TNEMEC

SUBJECT

A Novel Approach for Evaluating Protective Coatings Performance in Wastewater Environments

GENERAL

THE WASTEWATER MARKET PRODUCT INITIATIVE

In 1999, Tnemec Company embarked on a new wastewater product initiative to develop superior coatings for the barrier protection of concrete and metallic substrates exposed to high hydrogen sulfide gas exposure conditions in wastewater collection and treatment structures. The impetus for this R&D program was the awareness that products used successfully in the past were no longer performing as well under wastewater exposure conditions. In particular, amine-cured coal tar epoxy and standard epoxy products (e.g., polyamides), the longtime workhorse products of the wastewater industry, were prematurely failing. This awareness drove Tnemec to more carefully assess the associated coating failure mechanisms and the process changes responsible for more severe exposure conditions. This assessment effort, including consultation with experts in wastewater corrosion, yielded the following:

A. Most premature coating failures were associated with blistering combined with substrate chemical attack or corrosion.

B. Exposure conditions in the headspaces of wastewater structures have become more severe. Specifically, hydrogen sulfide gas concentrations have increased in the aerated vapor phase of sewer pipes, tanks, manhole chambers, and other structures. This increase, in turn, resulted in greater sulfuric acid generation by sulfur oxidizing bacteria, always present in the headspaces. The end result was higher sulfuric acid and acidic gas concentrations and more constant sulfuric acid formation. As the concentration of these chemicals increased, the performance of the old workhorse coatings technology became unacceptable; their life expectancy reduced from several years to a few months.

Although sulfuric acid concentrations increased somewhat, this was not sufficient to cause the blistering failures observed in several of the older amine cured epoxy formulations. The blistering mode of failure attracted our interest in the higher H2S gas concentrations known to be present. It is well known that gas and liquid molecules travel through coating films on the microscopic level. It became our belief that the coatings were no longer resistant to the permeation of those higher concentrations of H2S gas.

C. The causes of the more aggressive headspace environment are multifold and include the following:

Regionalizing of Wastewater Treatment

Since the late 1980's, the trend in wastewater treatment has been to build larger, regional wastewater treatment plants rather than constructing smaller, more local plants. Economy of scale reduces the cost of plant construction. However, the advent of larger, regional facilities has necessitated the need for transporting wastewater over longer distances. Because hydrogen sulfide is produced within the slime layers which form on sewer pipes and related surfaces, the more surface area in the collection system, the greater the hydrogen sulfide production will be. These longer transport distances for wastewater increase wastewater septicity and the dissolved H2S concentrations. When the wastewater becomes turbulent, the dissolved H2S is stripped out of solution as gaseous H2S. This process is further increased when the topography prevents gravity flow over the longer transport distances. Under such conditions, the wastewater must be pumped. Pumping of wastewater through force mains means the pipes run full. As such, the slime layer responsible for anaerobic sulfide production forms on the entire circumference of the piping.

This further increases the dissolved H2S concentration in the wastewater, which later becomes gaseous, leading to the more severe conditions for the old stand-by coatings described above. Furthermore, the pump stations required for the force mains generally increase the H2S production as they create turbulent wastewater flow and their wet wells often increase wastewater detention time.

Pretreatment Regulations

The Clean Water Act of 1979 required that all industrial contributions to municipal wastewater systems implement pretreatment for pH control and heavy metals removal prior to discharging their wastewater to municipal treatment systems. However, the removal of heavy metals such as mercury, lead, copper, etc., caused H2S production to rise because previously the heavy metals were toxic to the Sulfate Reducing Bacteria (SRB) responsible for dissolved H2S generation. With the toxins gone, the SRB bacteria became much healthier, again enhancing dissolved H2S production.

Odor Control Containment

Because the public finds wastewater related odors offensive and because these odors have become stronger due to higher sulfide production, wastewater headworks, clarifiers, grit removal tanks, and other structures are now typically covered. The gases are trapped by these covered structures and are then drawn away by fans to be filtered or scrubbed to control the odors. Odor control containment has greatly increased the severity of exposure in these covered headspaces. The result is higher H2S gas and H2SO4 liquid concentrations to which coating systems are exposed. In the past with open-top tanks, the gases went into the atmosphere. Now they are contained in the headspaces.

Most importantly, Tnemec Company recognized that new coating formulations having greater permeation resistance needed to be developed.

PRODUCTS DEVELOPED

Based on the above-discussed lessons learned, Tnemec Company determined that a group of complimentary coating products with very low permeability properties would be necessary to address the newer, more severe wastewater exposure conditions. A product initiative was established to develop the following products.

1. A trowel-applied (self-priming) 1/8" thick, moisture-tolerant, epoxy mortar lining for concrete substrates for retrofit and new construction. This product became Series 434.

2. A spray applied, 15-80 mil, moisture-tolerant, self-priming epoxy coating to be used as a gel coat for the troweled mortar or as a stand-alone coating for metallic substrates, or as a high-build liner used over new concrete. This product became Series 435.

3. A trowel-finished, spray applied waterborne epoxy, cementitious filler/surfacer for concrete substrates to be used for resurfacing prior to application of Series 434 or 435. This product is called Series 218 and can be applied up to 1/4" in depth.

Formulation of these products focused on developing superior H2SO4 resistance, H2S gas and liquid permeation resistance, and good working characteristics. Hundreds of candidate formulations were screened over a two-year period. Once the best candidate formulas were established, Tnemec Company and its consultant set out to develop a testing method specifically designed to replicate and accelerate wastewater headspace exposure conditions. That testing program is described in detail below.

DEVELOPMENT OF AN H2S GAS CHAMBER

The main objective for the testing program developed by Tnemec for the wastewater market was to establish a quantifiable method to evaluate the performance of coating systems with regard to permeation resistance to H2S, H2SO4, and other associated sewer gases and liquids. Once established, the evaluation method would be used to conduct comparative performance evaluation of Tnemec coating formulations against competitive products and to drive future improvements in Tnemec product technology. The testing program would be founded on test apparatus (see Figure 1 for the control chamber) permitting the simulation and acceleration of the exposure condition parameters characteristic of current wastewater collection and treatment systems. These parameters would need to include:

- Controllable concentrations of hydrogen sulfide.
- Intermittent immersion exposure to H_2SO_4, H_2S, and sodium-chloride at varying concentrations and time in immersion cycles. (The chloride exposure is needed for wastewater in coastal areas where sea water infiltration occurs in the collection system.)

- Immersion Schedule: Test panels immersed in H2SO4/H2S/NaCl solution for 15 minutes, 3 times per working day, Monday through Friday.
- Total Test Time: 30 days (in which 2 days were shut down for inspections). 28 days of exposure with 60 immersion cycles.

The measurement of the performance of the coating in the simulated wastewater environment was based on the barrier properties of permeability, blistering, adhesion, and visual inspection. Electrochemical Impedance Spectroscopy (EIS) was used to evaluate the permeability resistance of the coatings as related to barrier properties.

EIS readings were taken before the coating was exposed to the test; intermediate readings were also monitored at 10 and 20 days and at the completion of the test duration. The four readings were crucial to determine if the polymer was attacked or breached during the test. Any polymer degradation would be easily detected by a decrease in the measured impedance.

Figure 1

WHAT IS ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY (EIS)?

Polymeric coatings act as a barrier separating the substrate from the corrosive service environment. A key attribute in the performance of the protective coating is, therefore, a low permeability to salt, water, gases, and other corrosive species in the service environment. EIS is a technique well suited for evaluating coating permeability or barrier properties based on electrical resistance of the coating (referred to as impedance). The impedance of the coating is related to the nature of the polymer, its density, film thickness and its fillers. EIS has been widely used in the laboratory (Figure 3) and field for determining coating performance and obtaining quantitative information on coating deterioration.

The impedance of a coating is observed to decrease as a function of time of exposure to a corrosive environment. The decrease in impedance is observed to be related to the loss of barrier properties and deterioration of the coating under the specific environment. The quantitative data referred to as a Log Z value at 0.1 HZ (specific current) is tabulated and used as the basis of comparison between coatings, monitoring the change as a function of exposure time to the environment.

Anticipated performance of a coating based on the Log Z is shown below. The summary presented in Figure 2 is derived from a large body of literature of laboratory and field work.

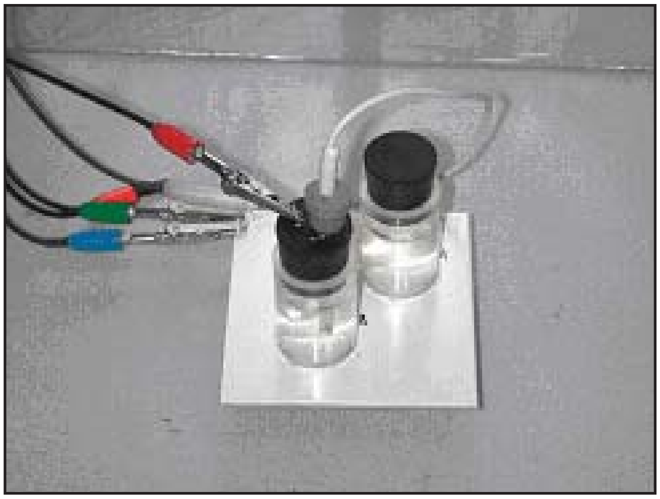


Figure 3

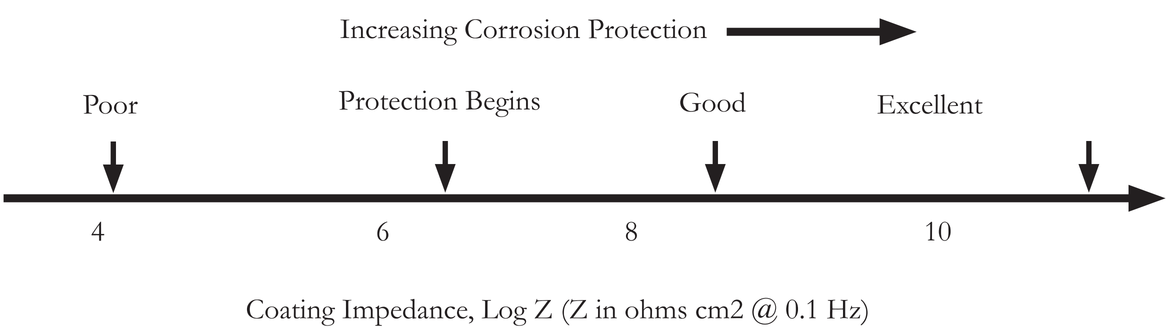


Figure 2
Corrosion Protection of Organic Coatings

Always remember that the higher and more stable the impedance over time, the better the long term permeability resistance and, therefore better long term coating performance. A high initial impedance followed by a fast decrease in impedance with exposure time means fast degradation of the coating's barrier properties.

TESTING OBJECTIVES

Numerous coatings were tested using the test cabinet and the EIS evaluation method. The testing was focused on four objectives:

1. To optimize the conditions of the chamber to best replicate real world exposure in an accelerated fashion.

2. To understand why some Tnemec formulations fail or perform in wastewater headspace service.

3. To compare performance of Tnemec Series 434 and 435 to the leading competitive products.

4. To assess coating system performance over concrete substrates, the most prevalent surface to be coated in wastewater environments. The top performing products were also run on concrete substrates. EIS cannot be used on concrete; only visual (cross-section after the test) and adhesion can be evaluated. Special modifications were also made to the chamber to evaluate the physical properties of free films.

Optimization of Chamber Conditions

The role of the chamber was established to simulate and accelerate a test method to evaluate coating performance in wastewater headspace conditions. Chemical selection was based on the most corrosive species found in all wastewater streams. H2S, CH4, CO2, NaCl and H2SO4 were selected.

We also decided that temperature and H2S would be the two parameters we would vary during the optimization. All others would be kept constant at a generally high concentration found in our specific environment. The run would also be kept at the same length of time, 28 days, and the same products would be analyzed.

Parameters of the Chamber

	Run #1	Run #2	Run #3
H2S	160 ppm	10000 ppm	536 ppm
Temperature	35˚C	65˚C	65˚C
H2SO4	10%	10%	10%
NaCl	4000 ppm	4000 ppm	4000 ppm

PRODUCTS TESTED

Some of the products evaluated in the three test runs included Series 434, Series 435, Plasite 5371, Sauereisen 210, Series 66, Series 104, and Series 406. Series 46H was tested in Run #1 and #2. Table 1 summarizes the results.

Table 1

Comparative Impedance Values for Coatings

Run #1 (160 ppm H2S)

Impedance	434	434/435	5371	210T	66	406	104	46H
Baseline	10.7	11.3	11.3	11.4	10.2	11.2	9.5	10.8
10 days	9.5	10.3	10.2	11.2	9.3	11.2	9.5	9.6
20 days	9.1	9.6	9.6	11.1	5.2	11.2	9.5	9.1
28 days	9.1	9.5	9.5	10.9	4.9	11.2	9.4	8.6

Run #2 (10000 ppm H2S)

Impedance	434	434/435	5371	210T	66	406	104	46H
Baseline	10.7	11.3	11.3	11.4	10.2	11.2	9.5	10.8
10 days	9.3	9.7	9.3	9.1	5.3	11.1	6.7	6.0
20 days	9.1	9.8	8.8	7.7	3.4	11.1	4.9	4.4
28 days	9.6	9.9	8.1	7.3	Fail	11.2	Fail	Fail

Run #3 (536 ppm H2S)

Impedance	434	434/435	5371	210T	66	406	104	46H
Baseline	10.7	11.3	11.3	11.4	10.2	11.2	9.5	NT
10 days	8.5	8.8	9.3	7.8	5.2	11.3	5.6	NT
20 days	9.0	9.8	9.1	7.7	4.9	11.3	4.9	NT
28 days	9.1	9.8	8.0	7.2	Fail	11.3	4.3	NT

NT – Not Tested

From these results, we can clearly conclude that 160 ppm of H2S was not high enough to differentiate and cause failure of standard coatings used in wastewater in an accelerated manner. H2S gas concentrations of 10,000 ppm and 536 ppm gave very similar results and demonstrated much more information regarding the mode of failure of the coatings tested for a 28-day period. The chamber set up for 536 ppm H2S is now routinely being used for all product comparisons based on the findings and parameters taken from Run #3.

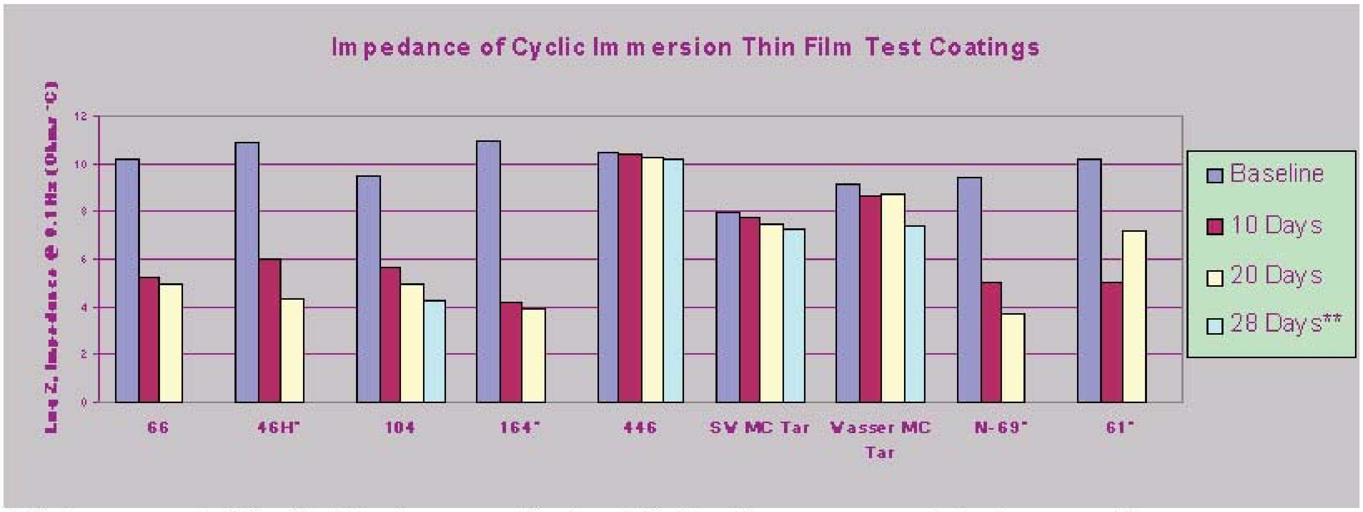
We can also conclude from the results that the chamber can truly give us a correlation with real life failure in a wastewater environment. The failure of the older Tnemec coating formulations used in wastewater correlated closely with our real life experience. Series 66, 104 and 46H failed early in the test by severe blistering and showed very low impedance values. As a matter of information, they did not fail due to sulfuric acid related attack associated with insufficient chemical resistance. Also impedance dropped rapidly within 10 days of exposure. The resulting impedance was below the protection level shown in Figure 2. This blistering failure has also been observed for these products in field applications after 12-16 months of exposure where H2S gas concentrations were measured between 50 and 100 ppm in headspaces. This confirms the poor permeation resistance of these products. Several other products were tested as well. Refer to Table No. 2 which lists all the products tested and the reasons for testing each product. The impedance numbers, combined with visual observations and adhesion evaluations will now be discussed in more detail.

Table 2
COATED STEEL COUPONS

PRODUCT	MANUFACTURER	GENERIC COATING TYPE	DRY FILM THICKNESS (MILS)	TESTED
Series 66	Tnemec	Polyamide epoxy	18	To understand failure observed in the field.
Series 104	Tnemec	Cycloaliphatic amine epoxy	20	To understand failure observed in the field.
Series 120	Tnemec	Vinyl ester	33	To evaluate impedance (perm resistance) relative to Series 435/435).
Series 164	Tnemec	Modified polyamine epoxy	22	New product to compare to 104.
Series 434*	Tnemec	Amine adduct and other amine cured epoxy	120	To compare performance to other products tested.
Series 434/435*	Tnemec	Amine adduct and other amine cured epoxy	139	To compare performance to other products tested.
Series 435	Tnemec	Amine adduct and other amine cured epoxy	60	To compare performance to other products tested.
Series 406*	Tnemec	Hybrid polyurethane elastomer	36	To compare performance to other products tested.
Series 400*	Tnemec	Polyurea elastomer	50	To compare performance to other products tested.
Series 262*	Tnemec	Tar-extended polyurethane	41	To compare performance to other products tested.
Raven 405	Raven	Cycloaliphatic amine/ aliphatic amine	109	To compare performance to other products tested
Plasite 5371*	Plasite	Amine adduct cured epoxy	120	To compare performance to other products tested
Sewergard 210*	Sauereisen	Amine cured epoxy	117	To compare performance to other products tested
1215 Cor-Cote HCR	Sherwin-Williams	Novolac epoxy	61	To compare performance to other products tested
Series 446	Tnemec	Moisture-cure poly-urethane with clean tar	10	To compare performance to other products tested.
Wasser MC Tar	Wasser	Moisture-cure polyurethane w/tar	21	To compare to Series 446.
Corothane 1Coal Tar	Sherwin-Williams	Moisture-cure poly-urethane w/tar	20	To compare to Series 446.
Protecto 401	Induron	Tar extended Novolac product	41	To compare performance to other products tested.
1214 Cor-Cote Cr	Sherwin-Williams	Novolac epoxy	87	To compare performance.
Series 46H	Tnemec	Tar polyamide	33	To understand failure in the field.
Series 282	Tnemec	Novolac epoxy	22	To compare performance to other products tested (
Series N-69	Tnemec	Polyamidoamine epoxy	12	To compare performance to other products tested
Series 61	Tnemec	Cycloaliphatic amine epoxy	15	To compare performance to other products tested

*Also run on concrete.

Graph 1



*Data presented for 2nd testing run. 2nd and 3rd testing runs correlated very well.
**Values of zero (missing column) represent failures of test coupon.

• Series 66, Series 104 and Series 46H failed early in the test by severe blistering and showed very low impedance values. Also, impedance dropped rapidly within 10 days of exposure. The resulting impedance was well below the protection level shown in Figure 2. This blistering failure has been observed in Series 66 and 104 in field applications at 50-100 ppm H2S after 12-16 months in service. This confirms poor permeation resistance of these products in the subject wastewater environment.

• Series 164, a developmental product for comparison to Series 104, had very high initial impedance, but its impedance dropped rapidly after 10 days of exposure. This product's permeation resistance was poor overall.

• Series N-69 from Tnemec had good initial impedance, but its impedance dropped considerably and rapidly over the 28 days of exposure. This product's permeation resistance is not good for wastewater H2S environments.

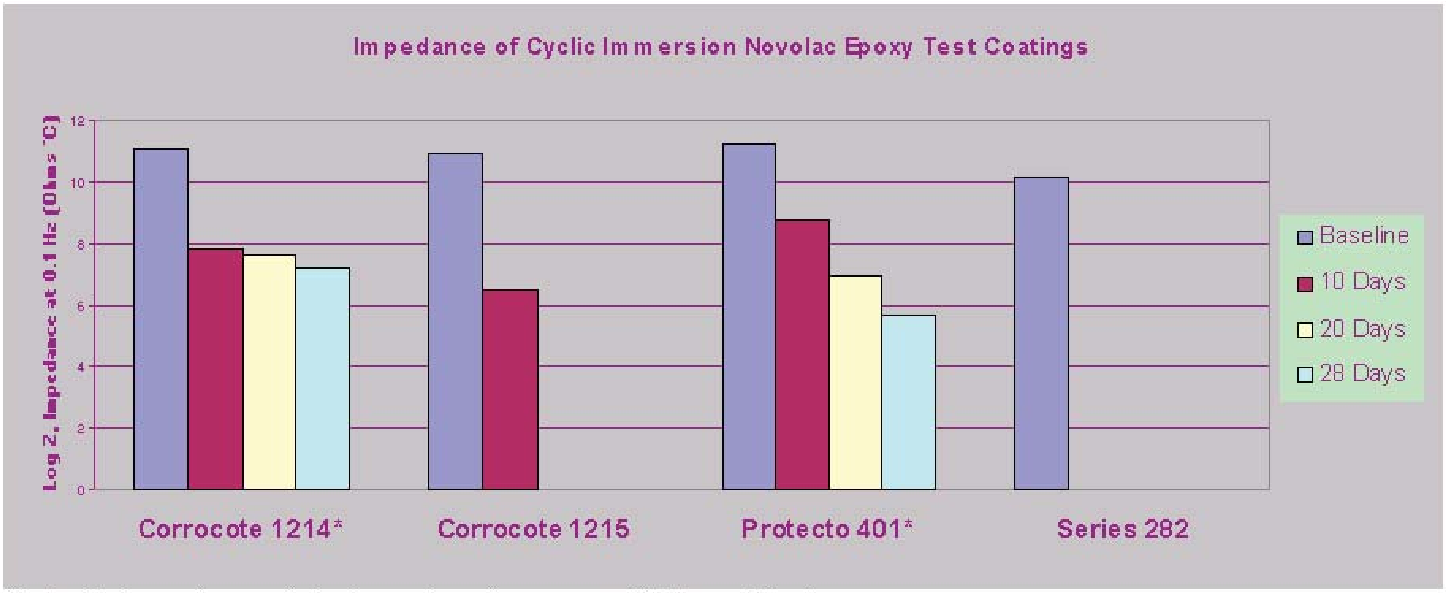
• Series 61 from Tnemec gave good initial impedance. It dropped to approximately 5 after 10 days of exposure and then increased after 20 days, but failed after 28 days of exposure.

• Series 446 gave excellent impedance values, but suffered loss of adhesion. This formulation will be considered for the next generation of Series 400 wastewater products. This is an experimental moisture cure polyurethane.

• The Wasser Moisture Cure Urethane Tar showed relatively poor impedance initially and its impedance dropped consistently through 28 days of exposure. It performed poorly when compared to Tnemec's MC polyurethane tar coating (Series 446).

• Sherwin Williams' Corothane 1 Coal Tar performed very badly in the cabinet with all impedance values well below the protection level. Again, the Tnemec MC Urethane Tar (Series 446) performed much better.

Graph 2



Note: Values of zero (missing column) represent failure of test coupon.
*See included photo.

• As can be seen, most thin film coatings fail in high H2S environments. Surprisingly, 446 seems to be a good future candidate. Series 446 keeps a very high and stable impedance for the 28-day test exposure. Further work is underway to improve adhesion by using a surface tolerant epoxy primer.

• Cor-Cote 1214 CR (Sherwin Williams) showed impedance values lower than many other products tested and the impedance dropped significantly during the 28 day test exposure. This indicates that Sherwin Williams does not have a viable product to compete with the Series 434/435.

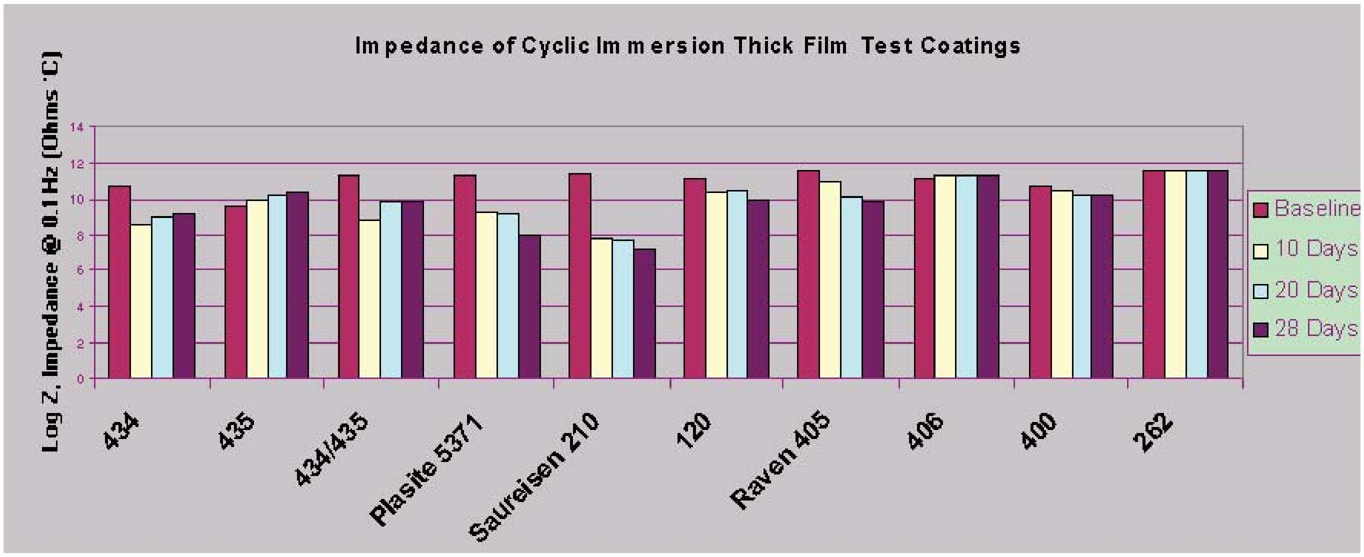
• Cor-Cote 1215 HCR (Sherwin Williams) delaminated and cracked in the test chamber after 20 days of testing and its impedance dropped to 6.5 after 10 days. No impedance could be measured after the cracking and delamination occurred. This product showed very poor performance.

• Protecto 401 had good initial impedance, but its permeation resistance dropped consistently below the protection level over the 28 day exposure. Tnemec's Series 435 outperformed it substantially. The panel also had strong visible cracking over its entire surface.

• Series 282 delaminated and cracked in a very short period of time. Very poor performance.

• This evaluation of Novolac epoxy also shows that the type of epoxy systems which are well known for their high chemical resistance are failing rapidly by stress cracking and delamination. By failing so fast, it confirms the importance of the permeability resistance of the coating to H2S in a wastewater headspace environment, rather than higher chemical resistance to sulfuric acid.

Graph 3



• Series 434 had excellent adhesion, no blistering, and very good impedance. It had a log Z impedance of 9.1 after 28 days of exposure. Its impedance was better than Sauereisen 210 and Plasite 5371 after 28 days. However, its impedance was slightly below the 434/435 and 435/435 systems tested. This confirms Tnemec's product initiative goals to produce a trowelable 434 for general H2S applications, but adding 435 as a topcoat or gel coat to 434 makes a system resistant to very high H2S conditions.

• The 434/435 system was only outdone (in epoxy technology) by the 435/435 system designed to be more permeation resistant. Note that 435 was designed to compete with products like Sauereisen 210S (sprayable) and Raven 405.

• Plasite 5371 and Sauereisen 210 had good adhesion, no blistering, and reasonable impedance. However, both coatings showed a continued drop in impedance over the test duration. This indicated that over time, these coatings will lose their protective qualities. Further testing (discussed later in this document) showed this to be true.

• Series 120 had good adhesion, no blistering, and excellent impedance over the 28 day test duration. The impedance remained high after 28 days despite a decreasing impedance over time of exposure. This shows why Series 120 has performed well in the field under high H2S gas exposure. However, the use of 120 is difficult in wastewater due to moisture sensitivity, safety concerns with styrene monomer in confined spaces, and lower temperature cure restrictions.

• Series 406 is a polyurethane formulation developed recently by Tnemec. It had the highest impedance of all the coatings tested over the 28 day duration. However, the coating lost adhesion in the test chamber. This is characteristic of elastomeric polyurethane coatings and Tnemec is now working on a study of various primers to solve this problem for future Series 400 product technology – 2nd generation.

• Series 400 had good adhesion, no blistering, and good impedance over 28 days of testing. It performed well, but showed major surface discoloration. This product is a polyurea elastomer and shows promise.

• Raven 405 had low adhesion to the parallel scribe test. The strip of coating was readily lifted from the steel surface. However, the underlying metal surface was bright and clean with no corrosion products. The impedance of coatings decreased with time, however, suggesting progressive deterioration; the impedance after 28 days was still relatively high, with Log Z = 9.8. Coatings were rather brittle and broke away in large pieces from the metal surface during bending. These coatings showed minor surface discoloration, with minimal penetration of the discoloration.

• Series 262 had very high impedance over 28 days, but lost adhesion and developed many surface divot type failures over the course of the testing.

Coated Concrete Coupon Testing

Several of the products tested on steel coupons for EIS evaluation were also tested in the cabinet over concrete. These products included the following:

- Series 434
- Series 434/435
- Series 401/406
- Series 435/406
- Series 66/262
- Plasite 5371
- Sauereisen 210
- Series 46H

Free films of Series 406, Series 400 and Series 262 were also tested to compare changes in physical properties before and after the 28 days of exposure. Modification was made to the test chamber to run concrete coupons and free films:

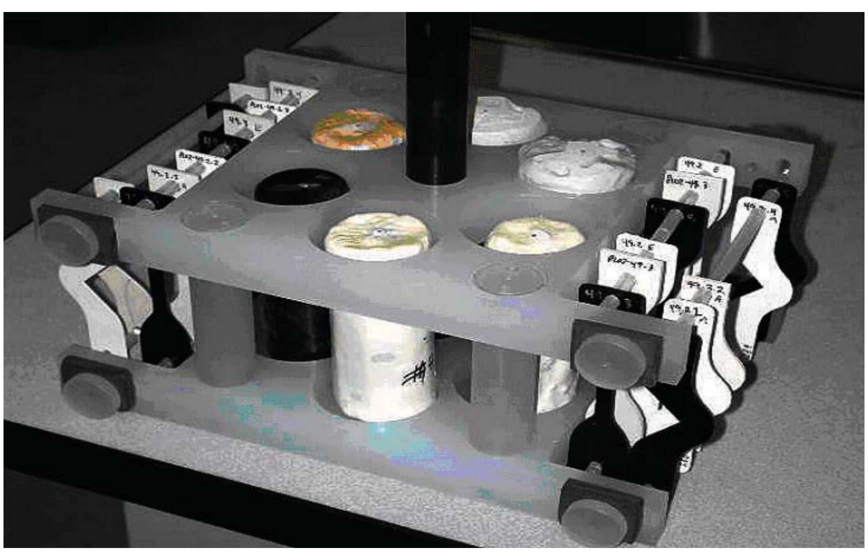


Figure #3

The coatings were applied to 1.5 inch x 4 inch concrete cylinders and tested under the 536 ppm H2S conditions given above in the test cabinet (see Run #3 exposure conditions).

Evaluation of the coupons included adhesion, blistering, foam, and color change.

EVALUATION RESULTS SUMMARIZED

Series 434, Series 434/435, Sauereisen 210, and Plasite 5371 showed no blistering, excellent adhesion to the concrete, and some color change which penetrated the surface of the coatings. All three systems experienced dark spotting from the exposure to the H2SO4 droplets in the test cabinet.

Microscopic examination of cross sections showed that discoloration penetrated the 434 and 434/435 by 5-10 mils and 3 to 5 mils respectively. Discoloration was more intense under the dark spots. The Plasite 5371 and Sauereisen 210 showed discoloration (bleaching) to a depth of 50 mils.

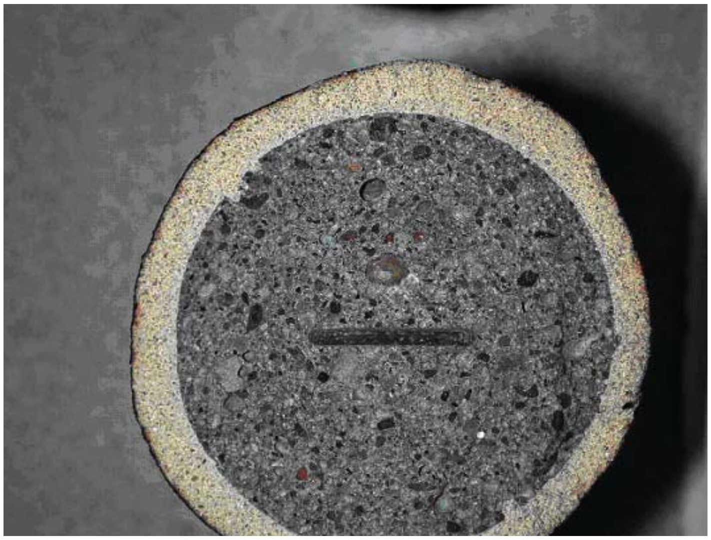


Figure #4
Series 434

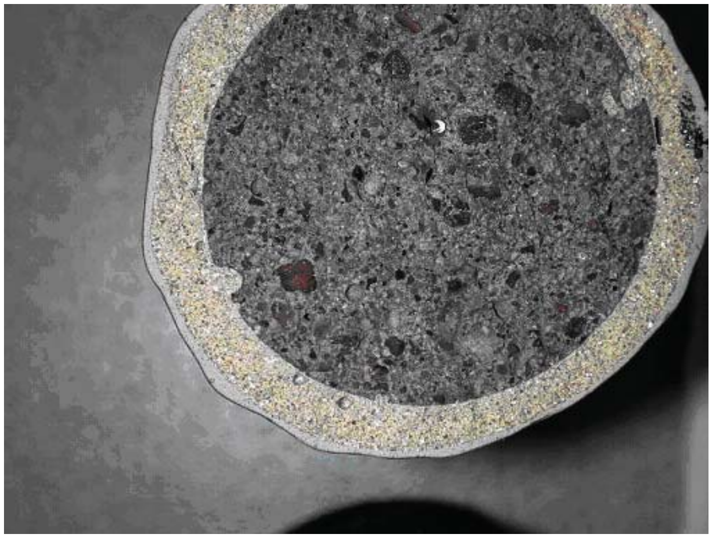


Figure #5
Series 434/435

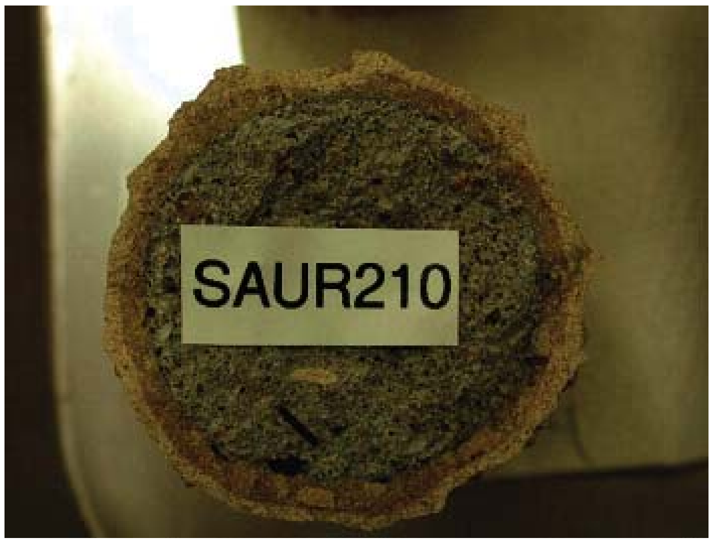


Figure #6
Sauereisen 210

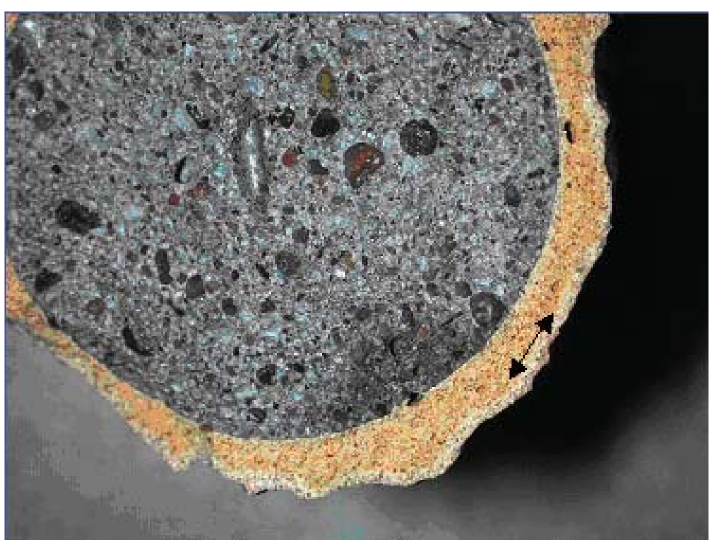


Figure #7
Plasite 5371

*The white layer (with the arrow) shows the penetration depth (50 mils) in the Plasite 5371. (Figure 7)

We can expect better resistance to H2S from 434 and 434/435 when compared to Sauereisen 210 and Plasite 5371 from these observations.

Figure #8 shows the concrete core coated with Series 46H that has been severely attacked after only 28 days of exposure in the chamber. This confirms the poor EIS number previously obtained for the Series 46H on the steel coupon and also duplicates the real life mode of failure of this coating.

Figure #8
Series 46H

Series 401/406 and 435/406 did not blister, but showed the typical dark spots associated with sulfuric acid droplet exposure. The discoloration penetrated the 406 topcoats for both samples by approximately 1 to 3 mils. However, the 401/406 sample cracked, permitting acid to reach the concrete. The system using 435 as a primer kept its adhesion and film integrity.

Figure #9
401/406 and 435/406

Coating system 66/262 did not blister, but discolored slightly and developed a roughened surface after 28 days of exposure. Examination showed a distribution of small pock marks over the surface, indicating a chemically eroded condition. Adhesion was good, but the topcoat was somewhat gummy although still fairly tough.

For the polyurethane systems, free films were also analyzed to compare physical properties before and after cabinet exposure. The data is reported in Table 3, Table 4 and Table 5 shown below.

Table 3
Summary of Tear Resistance

Sample I.D.	Peak Load/Thickness (psi)Control	Peak Load/Thickness (psi)Autoclaved	PercentDifference
#262 - Black	184	208	13.0%
#400 - White	669	458	-31.5%
#406 - Beige	502	491	-2.2%

Table 4
Summary of Tensile Break Strength Properties

Sample I.D.	Break Strength (psi)Control	Break Strength (psi)Autoclaved	PercentDifference
#262 - Black	730	618	-15.3%
#400 - White	3672	1643	-55.3%
#406 - Beige	3475	3259	-6.2%

Table 5
Summary of Elongation

Sample I.D.	Break Strain (%)Control	Break Strain (%)Autoclaved	PercentDifference
#262 - Black	430.05 ± 20.20	392.49 ± 12.81	-10.60%
#400 - White	361.92 ± 10.47	248.41 ± 27.66	-31.36%
#406 - Beige	30.37 ± 6.41	28.25 ± 6.88	-6.98%

From these summaries, we can see that Series 400 has an unacceptable loss of its physical properties when exposed to the simulated exposure conditions. It is Tnemec Company's conclusion that Series 400 and any type of polyurea should not be used in high H2S environments. A similar conclusion for Series 262 can be made. These two products should not be specified when high concentrations of H2S gas will be expected. Series 406 retains acceptable physical properties.

When considering the specification or use of polyurethane systems in a wastewater environment, it is essential to pay attention to the H2S level, and to determine whether it is municipal or industrial wastewater. Industrial wastewater can contain solvents and other chemicals that polyurethane coatings (Series 406) will not resist. Before any recommendation can be made, always have a good understanding of the type of wastewater exposures to which the coatings will be exposed.

CONCLUSION

In comparison to the testing conducted on coating systems over steel coupons, the concrete analysis results were very similar under the same cabinet exposure conditions. The Series 434 and 434/435 showed less shallow discoloration than Sauereisen 210 and Plasite 5371, which is consistent with the EIS impedance values reported earlier in this document. The Series 406 showed very good permeation resistance with very shallow discoloration, but poor adhesion to concrete substrates. The Series 66/262 samples discolored slightly, but experienced chemical erosion of the topcoat surface. Also, the topcoat's integrity appeared to be changed by the exposure which was confirmed by the free film testing.

We believe it is credible based on all the testing work performed to write specifications using the EIS results from the chamber as qualifying criteria. In the future, our performance criteria should be written as follows:

- H2S chamber testing: Coating exposed for 28 days at 65˚C to 536 ppm H2S, 4000 ppm NaCl, and 10% H2SO4.

- Impedance before testing should be a minimum of 10 and be over 9.0 after 28 days of exposure. No loss of adhesion or blistering should be observed.

Resume of Results

Coating	Impedance Before Exposure	After 28 Days Exposure
Series 434	10.7	9.1
Series 434/435	11.3	9.5
Series 435	9.6	10.3
Series 406	11.2	11.3
Plasite 5371	11.3	8.0
Sauereisen 210T	11.4	7.2
Raven 405	11.6	9.8

RB