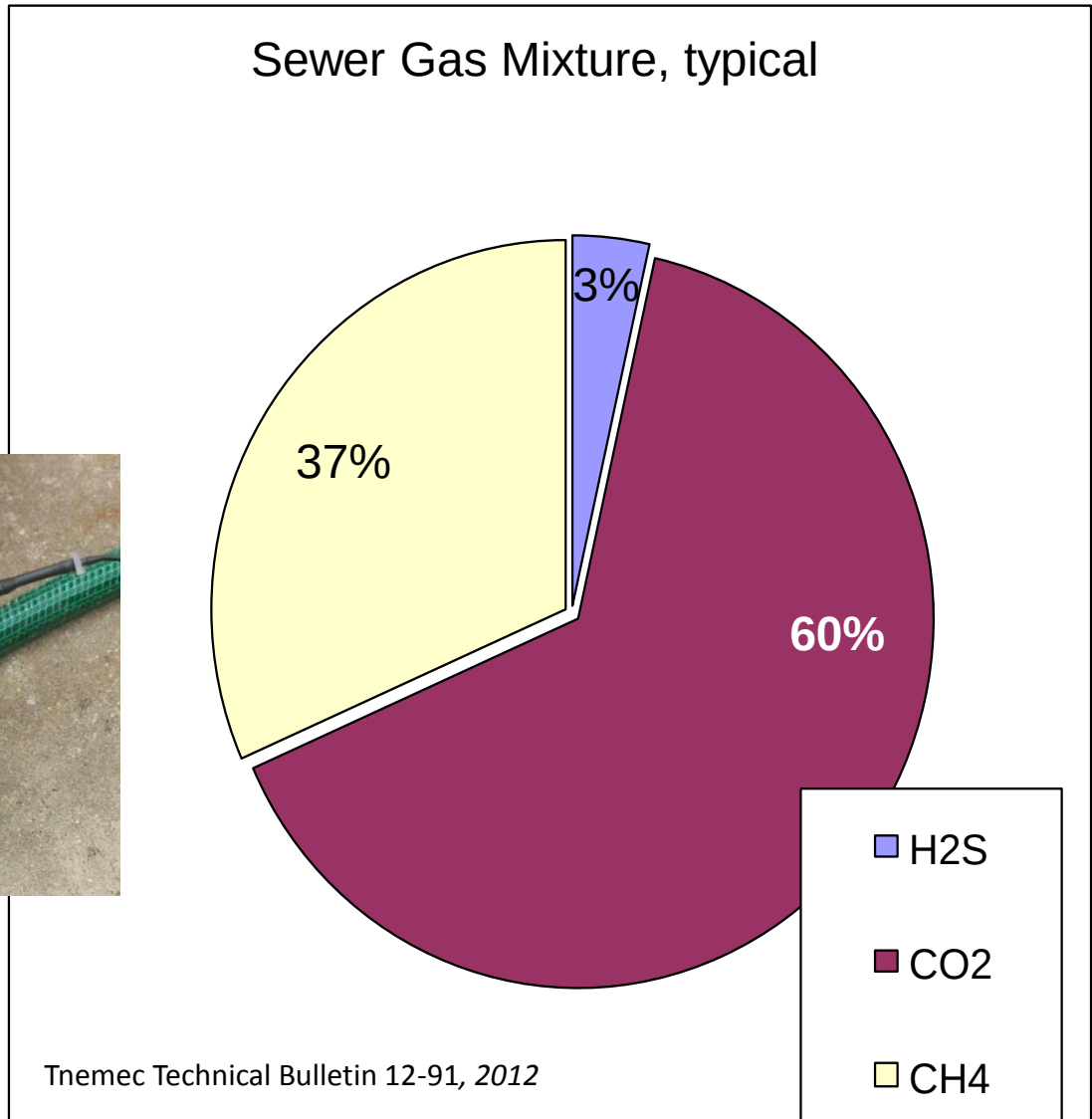
# Technical Reasons for Attack:

- Concrete is a mixture of portland or blend of cement, fine and coarse aggregates, water, and one or more admixtures.
- Freshly cast concrete has pH >12
  - High pH = result of formation of calcium hydroxide by-product of hydration
  - Surface will not allow growth of any bacteria
- Exposure to acids with pH below 6.5 will attack most cementitious materials and below pH 4 all types will be attacked.
- Acid solutions can be naturally occurring or manmade
  - Decayed organic matter (biogenic sulfide corrosion)
  - Treatment chemicals or manufactured inorganic acids

# SEVERE WASTEWATER ENVIRONMENTS

Sewer Gas Mixture

- Hydrogen sulfide ($H_2S$)
- Carbon dioxide ($CO_2$)
- Methane ($CH_4$)

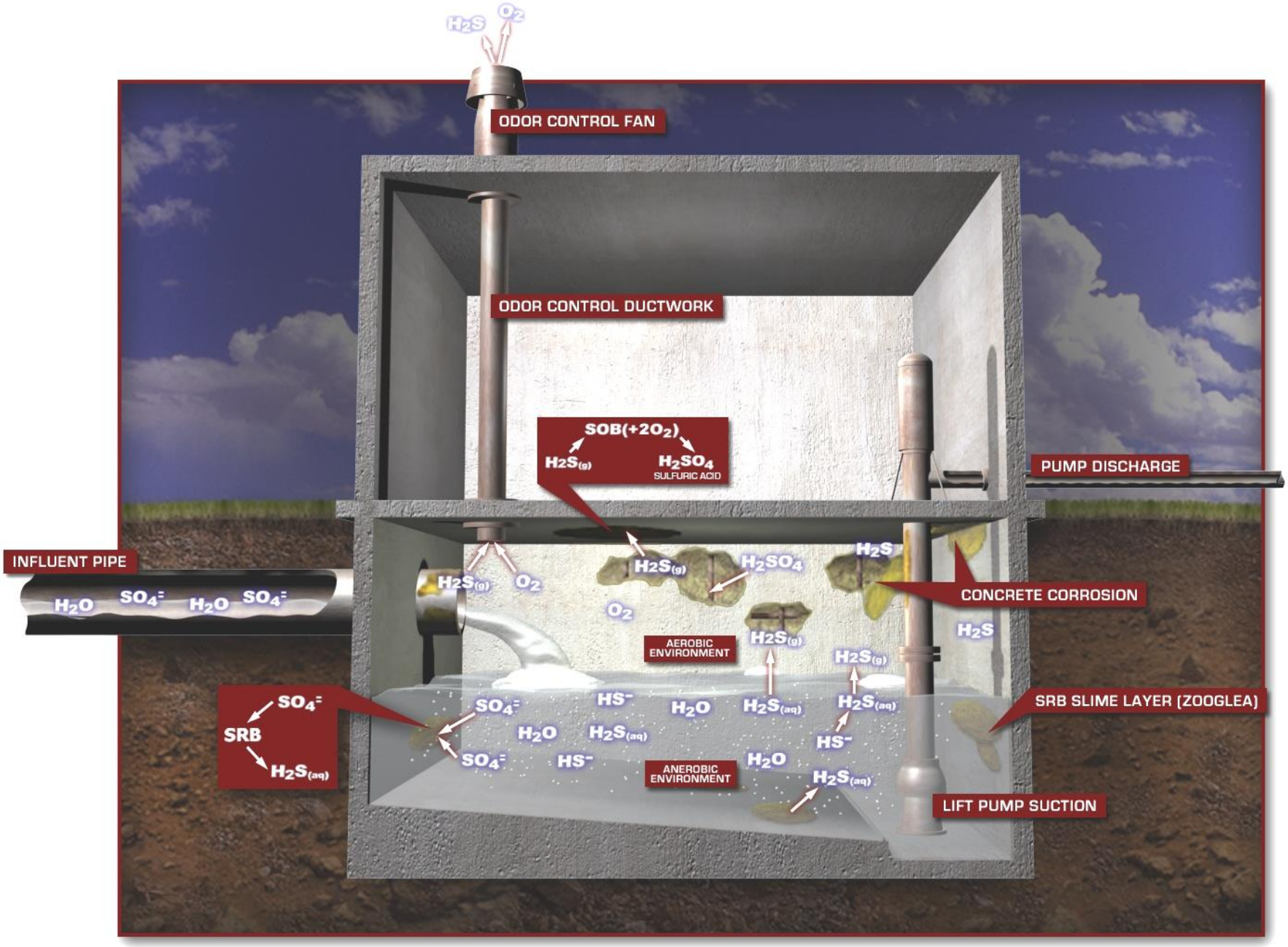

Tnemec Technical Bulletin 12-91, *2012*

# CONCRETE ATTACK

- Biogenic Sulfide Corrosion:
  - Biological oxidation of $H_2S$ to $H_2SO_4$ within headspace areas of enclosed wastewater structures

$$H_2S + 2O_2 \xrightarrow{\textit{Thiobacillus}\ \text{SOB}} H_2SO_4$$

  - $H_2SO_4$ attacks the matrix of the concrete above the waterline *(i.e., pipe crowns, walls, soffits)*




*biogenic sulfide corrosion process illustration*

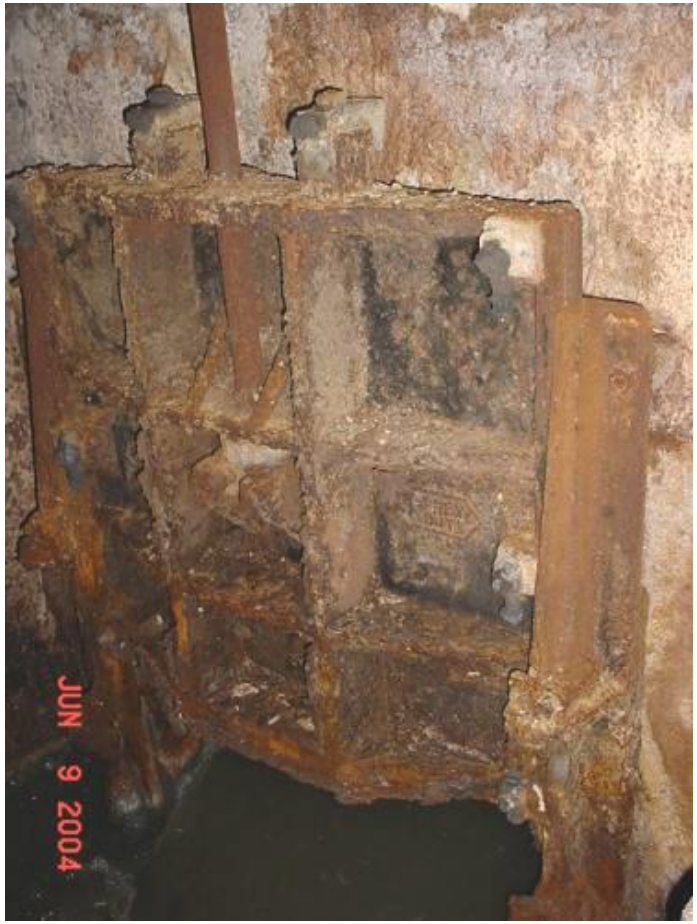
# SEVERE WASTEWATER ENVIRONMENTS

## Contributing Factors

- Removal of heavy metals from waste stream
- Longer detention times
- Higher strength wastewater (in terms of elevated biochemical oxygen demand, e.g.BOD)
- More turbulence in collection system
- Utilization of odor control covers
- Over-designed wet wells for future capacities

# METAL CORROSION

## Vapor Phase Corrosion




Metallic appurtenances in lift station

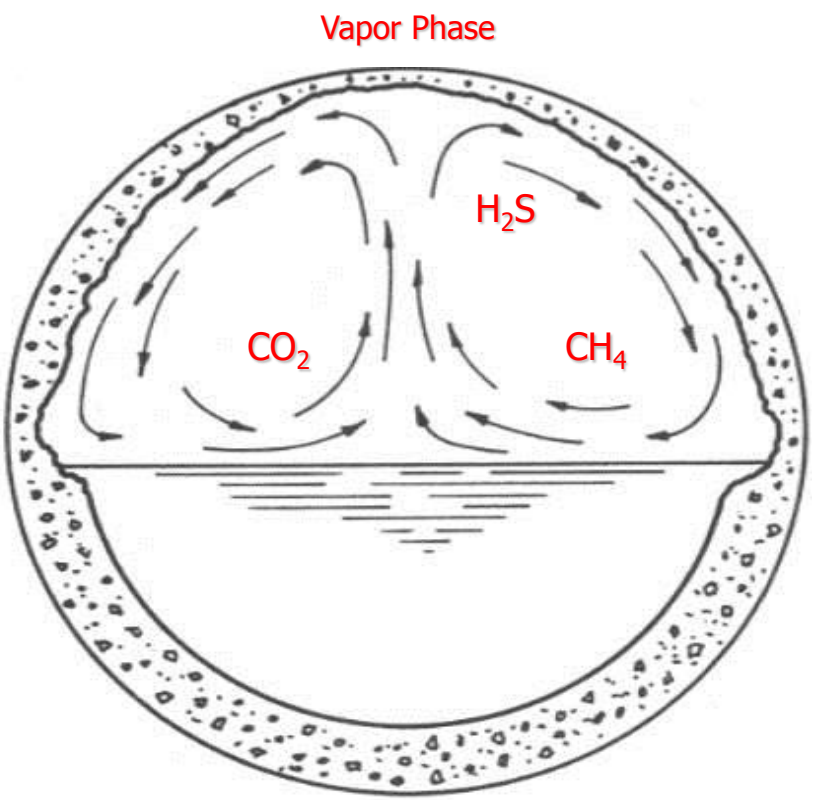
# METAL CORROSION

## Vapor Phase Corrosion

metallic surfaces in covered primary clarifier

# METAL CORROSION

## Vapor Phase Corrosion



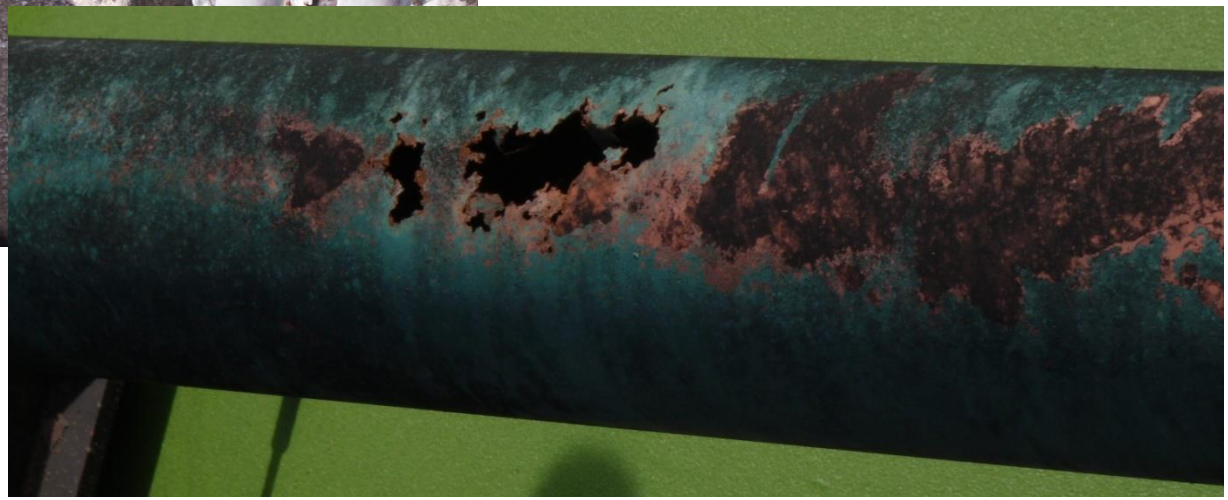

# METAL CORROSION

## Vapor Phase Corrosion

ductile iron pipe

# METAL CORROSION

## Vapor Phase Corrosion



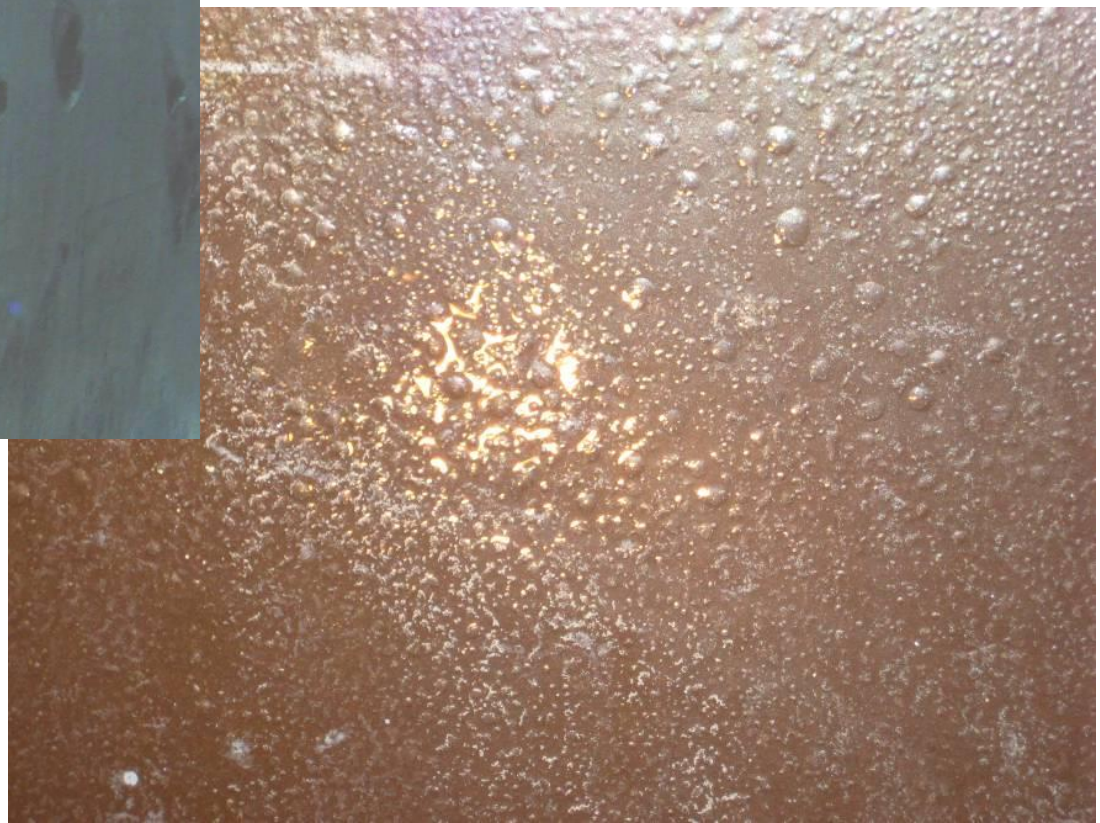
# METAL CORROSION

## Liquid Phase Corrosion

# Not All Protective Coatings Perform:

Many high-performance protective coatings (linings) insufficiently perform in wastewater vapor phase environments

# COATING FAILURES



*coal tar epoxy*

# COATING FAILURES

***Coal tar epoxy***

# COATING FAILURES

***Polyamide epoxy***

# COATING FAILURES


***Ceramic novolac epoxy on ductile iron pipe***

# COATING FAILURES

*polyurea elastomer*

# SEVERE WASTEWATER ANALYSIS TEST

- Developed by a coalition of industry experts to create an accelerated laboratory testing program to measure a coating's resistance to severe wastewater headspace conditions.
- Simulates & accelerates conditions characteristic of severe wastewater headspace environments
  - Eliminates the long periods of time during normal wastewater exposure
  - Introduced at WEFTEC 2003 (Water Environment Federation Technical Exhibition & Conference)
  - Presented at PACE 2008 (Paint And Coatings Exposition)
  - Presented at UCT 2010 Conference (Underground Construction Technology)
  - Submitted to ASTM 2011; Standard Practice expected 2013.
  - Received NACE International's MP Reader's Choice *Corrosion Innovation Award 2012*.

# SEVERE WASTEWATER ANALYSIS TEST, cont'd

- Measures the permeation and physical alterations of a protective lining in a period of 28-days
- Allows for quantitative evaluation of protective systems
- Commercially offered:
  1. **RAE Engineering & Inspection, LTD**

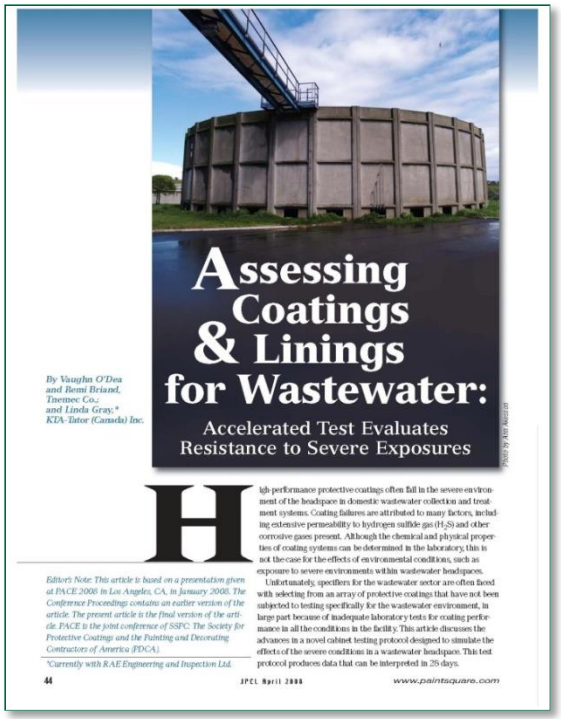
     www.RAEEngineering.ca
  2. **Corrosion Testing Laboratories, Inc.**

     www.CorrosionLab.com
  3. **KTA-Tator, Inc.**

     www.KTA.com

# SEVERE WASTEWATER ANALYSIS TEST, cont'd

- The vapor phase is novel compared to "acid contact" laboratory testing regimens oftentimes used or referenced by the wastewater industry.
- Topic of numerous technical articles and presentations.



Assessing Coatings & Linings for Wastewater:

Accelerated Test Evaluates Resistance to Severe Exposures

By Vaughn O'Dea and Remi Briand, Tnemec Co.; and Linda Gray,* KTA-Tator (Canada) Inc.

High-performance protective coatings often fail in the severe environment of the headspace in domestic wastewater collection and treatment systems. Coating failures are attributed to many factors, including extensive permeability to hydrogen sulfide gas ($H_2S$) and other corrosive gases present. Although the chemical and physical properties of coating systems can be determined in the laboratory, this is not the case for the effects of environmental conditions, such as exposure to severe environments within wastewater headspaces.

Unfortunately, specifiers for the wastewater sector are often faced with selecting from an array of protective coatings that have not been subjected to testing specifically for the wastewater environment, in large part because of inadequate laboratory tests for coating performance in all the conditions in the facility. This article discusses the advances in a novel cabinet testing protocol designed to simulate the effects of the severe conditions in a wastewater headspace. This test protocol produces data that can be interpreted in 28 days.

Editor's Note: This article is based on a presentation given at PACE 2008 in Los Angeles, CA, in January 2008. The Conference Proceedings contains an earlier version of the article. The present article is the final version of the article. PACE is the joint conference of SSPC: The Society for Protective Coatings and the Painting and Decorating Contractors of America (PDCA).

*Currently with RAE Engineering and Inspection Ltd.

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A NOVEL ANALYTICAL APPROACH FOR EVALUATING PROTECTIVE COATINGS PERFORMANCE IN WASTEWATER ENVIRONMENTS

Rémi Briand[1] and Randy Nixon[2]

*Tnemec Company, Inc., Kansas City, MO, USA,[1] and Corrosion Probe, Inc., Centerbrook, CT, USA[2]*

WEFTEC 2003

ABSTRACT

Municipal wastewater collection and treatment systems have historically had corrosive conditions in the aerated headspaces of concrete and metal structures. This biogenic sulfide corrosion has become more severe in recent years due to longer detention times, increased usage of force mains, industrial pretreatment for metals removal and the covering of tanks and channels for odor control purposes. Protective coatings that performed well in wastewater headspaces in the past have repeatedly failed under these newer and more severe exposure conditions. Failure analysis experience has shown that the performance of coatings in these more aggressive environments is closely related to permeability properties. Low permeability of coatings and linings to the corrosive gases and liquids present in the wastewater vapor phase has been shown to substantially increase coating performance.

Evaluating coatings that will provide the right barrier properties for long-term performance is currently based on in-service performance histories. This takes too much time for new coating formulations. Until recently, no existing laboratory test methods were available to more expeditiously evaluate coating performance for these newer, more aggressive conditions.

Tnemec Company, in collaboration with partners, established a testing project team and decided to develop a novel approach to accelerated laboratory testing for evaluation of coating performance in simulated wastewater headspace conditions. These coatings with superior barrier properties, combined with excellent substrate adhesion, are expected to offer the best performance.

A unique laboratory test chamber was designed and built to simulate the contributing exposure conditions pertinent to coating permeability and chemical resistance. Electro-chemical impedance spectroscopy is being used to monitor and evaluate the barrier and permeability properties of coating systems exposed to these replicated conditions.

A companion field test program is also been underway at the Deer Island Treatment Plant in Boston, Massachusetts. All coatings tested in the laboratory cabinet have also been exposed to real treatment plant exposure conditions, including intermittently high $H_2S$ gas concentrations.

This paper describes the simulated exposure conditions and the accelerated parameter capabilities of the cabinet. It further discusses the learnings from nearly two years of laboratory test results.

WEFTEC® 03

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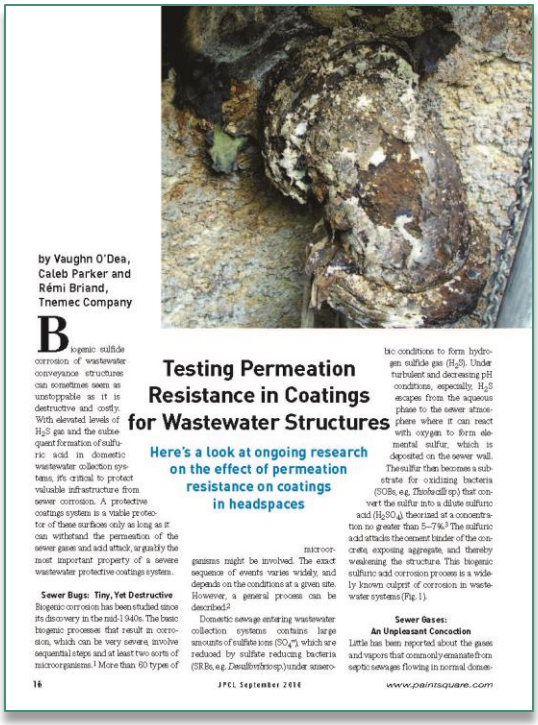

by Vaughn O'Dea, Caleb Parker and Rémi Briand, Tnemec Company

Testing Permeation Resistance in Coatings for Wastewater Structures

Here's a look at ongoing research on the effect of permeation resistance on coatings in headspaces

Biogenic sulfide corrosion of wastewater conveyance structures can sometimes seem as unstoppable as it is destructive and costly. With elevated levels of $H_2S$ gas and the subsequent formation of sulfuric acid in domestic wastewater collection systems, it's critical to protect valuable infrastructure from sewer corrosion. A protective coatings system is a viable protector of these surfaces only as long as it can withstand the permeation of the sewer gases and acid attack, arguably the most important property of a severe wastewater protective coatings system.

Sewer Bugs: Tiny, Yet Destructive

Biogenic corrosion has been studied since its discovery in the mid-1940s. The basic biogenic processes that result in corrosion, which can be very severe, involve sequential steps and at least two sorts of microorganisms.[1] More than 60 types of microorganisms might be involved. The exact sequence of events varies widely, and depends on the conditions at a given site. However, a general process can be described.[2]

Domestic sewage entering wastewater collection systems contains large amounts of sulfate ions ($SO_4^{2-}$), which are reduced by sulfate reducing bacteria (SRBs, e.g. *Desulfovibrio* sp.) under anaerobic conditions to form hydrogen sulfide gas ($H_2S$). Under turbulent and decreasing pH conditions, especially, $H_2S$ escapes from the aqueous phase to the sewer atmosphere where it can react with oxygen to form elemental sulfur, which is deposited on the sewer wall. The sulfur then becomes a substrate for oxidizing bacteria (SOBs, e.g. *Thiobacilli* sp.) that convert the sulfur into a dilute sulfuric acid ($H_2SO_4$), theorized at a concentration no greater than 5–7%.[3] The sulfuric acid attacks the cement binder of the concrete, exposing aggregate, and thereby weakening the structure. This biogenic sulfuric acid corrosion process is a widely known culprit of corrosion in wastewater systems (Fig. 1).

Sewer Gases: An Unpleasant Concoction

Little has been reported about the gases and vapors that commonly emanate from septic sewages flowing in normal domes-

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# SEVERE WASTEWATER ANALYSIS TEST, cont'd

- NACE Corrosion Innovation of the Year 2012 Award
- ASTM G210-13

# SEVERE WASTEWATER ANALYSIS TEST, cont'd

## TESTING PARAMETERS

## Laboratory Chamber Comprising:

1. Liquid Phase
2. Vapor Phase

*S.W.A.T. Chamber*

# SEVERE WASTEWATER ANALYSIS TEST

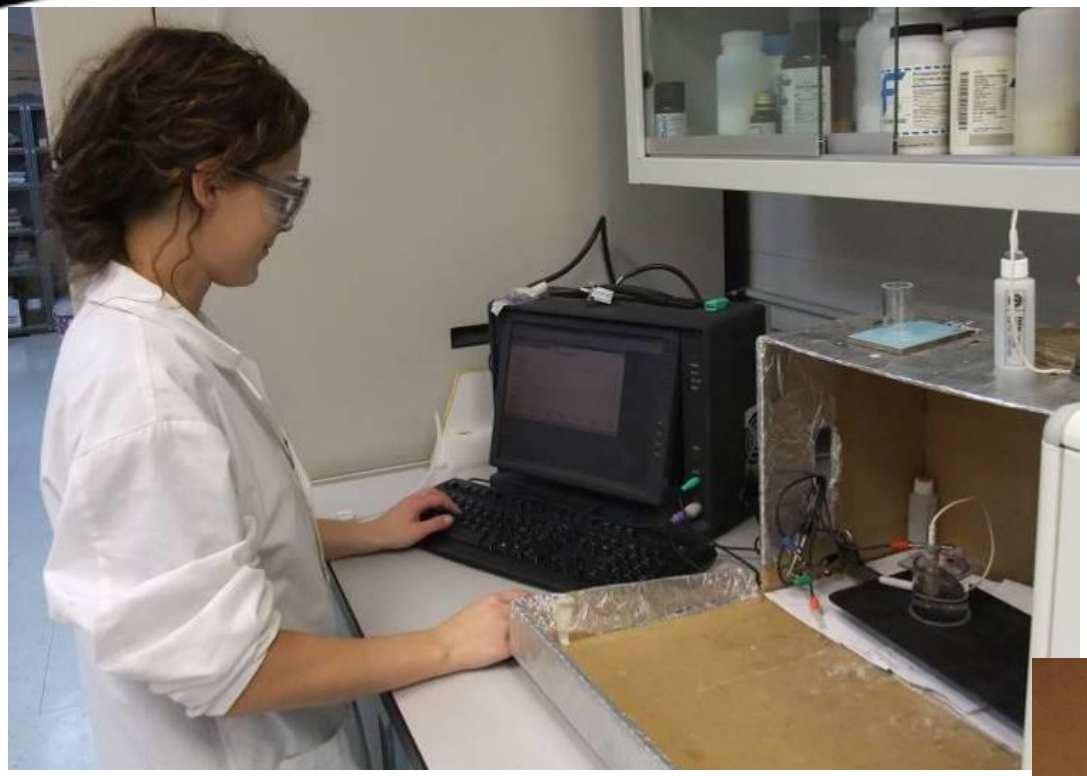
TESTING PROCEDURE, *cont.*

A. Permeability

- Coatings act as a barrier separating the substrate from the corrosive service environment
- Low permeability to salts, water, gases, acids and other corrosive species are desired

- Measured via:

1. Electrochemical Impedance Spectroscopy (EIS) Analysis
2. Optical Microscopy Measurements



*Electrochemical Impedance Spectroscopy Analysis*

# SEVERE WASTEWATER ANALYSIS TEST, cont'd

*Increasing Protection* →

| Poor | **Protection Begins** | Good | Excellent |
|---|---|---|---|
| ↓ | ↓ | ↓ | ↓ |

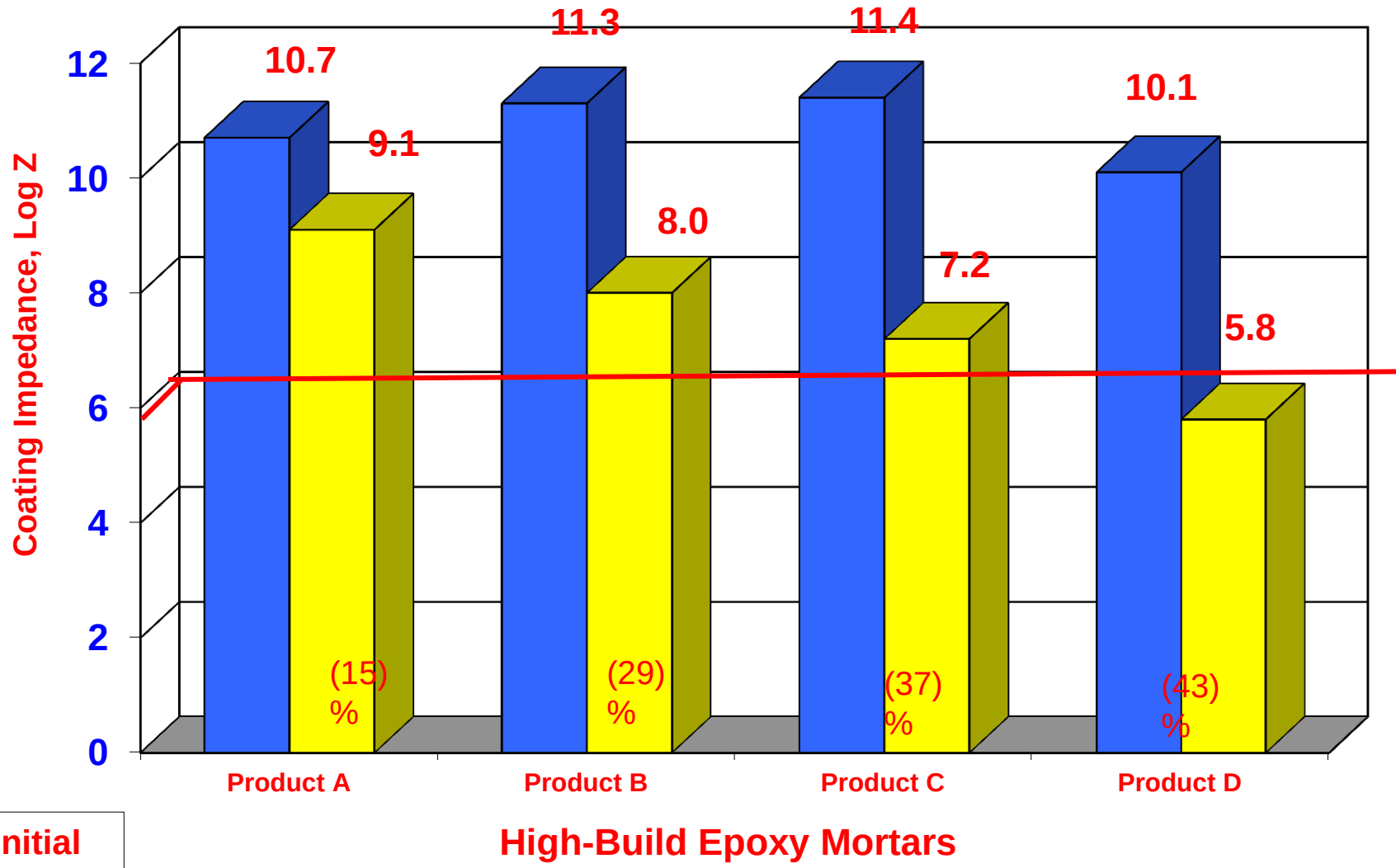
4 6 8 10

Coating Impedance, Log Z ($Z_{0.1\ Hz}$ Ω-cm$^2$)

Source: Gray, Linda "EIS: A Tool to Predict Remaining Coating Life," JPCL, February 2003.

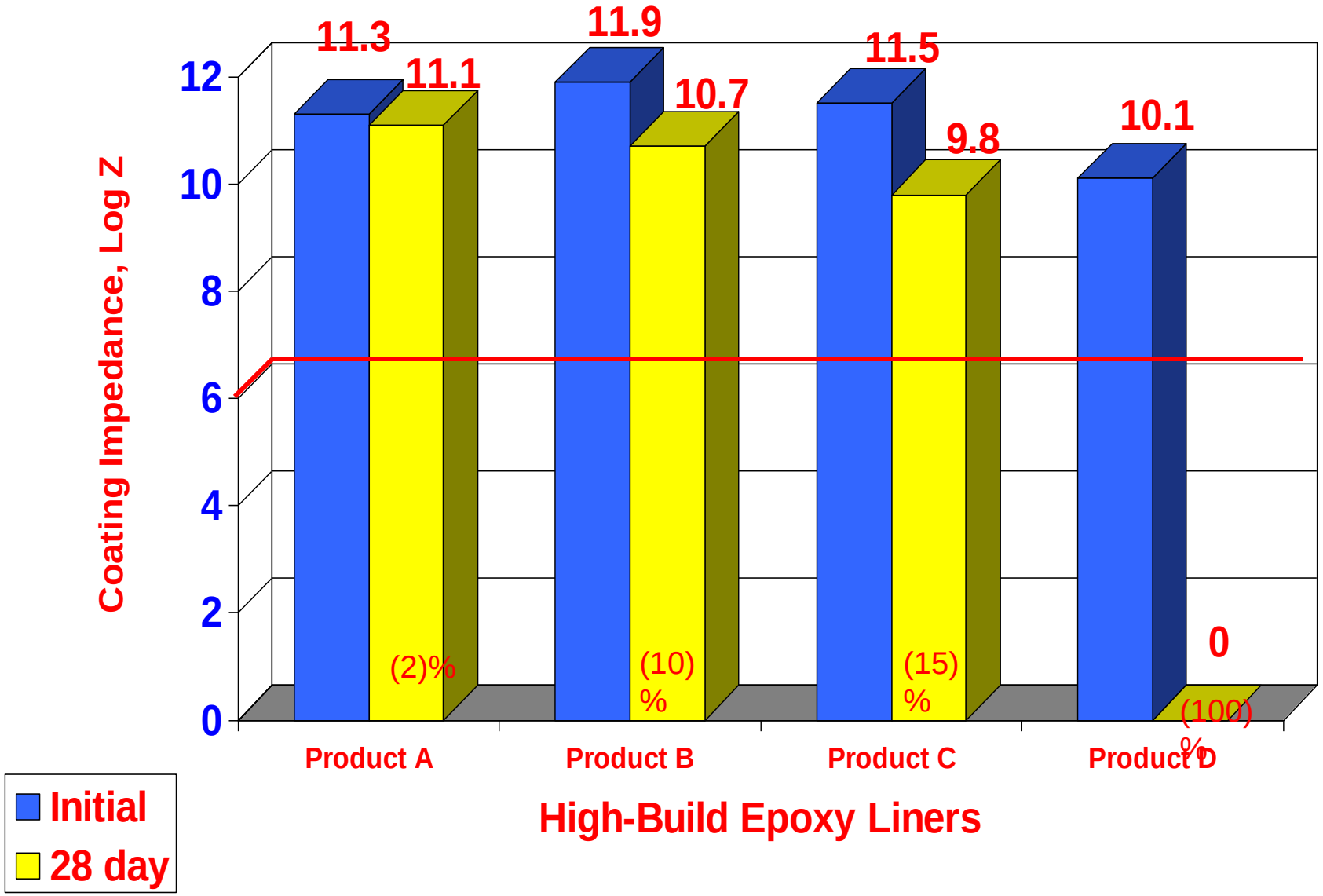
# SEVERE WASTEATER ANALYSIS TEST (S.W.A.T):

## EIS Analysis



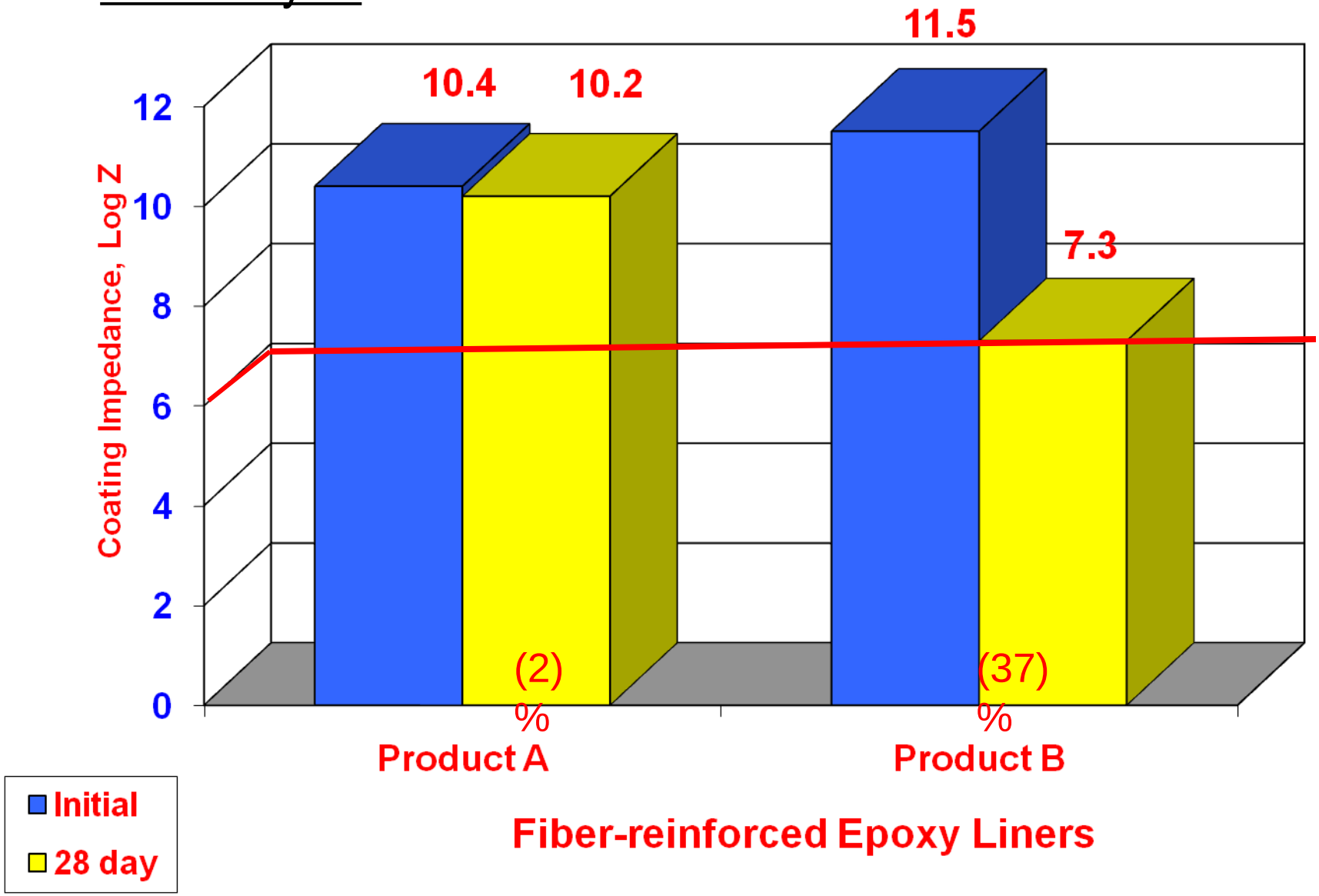
# SEVERE WASTEATER ANALYSIS TEST (S.W.A.T):

## EIS Analysis



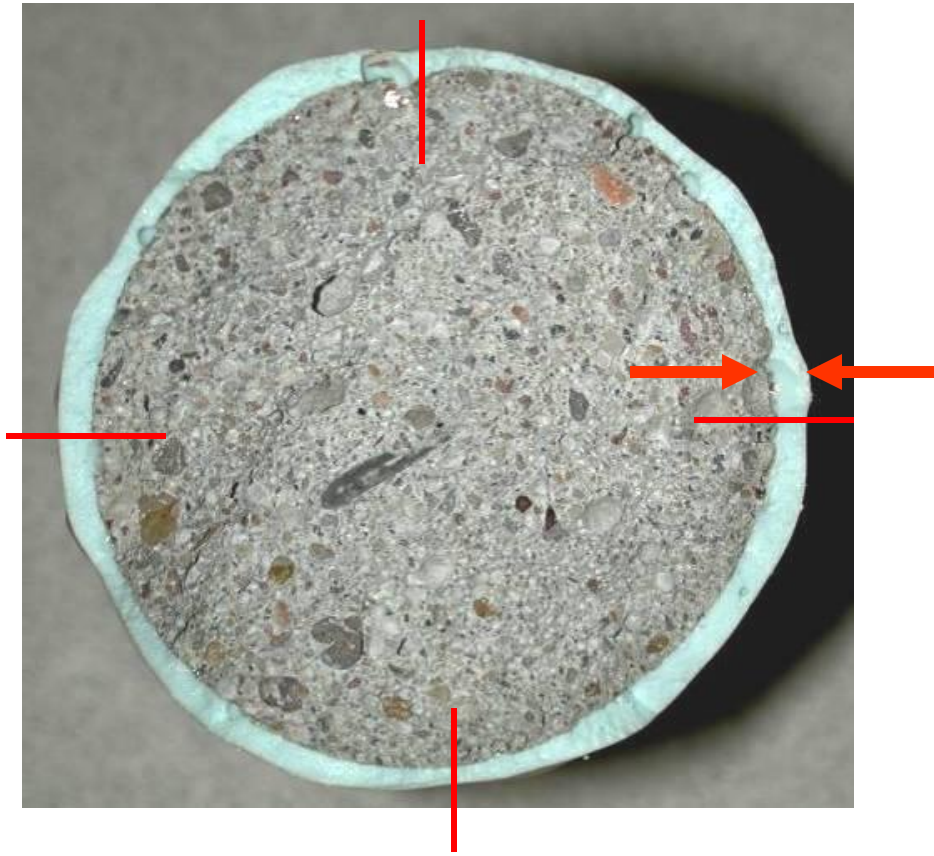
# SEVERE WASTEATER ANALYSIS TEST (S.W.A.T):

## EIS Analysis



# OPTICAL MICROSCOPY ANALYSIS


Typical concrete cylinder coated with candidate systems

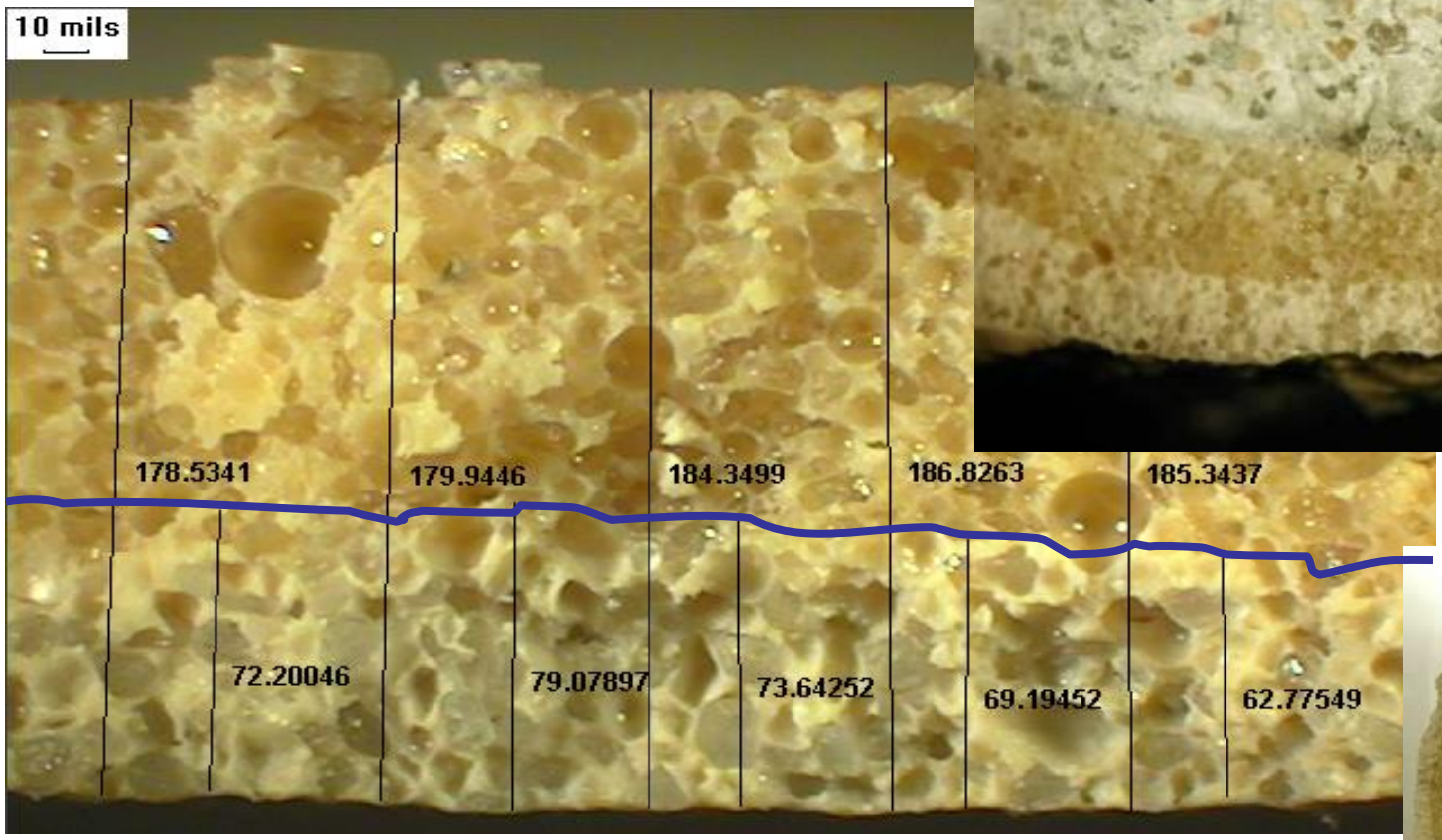


Concrete cylinder cross section

*N.T.S.*

# OPTICAL MICROSCOPICY ANALYSIS, *cont.*

## 100% Solids Epoxy Mortar




<u>Observation:</u>

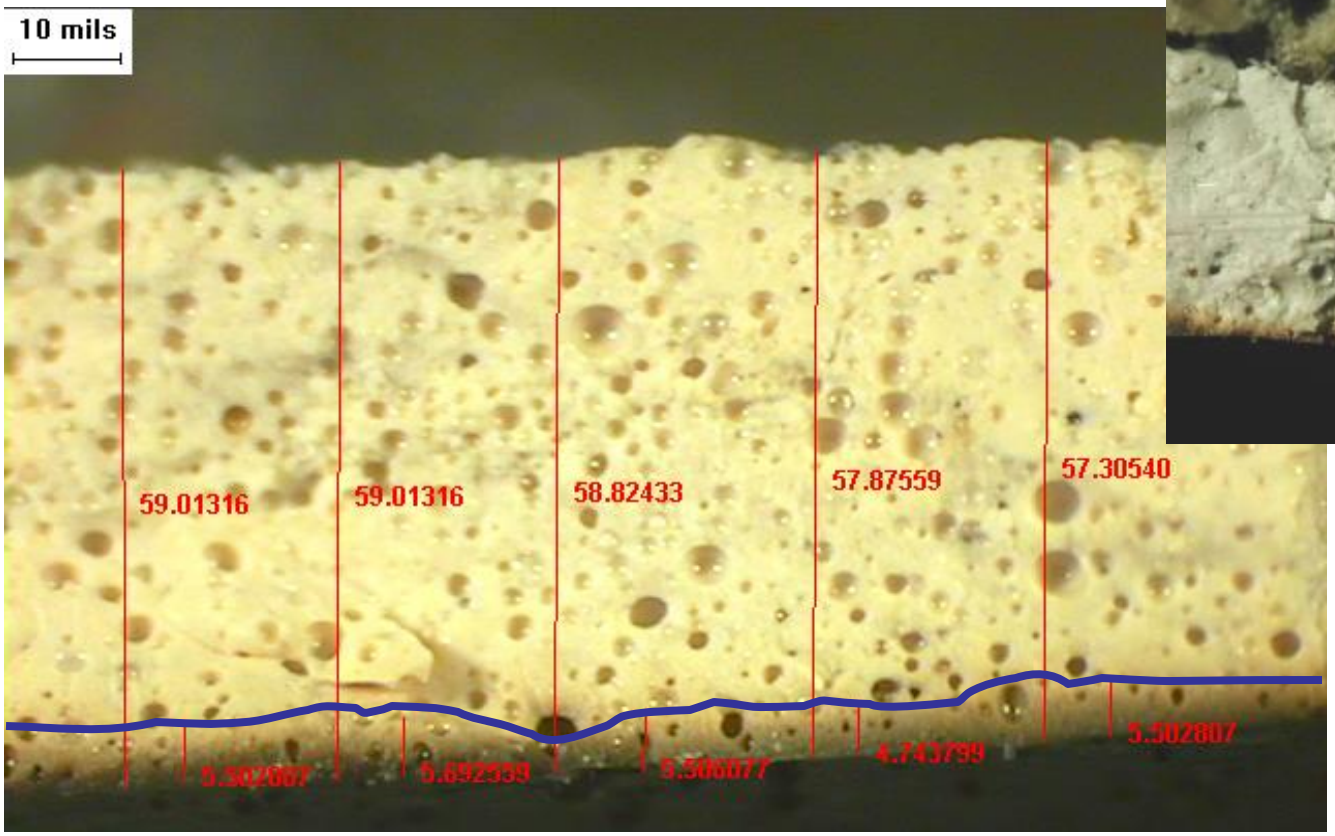
Total DFT 183 dft mils (avg.)

Permeation: 71 mils (avg.)

**Permeation: 39%**

# OPTICAL MICROSCOPICY ANALYSIS, *cont.*

## 100% Solids Epoxy Liner




Observation:

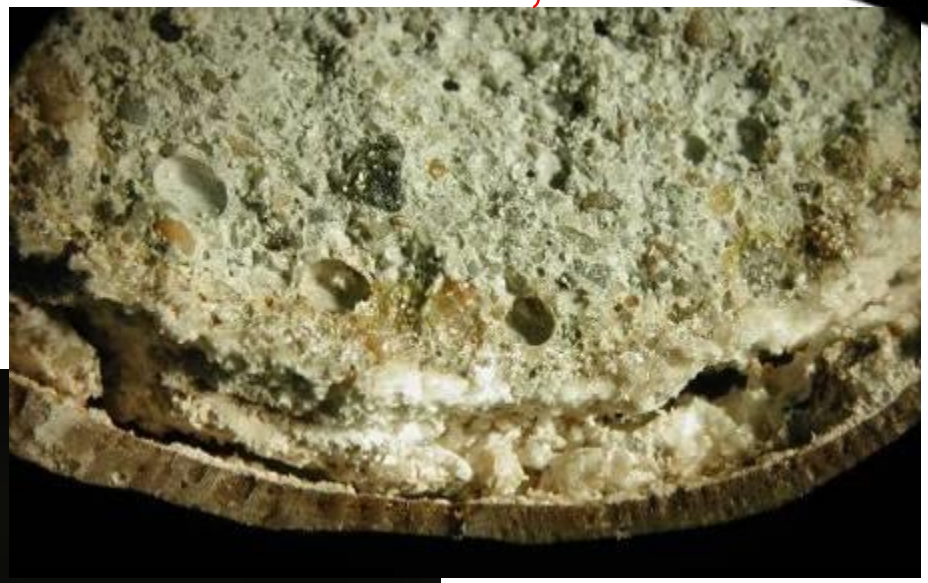
Total DFT: 59 dft mils (avg.)

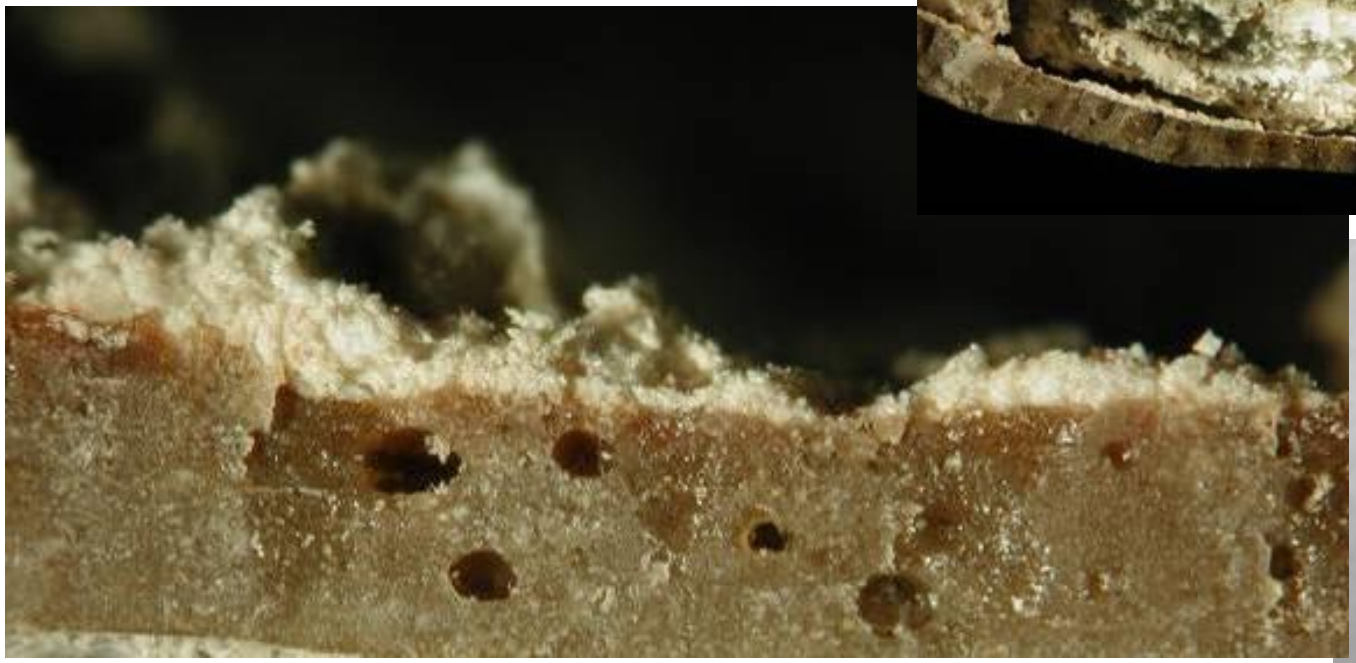
Permeation: 5.5 mils (avg.)

**Permeation: 9%**

# OPTICAL MICROSCOPICY ANALYSIS, *cont.*

100% Solids Epoxy Liner





<u>Observation:</u>

-Not attempted

**Permeation: 100%**

# SEVERE WASTEWATER ANALYSIS TEST

TESTING PROCEDURE, *cont.*

B. Physical Testing

- Any physical effects on the lining system are useful in detecting any significant changes a polymer may undergo as a result of exposure

- Commonly used laboratory tests to measure physical properties:
  - Tensile Strength Testing
  - Flexural Strength Testing
  - Adhesion Testing

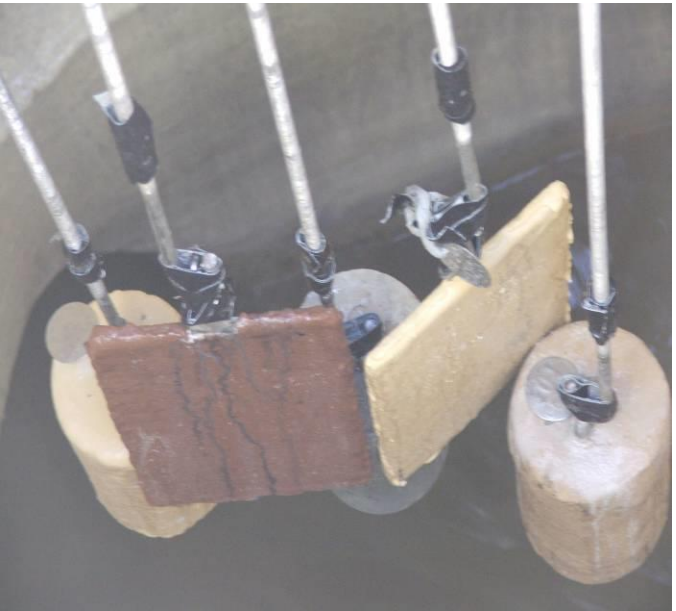
# FIELD TESTING

- Typical testing sites

*Field Racks & Permeation Samples, typical*

# FIELD TESTING, cont.

- Candidate coating systems
  - Concrete panels
  - Steel panels
- Concrete control panels

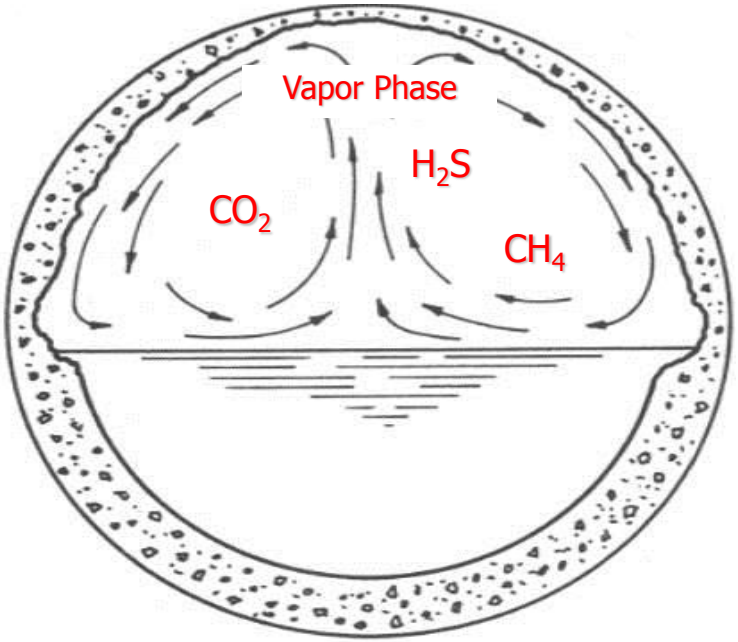




# The Solution:

Perma-Shield®

An advanced generation, 100% solids epoxy coating with low permeation to sewer gases.



Employing a hydraulic pump to spray transfer material onto surface

# Why Use High-Performance Protective Systems?

# PROTECTING CONCRETE

High-Performance Protective Coatings are commonly employed to protect concrete:

- Provide a surface that is resistant to immersion, splashes, spills, and vapors from corrosive solutions
  - Acid attack
  - Alkali attack
  - Sulfates
- Protect structural rebar from corrosion
  - Chlorides
- Protect and enhance concrete integrity
  - Mechanical damage and wear

# Trowel-Applied Epoxy

## Epoxy Modified Mortar

- 100% volume solids, modified amine epoxy mortar for severe wastewater environments
- Concrete: 1/8 inch (125 mils) minimum
- Trowel applied (or spray transferred)
- Conducive for “tight” areas
- Optional: Series 435 Perma-Glaze for added protection
  - 15-20 mils

Applying Mortar onto surface using hydraulic transfer equipment.

Back-troweling Mortar

Backrolling using to level trowel licks

*Example of finished Series 218/434/435 Perma-Shield system*

# Spray-Applied, Fiber-Reinforced Epoxy

## Fiber Reinforced Epoxy

- 100% volume solids, fiber-reinforced, high-build, spray-applied epoxy lining for severe wastewater environments
- Concrete: 50-125 mils
- Conducive for large areas
  - Wet wells, primary clarifiers, etc.
- Optional: Epoxy Glaze Finish for added protection
  - 15-20 mils

# Fiber Reinforced Epoxy Liner


*FR high-build liner applications*

*Epoxy Mortar followed by*

*Fiber-reinforced epoxy*

# Fiber Reinforced Epoxy

# KEYS To Coatings Success

- Permeation resistance to sewer gases
- Adequate physical properties
- Chemical resistance

1. Trowel-applied epoxy mortar
2. Spray-applied epoxy liner
   - Resinous epoxy
   - Fiber-reinforced epoxy

# High Performance Lining

Collection Systems

*manholes*

# High Performance Lining

## Collection Systems

*lift stations*

# High Performance Lining

## Wastewater Treatment

*Influent Channels*

# HIGH-PERFORMANCE LININGS

## Wastewater Treatment

*Screening ("headworks") Structures*

# High Performance Lining

## Wastewater Treatment

*Equalization Basins*

# HIGH-PERFORMANCE LININGS

## Wastewater Treatment

*(before/after)*

*Primary clarifier effluent channels*

# PERMA-SHIELD

## Wastewater Treatment


*Covered Primary Clarifiers*