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# NATIONAL BUREAU OF STANDARDS REPORT

10 857

QUARTERLY PROGRESS REPORT NO. 2

January 1, 1972 to March 31, 1972

NONMETALLIC COATINGS FOR CONCRETE REINFORCING BARS

Sponsored by

Federal Highway Administration



U.S. DEPARTMENT OF COMMERCE  
NATIONAL BUREAU OF STANDARDS

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<sup>2</sup> Part of the Center for Radiation Research.

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# NATIONAL BUREAU OF STANDARDS REPORT

## NBS PROJECT

4216442

May 25, 1972

## NBS REPORT

10 857

### QUARTERLY PROGRESS REPORT NO. 2

January 1, 1972 to March 31, 1972

## NONMETALLIC COATINGS FOR CONCRETE REINFORCING BARS

Sponsored by  
Federal Highway Administration  
U. S. Department of Transportation  
Washington, D. C. 20590

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Standards and Technology (NIST)  
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U.S. DEPARTMENT OF COMMERCE  
NATIONAL BUREAU OF STANDARDS



QUARTERLY PROGRESS REPORT NO. 2

JANUARY 1, 1972 TO MARCH 31, 1972

Prepared

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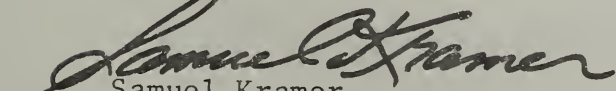
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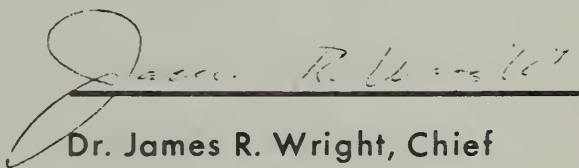
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## Abstract

This is the second quarterly progress report for the project Nonmetallic Coatings for Concrete Reinforcing Bars. The period of January 1, 1972 to March 31, 1972 is covered by this report.

Described in this report are: the procurement of samples of coating materials; the mixing and curing of the coating materials; and preliminary screening test that were carried out in order to select the most promising materials. The screening tests include: immersion testing of cured disc specimens; chloride permeability determinations of thin films; and accelerated corrosion studies of coated steel reinforcing bars.

Of the materials tested to date, the two component epoxy systems seem to have the most promise as protective coatings for steel reinforcing bars embedded in concrete.

Certain commercial materials are identified in this report in order to adequately specify the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material identified is necessarily the best available for the purpose.





## Quarterly Progress Report No. 2

(January 1 to March 31, 1972)

### 1. Study Identification: Order

No. 2-1-0614

Title: Nonmetallic Coatings for Concrete Reinforcing Bars.

### 2. Date Work Started: 9-17-71

Date of Report 4-3-72

### 3. Research Agency: National Bureau of Standards

### 4. Objectives

To investigate the feasibility of using epoxy systems and other organic systems to protect steel reinforcing bars embedded in the concrete of bridge deckings from corrosion. This corrosion is accelerated by chloride ions used as de-icing agents. The selection of appropriate protective coating systems is based on physiochemical testing with consideration given to economics involved in coating and fabrication of reinforcement.

### 5. Background

A discussion of some of the historic aspects of the problem of accelerated corrosion of steel reinforcing bars by chloride ions was given in the first progress report (NBS Report No. 10690). The first report also covered the initial selection of potential materials to protect the steel bars.

Included in the present report are results of screening tests used for the purposes of choosing the best coating systems.

## 6. Progress

The work in the second quarter of the project was concentrated in the procurement of samples of organic coatings and in making screening tests of cured specimens.

### 6.1 Procurement

To date, 27 coating materials listed in Table 1 have been received. All of these materials are liquid systems, with 14 being essentially 100 percent solid systems and 13 containing considerable amounts of volatile solvents. Twenty two of the listed coatings are classified as epoxies with the remaining five being various types of organic coatings, including one zinc metal filled system. It is felt that the materials listed in Table 1 are a good representation of the available liquid coatings which have potential use in protecting steel reinforcing bars and, therefore, no further soliciting of liquid coatings will be made.

Powder coatings promise to have numerous advantages compared to liquid coating materials (see the papers in Reference 1 for a detailed discussion of powder coatings, their applications, and advantages), and are being incorporated into the present project. The most feasible method to acquire test specimens of powder coated bars is to have experienced powder coaters apply the materials to steel reinforcing bars that we have supplied. Firms agreeing to apply powder coatings to rebars are listed in Table 2. These firms are Celanese Coatings Company, H. C. Price Company, Farboil Company, Robroy Industries, CIBA-GEIGY Corporation, H. B. Fuller Company and the Du Pont Corporation. The coated bars should be returned to NBS and available for testing in April 1972. Samples of the untreated powders are also being

supplied by the above named firms. The Polymer Corporation has also been contacted and probably will agree to coat rebars with their powder epoxy.

Included in Table 2 are several firms that are applying liquid coatings, they are Celanese Coating Company, Mobil Chemical Company, CIBA-GEIGY Corporation, General Mills Chemical, Inc., H. B. Fuller Company, and SIKA Chemical Company. To date, coated bars have been received from Celanese Coating Company, Mobil Chemical Company, and CIBA-GEIGY Corporation.

The listing in Table 2 is not necessarily complete as additional firms may possibly be requested to coat rebars. However, it is anticipated that this selection will be completed during the April to June 1972 work quarter.

## 6.2 Curing of Two-Component Coating Materials

The two component systems listed in Table 1 are all of the epoxy type, consisting essentially of an epoxy resin and a curing component. Often catalysts are added to accelerate the curing reaction. The curing of epoxies is attributed to chemical reactions between the epoxy resin and curing agents leading to polymerization of the mixture. Two component epoxies are classified as thermosetting materials for their cure is accelerated by heat and they harden and retain their shape when heated.

In the present work the ratio of curing component to epoxy resin and the mixing and curing times were closely controlled and were the same as those specified by the accompanying manufacturers instructions. The epoxy resin and curing component were mixed at room temperature,



ca. 24°C (75°F), relative humidity of ca. 35 percent, using either an electric stirrer (100 percent solid epoxies) or a metal spatula (solvent containing epoxies).

The 100 percent-solids liquid epoxy systems (solvent free systems) required little pre-mixing of the respective components and, although the components were very viscous, they could be readily mixed together with the exception of the epoxies supplied by H. B. Fuller Company (discussed later). Little odor was detected with the 100 percent-solids systems. These epoxies had good flow characteristics when applied to rebars using paint brushes, i.e. little sag or dripping of the films was present. The solvent containing epoxies required considerable mixing of the respective components due to solvent separation and their inherit low viscosities often lead to spillage and dripping. The aromatics and ketones solvents caused considerable human discomfort even when mixed in a well-ventilated laboratory hood. These types of solvents also constitute a fire hazard due to their high volatility and low flash point. The flow characteristics of the solvent containing epoxies were not as good as 100 percent solids epoxies; when applied to rebars using paint brushes or by dipping methods, much sag and dripping of the film occurred.

The two epoxies supplied by H. B. Fuller Company, Resiweld 7251 and 7259, required lengthly pre-mixing of the components and when mixed never cured as evidenced by their liquid state after a two month period. Heating the mixed samples to 100°F for 10 minutes, which should accelerate the cure, did not have any pronounced effects. Later a representative of H. B. Fuller Company apologetically advised us that they had inadvertently submitted samples from a three year old stock and probably the epoxy

resins had self-polymerized, thereby quenching any possible reaction with the curing component. Fresh samples are being supplied by H. B. Fuller Company.

A substantial quantity of entrapped air or gas was contained in the cured specimens of the two epoxies from Gates Engineering Company, GACO EHS-55 and EHS-58. The manufacturer's accompanying technical bulletin suggested an aging period of approximately one hour before application, however, even after this aging period the bubbles were still present in 3 mil films. Since the bubbles are a potential source of pin holes, these epoxy coatings have been judged to be unacceptable as protective coatings for steel reinforcing bars.

Two non-epoxy, two component coating materials supplied by the Witco Chemical Corporation, WITMER T830 and WITMER 520, are classified as urethane type elastomeric polymers. They have properties similar to flexible rubbers, low tensile strengths (450 psi and 100 psi respectively), and their percentages of elongation are between 550 to 600 percent. It is obvious that these materials will not pass the pull-out and creep tests and will not be further investigated. However, these materials have potential as impervious membranes.

### 6.3 Thermoplastics

The one component coating materials listed in Table 1, contain solvents and can be classified as thermoplastics as they soften and change shape when heated. It is felt that the term "epoxy" for the one component systems supplied by the 3M Company, Scotch-Clad Protective Coating 1706, and by Wailles Dove Bitumastic, Ltd., Comastic, is a misnomer as they are actually lacquer-like and do not involve the chemical cure

characteristics of two component epoxy materials.

All of the one component coatings were applied to rebars using a paint brush yielding a coating film thickness of about 5 mils and were allowed to thoroughly dry. Subsequently, the coated bars were heated in a water bath to 60°C (140°F) for 1/2 hour and the hardness of the coatings were qualitatively determined by cutting across the coatings with a metal spatula. In all cases, it was found that the coatings were much softer than at room temperature and could be easily removed from the bars. Similar tests with cured epoxy coated bars indicated that the coatings remained hard and well adhered to the bar (with the exception of the epoxy polysulfide-straw coated bars submitted to Mobil Chemical Company). Although these tests were crude, the superiority of the cured epoxy coatings over the one component coatings was clearly evident. In general, epoxy coatings have better abrasion and impact resistance, chemical resistance, and durability than thermoplastic materials [1]. No further testing of the one component materials is presently being contemplated.

#### 6.4 Immersion Testing

Cured epoxy specimens have been immersed in water and aqueous solutions of 3M  $\text{CaCl}_2$ , 3M NaOH, and a solution containing saturated  $\text{Ca}(\text{OH})_2$  saturated  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  and 0.5M  $\text{CaCl}_2$ . Their weight change is measured periodically. The epoxy specimens were cast into discs using aluminum weighing dishes as molds and have diameters of 2 1/4 inches and thicknesses of ca. 3/8 inches (the thickness of solvent containing epoxies were ca. 3/16 inches). The discs were immersed in water for a few minutes before measuring the original weight prior to the immersion studies. The temperatures of the testing solutions were 24±1°C.



The immersion data are presented in Table 3 for specimens immersed for seven and five weeks. The two samples having the greatest percentages of weight changes are primers, Chemfast E. P. and Epoloid 7-WE-20, which should only be used with a topcoat.

The immersion test, with periodic weighing, will be continued until the specimens have been immersed for a year.

If possible, the powder epoxies will be subjected to the same tests. It may be difficult to cure the powder epoxies at elevated temperatures in the aluminum weighing dishes and still release the cast specimens.

#### 6.5 Chloride Permeability

The permeability of thin films of cured epoxies is being measured using permeability cells designed and constructed at the National Bureau of Standards. Essentially, a cell consists of two glass compartments, separated by an epoxy film sandwiched between two glass plates, each having centered one-inch diameter holes. One compartment contains 175 mls of 3N NaCl and the other has 115 mls of distilled water. The activity of chloride ions passing through an epoxy membrane is measured using an Orion Specific Ion Meter, Model 401, along with Orion Chloride Electrode, Model 94-17, and Orion Double Junction Electrode, Model 90-02. Activity readings are converted into concentration values in moles per liter by using a conversion diagram, constructed by plotting measured chloride ion activity vs. known chloride ion concentrations.

Presented in Table 4 is the permeability data obtained during the period of this report. At the present time, the consequences of the values have not been ascertained, however, in no case did the permeating chloride ion concentration even approach the threshold concentration

found to induce corrosion of reinforcing bars [2]. Possibly, at a later date in this study, proper evaluations of the permeability data can be given. Probably a sudden change in permeabilities with time will be more meaningful than the absolute values.

#### 6.6. Accelerated Corrosion Testing

In these tests coated bars are partly immersed in aqueous solutions of 1.5N NaCl (8.9% by weight) and subjected to a D. C. voltage sufficient to cause the evolution of  $H_2$ .

The results of the tests are summarized in the following:

1. No corrosion was observed where a coating was continuous.
2. When pin hole areas were detected, no back-spread was found in relatively short exposures of less than 2 volts, i.e. corrosion did not spread under coated areas surrounding the pin holes.
3. When pinholes were present 1 to 2 volts were sufficient to cause the evolution of hydrogen gas. In the case of continuous coatings, a much greater voltage, about 15 volts, was needed to be applied before hydrogen gas was evolved. Apparently, at this high voltage some breakdown of the coating took place at areas of weakness, mainly along the high ridges parallel to the axis of the bar. Prolonged evolution of hydrogen at high voltages caused disbonding of the coating.

#### 6.7 Meetings Attended

Meetings attended in conjunction with study are as follows:

1. Highway Research Board Meeting in Washington, D. C., January 17 to 21, 1972, by Ramon Cilimberg, Robert Mathey and James R. Clifton.
2. National Association of Corrosion Engineers, St. Louis, Missouri, March 20 to 25, 1972, by James R. Clifton

3. Powder Coating 72 Conference of the Society of Manufacturing Engineers, Cincinnati, Ohio, March 28 to 30, 1972, by Hugh Beeghly.

4. American Concrete Institute Annual Convention, March 7 to 9, 1972, by Robert Mathey.

#### 6.8 Status of the Work

The general project schedule submitted in the first quarterly progress report, NBS Report No. 10 690, under Table 3, is closely being adhered to and it is felt that the current work is progressing according to schedule.

#### 7. Problems

##### 7.1 Staffing

Mr. Ramon Cilimberg has been assigned on a full-time basis to another project that will last at least through July 1972. Afterwards, we anticipate that he will be reassigned to this project of protecting rebars.

##### Procurement

The contemplated testing of powder epoxies and coated bars during the next quarter is dependent on the receipt of materials. Although promises of prompt application of powders to rebars have been made, only a few coated bars have been received and none coated with powders; numerous excuses have been by other applicators for unscheduled delays.

#### 8. Work Planned for the Next Quarter

The immersion, chloride ion permeability, and accelerated corrosion studies will be continued and cured powder epoxies will be incorporated into these screening tests.



Specimens for abrasion testing will be prepared and possibly such tests will be performed in the next quarter.

Impact and bend tests will be initiated as soon as the majority of powder coated bars are received from the applicators.

It is anticipated that concrete prisms containing coated and uncoated bars (for control purposes) will be cast during the latter portion of the next quarter. These specimens will be used in the creep, pull-out studies, and in corrosion testing.

Corrosion testing on coated bars (not cast in concrete blocks) that are partially immersed in three percent aqueous solutions of chloride ions will be commenced. The potentials and resistances of the coated rebars will be measured as an indication of the protecting qualities of the coatings.

## References

1. S. Kut, Product Finishing with Epoxy Powder Coatings, Part 1, Metal Finishing, Page 34, August (1971); *ibid*, Part II, Page 46, September (1971); *ibid*, Part III, Page 75, October (1971); *ibid*, Part IV, Page 56, November (1971); *ibid*, Part V, Page 53, December (1971).
2. D. A. Hausmann, Steel Corrosion in Concrete, Materials Protection and Performance 6, 19 (1967) November.





TABLE 1 COATING MATERIALS RECEIVED

<u>Material and Source</u>	<u>Chemical Type</u>	<u>Vehicle and Solvent System (all systems are liquid)</u>	<u>Comments</u>
<u>U. S. Steel Corporation</u>			
1. NEXUS S-8002	Epoxy	100% solids	Two component adhesive
<u>Mobil Chemical Company</u>			
2. 80-R-8	Vinyl primer	21% solids, ketones, and aromatic solvents	One component, used for priming clean steel prior to applying other vinyl coatings. Red in color. Thermoplastic.
3. VAL-CHEM HI-BUILD EPOXY 89-W-9	Epoxy resin with polyamide curing agents	53% solids, ketones, and aromatic solvents	Two component, low sheen finish, white.
4. VAL-CHEM EPOXY ENAMEL 84-D-7	Epoxy resin with polyamide curing agents		Essentially the same as No. 3, except for a high gloss.
<u>GATES ENGINEERING CO.</u>			
5. GACO EHS-55	Epoxy	97% solids	Two component, requires relative humidity above 50% for proper cure, white.
6. GACO EHS-58	Epoxy	97% solids	Two component, limited flexibility, Green
<u>Adhesive Engineering Co.</u>			
7. Concresive 1170	Epoxy	100% solids	Two component, low viscosity, grey.
8. Concresive 1026	Coal tar epoxy	100% solids	Two component, coal tar modified thermosetting epoxy used as a protective overlay on concrete pavements.

TABLE 1 COATING MATERIALS RECEIVED cont.

<u>Material and Source</u>	<u>Chemical Type</u>	<u>Vehicle and Solvent System (all systems are liquid)</u>	<u>Comments</u>
<u>ROWE PRODUCTS, INC.</u>			
9. Epoloid 2020	Polyamide curing agent, epoxy resin	60% solids	Two component, coating thickness should be 12 mils for optimum service life, black.
10. Epoloid 2027	Polyamide curing agent, epoxy resin	60% solids	Two component, coating thickness should be 12 mils for optimum service life, red.
11. Epoloid 7-WE-20	Water emulsion activated epoxy system	48% solids by volume	Two component, primer.
12. Epoloid 5-WB-5	Water emulsion activated epoxy system	46% solids by volume	Two component, overcoat for Epoloid 7-WE-20, primer, gray.
<u>GENERAL MILLS CHEMICAL, INC.</u>			
13. Versamid 140-GenEPOXY 185	Polyamide cured epoxy resin	100% solids	Two component, amber, has been tested on steel reinforcement bars by General Mills.
14. Green primer, Formula 150	Polyamide-epoxy	68% solids	Two component, green, meets military specification MIL-P-24441 (SHIPS).
<u>H. B. FULLER CO.</u>			
15. Resiweld 7251	Ketamine curing agent, epoxy resin	100% solids	Two component, white, pot life of 3 to 5 days at 25°C, high viscosity
16. Resiweld 7259	Ketamine curing agent, epoxy resin	100% solids	Two component, orange, pot life of 3 to 5 days at 25°C, anti-corrosive.

TABLE 1 COATING MATERIALS RECEIVED cont.

<u>Material and Source</u>	<u>Chemical Type</u>	<u>Vehicle and Solvent Systems (all systems are liquid)</u>	<u>Comments</u>
<u>CELANESE COATINGS CO.</u>			
17. EPI -TOP 100	Polyamide curing agent, epoxy resin	100% solids	Two component, various colors, used for mortar overlay, well studied system.
18. Chemfast E. P. Primer	Polyamide-epoxy paint	50% solid, aromatic and ketone thinners	Two component red primer, low viscosity.
<u>SIKA CHEMICAL CO.</u>			
19. Colma Fix	Epoxy-polysulfide	100% solids	Two component, used to bond fresh plastic concrete to hardened concrete, light brown.
20. Colma-Kote M undercoat	Epoxy	100% solids	Two component primer, high viscosity, cures under water.
21. Colma-Kote M topcoat	Epoxy	100% solids	Two component to be applied over Colma-Kote M undercoat.
<u>3M COMPANY</u>			
22. Scotch-clad Protective Coating 1706	Epoxy resin, no curing agent	32% solids, aromatic solvent	One component, lacquer, either black or gray. Thermoplastic.
<u>WAILLES DOVE BITUMASTIC LTD. England</u>			
23. COMASTIC	Epoxy resin-coal tar, no curing agent	about 50% solids	One component system modified with coal tar, black. Thermoplastic.

TABLE 1 COATING MATERIALS RECEIVED cont.

<u>Material and Source</u>	<u>Chemical Type</u>	<u>Vehicle and Solvent Systems (all systems are liquid)</u>	<u>Comments</u>
<u>WITCO CHEMICAL CO.</u>			
24. Witmer 520	Urethane system	100% solids	Two component, flexible elastomer, 600% elongation.
25. T-830	Urethane system	100% solids	Two component, flexible elastomer, 550% elongation.
<u>WHITTAKER CORP.</u>			
26. Metlbond 402	Nitrile-phenolic	30% solids, solvent methyl ethyl ketone	One component, adhesive.
<u>CARBOLINE CO.</u>			
27. Carbo Zinc 11	Zinc filled, Zinc silicate	80% solids	Two component, not recommended for alkaline exposure without topcoat, brittle.

TABLE 2 FIRMS COATING STEEL REINFORCEMENT BARS

<u>Firm</u>	<u>Description of Coating Material</u>	<u>Method of Application</u>	<u>Comments</u>
1. Celanese Coating Co.	A. EPI-TOP 100% solids, liquid epoxy B. Celanese powder epoxy	A. Brush B. Electrostatic spray gun	A. Coated bars received
2. Mobil Chemical Co. <sup>a/</sup>	A. Vinyl primer, 80-R-8 B. Val-Chem Hi-Build epoxy C. Val-Chem epoxy enamel, 84-D-7 D. Metallic zinc in ethyl silicate E. Epoxy polysulfide-straw	Brush	A. Thermoplastic B. Will coat more bars using electrostatic spray gun C. Essentially the same material as B D. Coating is too brittle and does not adhere well E. Softens at about 38°C (100°F)
3. H. C. Price Co.	ScotchKote protective resin No. 202 (The 3M Co.) powder epoxy	Electrostatic spray gun	Bars will be coated in early April 1972
4. Farboil Co.	Powder epoxy	Electrostatic spray gun	Coated bars will be received
5. Robroy Industries	A. ScotchKote protective resin no. 202 (The 3M Co.) powder epoxy B. Polyvinyl chloride, powder C. Polyethylene, powder	Fluidized bed	Bars will be coated in early April 1972
6. CIBA-GEIGY Corp.	A. CIBA-GEIGY 902-1, newly developed epoxy, liquid system. Cures at 120°C (300°F) B. CIBA-GEIGY powder epoxy	A. Dipping B. Electrostatic spray gun	A. Some bars received, will coat more using this material
7. General Mills Chemical Inc.	A. Versamid 140 with GenEPOXY 185, epoxy B. Green Primer Formula 150, epoxy	Air spray	Coated bars will be received in early April 1972



TABLE 2 FIRMS COATING STEEL REINFORCEMENT BARS cont.

<u>Firms</u>	<u>Description of Coating Material</u>	<u>Method of Application</u>	<u>Comments</u>
8. H. B. Fuller, Inc.	A. Resiweld 7251 100% solids liquid epoxy B. Resiweld 7259 100% solids liquid epoxy C. Fuller powder epoxy	A. Air spray or brush B. Air spray or brush C. Electrostatic spray gun	Coated bars should be received soon
9. Sika Chemical Co. <sup>b/</sup>	A. Colma Fix, liquid epoxy B. Colma-Kote M undercoat, liquid epoxy C. Colma-Kote M topcoat, liquid epoxy	Probably by brush	Coated bars should be in transit. Left at Sika during visit in December 1971
10. Shell Chemical Co. <sup>c/</sup>	Epoxy nature not presently known	Not presently known	Bars left at Shell's site in December 1971
11. The Polymer Corporation	CORVEL ECA-1555	Fluidized bed and Electrostatic spray gun	Awaiting confirmation from the Polymer Corp. prior to shipping bars to their site

<sup>a/</sup> Only the Val-Chem Hi-Build epoxy, 89-W-9 will be subjected to thorough tests. Other materials are not as satisfactory.

<sup>b/</sup> Only a few bars are being coated. Upon their receipt will determine if materials are worthy of further consideration.

<sup>c/</sup> Slow in submitting test samples and coated rebars.



TABLE 3 WEIGHT STABILITY OF SPECIMEN DISC IMMERSSED IN AQUEOUS SOLUTIONS

Material	Immersion Time (Weeks)	PERCENT WEIGHT CHANGE				Saturated $\text{Ca}(\text{OH})_2$ Saturated $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ and 0.5M $\text{CaCl}_2$
		Water	3M $\text{CaCl}_2$	3M $\text{NaOH}$		
1. EPI-TOP 100 (Celanese)	7	1.0	0.8	0.9		1.1
2. Chemfast E. P. (Celanese)	7	-5.8	-7.0	1.4		-2.7
3. Versamid-GenEPOXY (General Mills)	7	1.4	1.0	1.2		1.7
4. Green Primer (General Mills)	7	-0.6	-0.7	0.9		1.3
5. Colma-Kote M undercoat (SIKA)	7	1.0	0.8	0.8		1.0
6. Colma-Kote M topcoat (SIKA)	7	1.6	1.2	1.2		1.4
7. Colma Fix (SIKA)	7	0.8	0.9	1.1		1.4
8. Epoloid 7-WE-20 (ROWE)	7	19	18	17		18
9. Epoloid 2027 (ROWE)	7	-2.5	-3.6	-1.1		-2.7
10. GACO EHS-58 (GATES)	5	0.7	0.0	1.3		0.8
11. GACO EHS-58 (GATES)	5	3.2	1.4	2.1		2.2
12. Carbo Zinc 11 (Carboline)	3	-	-	-		2.4

The following materials will be tested:

13. Nexus S-8002 (U. S. Steel)
14. Val-Chem 89-W-9 (Mobil)
15. Concresive 1170 (Adhesive Eng.)
16. Concresive 1026 (Adhesive Eng.)



Table 4. Permeability of Chloride Ions

<u>Epoxy</u>	<u>Film Thickness (mils)</u>	<u>Exposure Time (weeks)</u>	<u>Permeability</u>
1. Epoloid 2027 (ROWE)	7	2	$3.3 \times 10^{-4}$
2. EPI-TOP (Celanese)	7	3	$5.1 \times 10^{-3}$
3. Epoxy Enamel 89 (Mobil)	7	4	$4.9 \times 10^{-3}$
4. Colma-Kote M Primer (SIKA)	3	4	$7.3 \times 10^{-5}$
5. Colma-Kote M Overcoat (SIKA)	3	4	$7.3 \times 10^{-5}$
6. Versamid-Epoxy (General Mills)	3	4	$7.3 \times 10^{-5}$
7. EHS-55 (GATES)	3	4	$5.8 \times 10^{-4}$

a/ Permeability units are: (grams per day)/ exposed area (in<sup>2</sup>)/film thickness (mils), i.e. theoretically the number of grams of chloride ions passing per day through a film having an exposure area of one square inch and a thickness of one mil.





