CVC Specialty Chemicals, Inc.	Technical Service Report	TSR070215-CZ

The Formulation and Evaluation of Water-Borne Epoxy Primers Based on Erisys GA-240 Water Soluble Epoxy Resin

Objective:

The purpose of this study was to obtain a controlled comparison of the Erisys GA-240 water soluble epoxy resin technology and competitive water-borne epoxy-amine cured technologies when utilized in corrosion inhibitive primer formulations.

This study was carried out by Specialty Coating Services, Inc. as requested by CVC Specialty Chemical, Inc.

SPECIALTY COATING SERVICES, INC.
8003 Vinecrest Avenue Unit 2
Louisville, KY 40222
(502) 327-7252

The Formulation and Evaluation of Water-Borne Epoxy Primers Based on CVC's Erisys GA-240 Water Soluble Epoxy Resin

Revised Final Report
August 30, 2006

Prepared for: CVC Specialty Chemicals, Inc.
844 N. Lenola Road
Moorestown, NJ 08057

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SPECIALTY COATING SERVICES, INC.

8003 Vinecrest Avenue Unit 2
Louisville, KY 40222
(502)327-7252

August 29, 2006

TO: Mr. William Starner
CVC Specialty

FROM: Specialty Coating Services, Inc.

SUBJECT: Revised Final Report on the Formulation and Evaluation of Water-Borne Epoxy Primers Based on CVC's Erisys GA-240 Water Soluble Epoxy Resin

The purpose of these studies was to obtain a controlled, comparative study of the Erisys GA-240 water soluble epoxy resin technology and competitive water-borne epoxy-amine cured technologies when utilized in corrosion inhibitive primer formulations. In review of the Erisys GA-240 literature, there are several things that are relatively unique as compared to conventional DGEBA epoxy resins used in the formulation of water-borne epoxy primers.

Most water-borne epoxy primers in use today are based on the dispersion of 500-700 EEW epoxy resins. The inherent film forming properties of these DGEBA epoxy resins allows for rapid dry times and a high degree of aromaticity as compared to the more hydrophilic curing agent. The high EEW also requires the use of less curative to achieve a 1 : 1 stoichiometry, and will also allow for the use of excess epoxy resin, if solvent and fluid resistance are not a primary concern.

In additional to limited solvent and fluid resistance, these primers also lack other characteristics of highly cross-linked systems such as a high degree of film hardness and abrasion resistance. However, the key aspects of performance for these primers is their corrosion resistance and long term water/humidity resistance.

<u>Formulation of a Erisys GA-240 Based Water-Borne Epoxy Primer</u>
In the formulation of a water-borne epoxy primer using Erisys GA-240, it was determined that the curing agent should be one possessing good water dispersibility and the ability to emulsify liquid epoxy, and it should have little or no acetic acid neutralizer. Based on prior studies conducted by CVC, and the known performance of Air Product's Anquamine 419 curing agent it was ultimately determined this would be the curative for the GA-240 evaluation. The Anquamine 419 is a water miscible curing agent supplied at 60% NV in a 62.5:37.5 blend of water and glycol ether PM.

Prior to formulation of the Erisys GA-240/Anquamine 419 based primer, it was necessary to consider several formulation variables that could have a definite impact on coating performance.

In the formulation of water-borne epoxy primers, it is key to minimize the use of all ingredients which could be detrimental to the development of long term water, humidity, and corrosion resistance. Variables identified and addressed in formulation of the GA-240 based primers include the following:

- **Erisys GA-240 Component Stability** - Known to optimum when used as supplied. The addition of acetic acid and water would limit component stability and the added acetic acid could inhibit good resistance to water, etc. To avoid any problems with coating performance attributable to GA-240 stability, no acid or water was added to the GA-240 component. This was possible with a low level add of glacial acetic acid and additional water to the curing agent component. In addition, the Anquamine 419 curative also proved to be assisting in the emulsification of the Erisys GA-240 epoxy resin upon blending.
- **Package Ratio of the Formulation -** The epoxy to curing agent ratio based on a 1:1 stoichiometry for this resin/curative combination is 27.4 % : 72.6 %, as supplied, or 38.6 % : 61.4 % on solids. Given the limited amount of available epoxy resin for pigmentation, and the high pigment loadings employed in these types of primers, pigmentation of the curative was a necessity. The resulting volumetric package ratio for GA-240 based primers was determined by the stoichiometry and no attempts were made to adjust these ratios to a convenient package ratio, as it would have required adding water to the GA-240 component.
- **Coating Solids -** While the goal was to maintain comparable solids to current available water-borne epoxy systems based on higher EEW epoxy resin dispersions, this did not prove to be possible. All Erisys GA-240 based sample required some reduction to achieve a suitable spray viscosity.
- **Pigment Volume Concentration (PVC) -** The need to have a PVC comparable to current available water-borne epoxy systems based on higher EEW epoxy resin dispersions was addressed. All test coatings were formulated to a PVC of ~ 35 %.

To ascertain the impact of varying the stoichiometric ratio on coating performance, it was determined that an evaluation that included stoichiometric ratios of 1:1, 1.25:1 and 1.5:1, epoxy to curative based on equivalents should be conducted. **(Note: Most currently available offerings using epoxy resin dispersion utilize an excess of epoxy resin to allow for more rapid dry time, more aromatic character in the cured film, and lower formulated cost.)**

The resulting test formulations are identified as follows:

Formula No.	Epoxy	Curative	Stoichiometry
MAJ-1374-1	ErisysGA-240	Anquamine 419	1.50 : 1.0
MAJ-1374-2	ErisysGA-240	Anquamine 419	1.25 : 1.0
MAJ-1374-3	ErisysGA-240	Anquamine 419	1.00 : 1.0
MAJ-1374-4	EpiKote 5522-WY55 (1)	Anquamine 419	1.60 : 1.0
MAJ-1374-5	Ancarez AR-550 (2)	Anquamine 419	0.80 : 1.0 (3)

(1) - supplied by Hexion, Inc.

(2) - supplied by Air Products and Chemicals, Inc.

(3) - based on Ancarez AR-550 EEW of 715 based on solids

Substrate Selection

The substrates selected for evaluation of these corrosion inhibitive primers were Q-Panel’s QS-48 bare, polished cold rolled steel panels, and Q-Panels's S-46 iron phosphate treated cold rolled steel. All panels were washed with xylene, followed by an acetone rinse, and were then air dried prior to coating application.

Coating Application and Cure Conditions
Each coating was allowed 45 minutes induction after blending of components to assure that all test coatings were fully compatible. All test coatings were applied to a dry film thickness of 2.0-2.5 mils over each of the selected substrates. All coating viscosities were reduced to 65-70 K.U. to accommodate spray application. Reduction level required for each system is listed in Table 1.

Coated panels were allowed to cure at ambient conditions of 72°F and 30-35% RH. for fourteen days prior to any testing typically conducted on fully cured films. Gloss and hardness measurements were taken periodically during the cure process.

Test Methods and Procedures
All test methods were conducted as per ASTM recommendations. A full listing of all methods utilized can be found in a comprehensive listing following the formulary.

Results
All test data generated in this study is listed in TABLES I through VIII. The contents of these Tables are as follows.

- **TABLE I** Viscosity Reduction and Pot Life Profile
- **TABLE II** Specular Gloss Through the Usable Pot Life
- **TABLE III** Physical Properties
- **TABLE IV** Chemical Resistance
- **TABLE V** Solvent and Fluid Resistance
- **TABLE VI** Condensing Humidity Resistance
- **TABLE VII** Salt Spray Resistance – bare cold rolled steel
- **TABLE VIII** Salt Spray Resistance – treated cold rolled steel

In review of the performance data, there are several aspects of performance with significant implications.

Compatibility and Reducibility
All coatings exhibited good compatibility. Primers based on Erisys GA-240 all exhibited high blend viscosities and required substantial reduction with water to achieve a suitable spray viscosity of 65-70 K.U. The amount of water required to lower viscosity to this range increased with increasing Anquamine 419 levels. As a result, only Formula: 1374-1, the primer formulated to a 1.5 : 1 stoichiometry, had a volume solids content comparable to the "standards" after reduction. The primer formulated to a 1.25 : 1 stoichiometry was ~ 7 % lower in volume solids, while the 1 : 1 formulation was ~ 10 % lower.

Physical Coating Properties
In review of physical coating properties, the primers based on the Erisys GA-240 epoxy resin have some notable strengths including no induction time, a good usable pot life of 5-6 hours, excellent early and fully cured film hardness, and excellent adhesion with a 1: 1 stoiciometry (1374-3). The only physical properties tested that revealed any shortcomings in the GA-240 based primers were dry times, which are adequate, and flexibility, which is also comparable to the 1374-4 and 1374-5 standards,

Chemical Resistance Studies
In terms of Chemical resistance, the Erisys GA-240 based primers provide poor, but comparable resistance to the "standards" with dilute acid exposures. However, some other facets of chemical testing such as alkaline and de-ionized water resistance were less positive with more film blistering and more softening than was observed with the "standards". This becomes more prevalent with higher Erisys GA-240 levels. This is an indication that perhaps the amine functionality of the GA-240, and /or the lack of the high aromatic characteristic of DGEBA epoxies, imparts greater moisture sensitivity in the cured films.

Solvent and Fluid Resistance
In testing of primer resistance to solvents and industrial fluids, the GA-240 based primers excelled due to the high level of cross-link density achieved with this tetra-functional epoxy. Even the primers with a significant excess of the GA-240 were very strong in this facet of testing. All GA-240 based primers yielded >300 MEK double rubs, as compared to less than 100 double rubs for the "standards". In addition, each of the GA-240 based primers also produced excellent resistance to anti-freeze, brake fluid, unleaded gasoline, and Skydrol 500 B4. The "standards" only provide good resistance to anti-freeze. In all other exposures, significant film softening was observed, with minimal recovery.

QCT Condensing Humidity Exposures
In evaluation of condensing humidity resistance, signs of water/moisture sensitivity arose again with all Erisys GA-240 based primers exhibiting early blistering in applications conducted over bare cold rolled steel. However, significant improvement was observed with the same coatings when applied to the iron phosphate treated cold rolled steel. Over this substrate, primers at 1.5 and 1.25 : 1 stoichiometries yielded good long term resistance. These coatings are in relatively good condition after 1000 hours of exposure, despite some light blistering which occurred within the first 168 hours of exposure. The GA-240 primer at 1.0 : 1.0 (1374-3) stoichiometry failed to fare as well, with significant blistering after one week exposure. Overall, the performance of these primers relative to the "standards" is comparable over treated steel and totally inferior when applied over bare steel. No finite explanation can be offered for this variance in performance with treated and untreated steel, although film adhesion is suspect with all GA-240 based primers, with the exception of Formula 1374-1 (1.5 : 1 stoich), when applied to bare cold rolled steel.

Salt Spray Corrosion Exposures
The results of salt spray corrosion resistance also indicate that early water resistance is a problem. Lower GA-240 levels seem to provide the best corrosion protection with Formula MAJ-1374-3 (1.1 : 1 stoich) producing the best performance of GA-240 based primers. This is contrary to QCT condensing humidity data wherein higher GA-240 levels yielded superior performance.
The
1374-3 formulation primers exhibits excellent film protection for 500 hours, while primers with higher GA-240 levels (1374-1 and 1374-2) begin to exhibit blistering at 500 hours. With the 1374-2 formulation, slight blistering begins to occur and propagates to more significant blistering at 1000 hours exposure time. The "standards" offer near blister/rust-free performance for over 1000 hours. It is suspected that all GA-240 based primers will exhibit improved corrosion resistance if formulated with a more water-soluble anti-corrosive pigment. Such a pigment would become active more rapidly in the exposed film, thus enhancing the early corrosion observed with 2 of the 3 GA-240 primers tested.

Summary

In summary of the data generated, there are two aspects of film properties that characterize the performance observed in these studies. These being the high cross-link density of the GA-240 based primers and lack thereof with the "standards", and the high degree of water resistance of the "standards" and weaknesses in this aspect of performance with the GA-240 primers. In this study, the Erisys GA-240 based primers with excess GA-240 (1374-1 and 1374-2) yielded improvements in water resistance relative to the 1374-3 formulation (1:1 stoichiometry). However, this trend was reversed in salt spray corrosion testing wherein the 1374-3 formulation yielded superior resistance to those primers based on excess GA-240. The competitive "standards" were relatively strong in both facets of exposure.

However, the overall strengths of the Erisys GA-240 out weigh the weaknesses given the relatively positive performance of the Erisys GA-240 based primers in corrosion protection. This is particularly true in light of the fact that the GA-240 based formulas were not optimized for PVC or for identification of the best anti-corrosive pigment for these primers. Through formulation optimization, and perhaps modification, many of the issues surrounding water resistance may be resolved. Polymer modifications that could address this limitation include modifying with conventional liquid epoxy resin or perhaps a hydrocarbon resin dispersion in an effort to enhance the water resistance of the cured primer. Due to potential reactivity with LER, hydrocarbon modifications may offer the best potential.

Alternatively, you may wish to attempt to improve water resistance through identifying a high molecular weight curative with more aromatic character than the Anquamine 419. This could be particularly beneficial in efforts to improve the humidity resistance of Erisys GA-240 based primers formulated without excess GA-240. It could also result in primer formulations that have higher volume solids than competitive offerings at a 1:1 stoichiometry, rather than the lower volume solids exhibited by the 1:1 GA-240/Anquamine 419 based primer in this study (1374-3).

However, based on all data generated, the Erisys GA-240 epoxy should provide outstanding performance in applications where its inherent cross-link density is utilized to the fullest. Most of these opportunities will arise in industrial maintenance applications such as concrete floor sealers and topcoats, areas requiring excellent hardness and high abrasion resistance (i.e. polymer system for aircraft anti-skid coatings), and in primers requiring a high degree of solvent/fluid resistance, such as military and commercial aircraft primers. These aerospace primers are applied over treated aluminum. The main function of the primer is to act as a "bonding or tie coat" for the 2K urethane topcoat. This adhesion comes from the polymer system, and by the use of strontium chromate as the anti-corrosive pigment. The strontium chromate has been shown to be key in achieving the required adhesion. Current efforts in developing a suitable water-borne replacement for this solvent based primer centers on utilizing a chromate free inhibitor that will provide comparable adhesion to that achieved with the strontium chromate.

TEST METHODS

Parameter	**Test Method**
* Viscosity	ASTM D562
* Film Thickness (DFT)	ASTM D1186
* Speed of Dry	ASTM D1640 (BYK circular dry time recorder)
* Hardness (pencil)	ASTM D3363
* Specular Gloss	ASTM D523
* Adhesion (cross-hatch)	ASTM D3359 (method B)
* Impact Resistance	ASTM D2794
* Chemical Resistance	ASTM D1308 (sec. 6.2)
* Fluid Resistance	ASTM D1308 (sec. 6.2 – uncovered)
* Condensing Humidity	ASTM D4585
* Salt Spray (Corrosion Protection)	ASTM B117

APPENDIX 1
Tables of Results

TABLE I: VISCOSITY REDUCTION & POT LIFE PROFILE

Viscosity Reduction to Spray Viscosity of 65-70 K.U.

	Viscosity		Volume Solids	
Formula No.	**Initial**	**After Reduction**	**Initial**	**After Reduction**
• MAJ-1374-1	127 K.U.	68 K.U	51.2 %	45.5 %
• MAJ-1374-2	>141 K.U.	68 K.U.	51.1 %	39.9 %
• MAJ-1374-3	>141 K.U.	70 K.U.	51.1 %	36.9 %
• MAJ-1374-4	68 K.U.	Not Required	46.8 %	Not Required
• MAJ-1374-5	61 K.U.	Not Required	46.7 %	Not Required

Pot Life Profile

	Viscosity (K.U.)						
Formula Number	**Initial**	**30 min.**	**1 hr.**	**2 hrs.**	**4 hrs.**	**5 hrs.**	**6 hrs**
• MAJ-1374-1	68	63	61	61	94	89	loss of stability
• MAJ-1374-2	68	72	70	68	78	76	loss of stability
• MAJ-1374-3	70	76	70	100	116	131	>141
• MAJ-1374-4	68	65	65	61	63	63	64
• MAJ-1374-5	61	58	60	61	58	58	57

TABLE II: SPECULAR GLOSS THROUGH THE USABLE POT LIFE

Formula Number	Initial	30 min.	1 hr.	2 hrs.	4 hrs.	5 hrs.	6 hrs
• MAJ-1374-1							
60 Degree	72	58	32	6	0.6	0.4	--------
20 Degree	24	14	5	0.6	0.2	0.2	--------
• MAJ-1374-2							
60 Degree	64	49	29	3	0.8	0.5	--------
20 Degree	17	10	4	0.3	0.2	0.2	--------
• MAJ-1374-3							
60 Degree	61	38	16	2	0.9	0.6	0.5
20 Degree	15	6	2	0.3	0.2	0.2	0.2
• MAJ-1374-4							
60 Degree	28	20	13	9	5	4	4
20 Degree	4	2	1	0.8	0.5	0.4	0.4
• MAJ-1374-5							
60 Degree	16	11	8	7	8	8	6
20 Degree	2	1	0.8	0.7	0.8	0.7	0.6

TABLE III: PHYSICAL PROPERTIES

Substrate: Bare Cold Rolled Steel
Dry Film Thickness: 2.0 mils
Induction Time: 1 Hour
Cure: 2 Wks. @ R.T. conditions of 72 F and 40-45 % R.H.

Property	Formula No. 1374-1	1374-2	1374-3	1374-4	1374-5
• **Dry Times**					
Set-to-Touch	1.20 hrs.	1.30 hrs.	1.20 hrs.	1.10 hrs	0.75 hrs.
Surface Dry	2.25 hrs.	2.50 hrs.	1.80 hrs.	3.00 hrs.	1.10 hrs.
Dry Through	6.80 hrs.	6.4 hrs.	4.50 hrs.	7.40 hrs.	3.50 hrs.
• **Hardness Development**					
24 Hours	HB	F	H	B	HB
48 Hours	HB	F	2H	HB	HB
1 Week	3H	5H	>6H	F	F
2 Weeks	>6H	>6H	>6H	2H	2H
• **Specular Gloss (2 wk. cure)**					
24 Hours Cure					
60 Degree	9.0	12.2	5.3	8.9	7.6
20 Degree	0.9	1.2	0.5	0.9	0.7
2 Weeks Cure					
60 Degree	9.0	12.2	5.3	7.1	7.0
20 Degree	0.9	1.2	0.5	0.7	0.7
• **Cross-Hatch Adhesion**	5B	3B	3B	5B	5B

TABLE III: PHYSICAL PROPERTIES (cont.)

Substrate: Bare Cold Rolled Steel
Dry Film Thickness: 2.0 mils
Induction Time: 1 Hour
Cure: 2 Wks. @ R.T. conditions of 72 F and 40-45 % R.H.

Property	Formula No. 1374-1	1374-2	1374-3	1374-4	1374-5
• **Mandrel Bend Flexibility**	Fail	Fail	Fail	Pass	Pass
• **Impact Resistance**					
Direct (In/Lbs)	20	10	10	30	20
Reverse (In/Lbs)	<5	<5	<5	<5	<5

TABLE IV: CHEMICAL AND DETERGENT RESISTANCE

Substrate: Bare Cold Rolled Steel
Dry Film Thickness: 2.0 mils
Induction Time: 1 Hour
Cure: 2 Wks. @ R.T. conditions of 72 F and 40-45 % R.H.

Property	Formula No. 1374-1	1374-2	1374-3	1374-4	1374-5
Dilute Acid and Base Solutions					
• 5 % Acetic Acid	CLOA	CLOA	CLOA	Softens to >6B	Softens to F
• 10 % Hydrochloric Acid	CLOA	CLOA	CLOA	CLOA	CLOA
• 10 % Sulfuric Acid	CLOA	CLOA	CLOA	Loss of Gloss	Softens to F
• 10 % Nitric Acid	CLOA	CLOA	CLOA	CLOA	CLOA
• 10 % Ammonium Hydroxide	No Blistering Softens to 3B	8M Blisters Softens to HB	8M Blisters Softens to HB	No Blistering Softens to B	No Blistering Softens to F
• 10 % Sodium Hydroxide	6M Blisters Softens to 3B	6MD Blisters Softens to HB	6MF Blisters Softens to HB	No Blistering Softens to 3B	6F Blisters Softens to F
• De-Ionized Water	No Blistering Softens to 3B	8MD Blisters Softens to 3B	8M Blisters Softens to B	No Blistering Softens to 2B	No Blistering Softens to F

Key: CLOA = complete loss of adhesion

Hardness Scale: 6B → 5B → 4B → 3B → 2B → B → HB → f → H → 2H → 3H → 4H → 5H → 6H

Softest ←--→ Hardest

TABLE V: SOLVENT AND FLUID RESISTANCE

Substrate: **Bare Cold Rolled Steel**
Dry Film Thickness: **2.0 mils**
Induction Time: **1 Hour**
Cure: **2 Wks. @ R.T. conditions of 72 F and 40-45 % R.H.**

	Formula No.				
Property	**1374-1**	**1374-2**	**1374-3**	**1374-4**	**1374-5**
Solvent and Fluid Resistance					
• MEK (double rubs)	>300	>300	>300	100 - softens to >6B	100 - softens to >6B
• Anti-Freeze	Softens to 4H	No Effect	No Effect	No Effect	No Effect
• Unleaded Gasoline	Softens to 5H	No Effect	No Effect	Softens to 4B	Softens to 4B
• Skydrol 500 B4	Softens to 4H	No Effect	No Effect	Softens to >6B	Softens to >6B
• Brake Fluid	Softens to 3H	No Effect	No Effect	Softens to >6B	Softens to >6B

Hardness Scale: 6B → 5B → 4B → 3B → 2B → B → HB → f → H → 2H → 3H → 4H → 5H → 6H

Softest ←--→ Hardest

TABLE VI: QCT CONDENSING HUMIDITY RESISTANCE

Substrates: Bare Cold Rolled Steel (CRS), Iron Phosphate Treated CRS
Dry Film Thickness: 2.0 mils
Induction Time: 1 Hour
Cure: 2 Wks. @ R.T. conditions of 72 F and 40-45 % R.H.

Formula No.	Exposure Time (Hrs.)	Coating Condition
Bare CRS Substrate		
MAJ-1374-1	168	2-6D Blisters, slight color fade
MAJ-1374-2	168	6VD Blisters, slight color fade
MAJ-1374-3	168	6VD Blisters, slight color fade
MAJ-1374-4	1000	No Blistering, severe color fade
MAJ-1374-5	792	4-6D Blisters, severe color fade
Treated CRS Substrate		
MAJ-1374-1	1000	2F Blisters, slight color fade, 1^{st} blisters observed @ 168 hours
MAJ-1374-2	1000	2MF Blisters, slight color fade, 1^{st} blisters observed @ 168 hours
MAJ-1374-3	168	6-8D Blisters, slight color fade
MAJ-1374-4	1000	No Blistering, severe color fade
MAJ-1374-5	1000	8VF Blisters, severe color fade

TABLE VII: SALT SPRAY RESISTANCE

Substrate: **Bare Cold Rolled Steel (CRS)**
Dry Film Thickness: **2.0 mils**
Induction Time: **1 Hour**
Cure: **2 Wks. @ R.T. conditions of 72 F and 40-45 % R.H.**

Formula No.	Exposure Time (Hrs.)	Field	Scribe
Bare CRS Substrate			
MAJ-1374-1	500	8D Blisters	6D Blisters, 2 mm creepage
	675	6D Blisters	6D Blisters, 11 mm creepage
MAJ-1374-2	500	8MD Blisters	6D Blisters, 1-2 mm creepage
	675	8D Blisters	6D Blisters, 8 mm creepage
MAJ-1374-3	500	No Blisters	8MF Blisters, 1-2 mm creepage
	675	8M Blisters	8MD Blisters, 4 mm creepage
	1000	6-8VD Blisters	2-4VD Blisters, 8-10 mm creepage
MAJ-1374-4	500	No Blisters	No Blisters, 1-2 mm creepage
	675	No Blisters	No Blisters, 2 mm creepage
	1000	No Blisters	2VF Blisters, 3 mm creepage
MAJ-1374-5	500	No Blisters	No Blisters, 1-2 mm creepage
	675	8VF Blisters	No Blisters, 2 mm creepage
	1000	2-8VF Blisters	No Blisters, 3 mm creepage

TABLE VIII: SALT SPRAY RESISTANCE

Substrate: **Iron Phosphate Treated CRS**
Dry Film Thickness: **2.0 mils**
Induction Time: **1 Hour**
Cure: **2 Wks. @ R.T. conditions of 72 F and 40-45 % R.H.**

Formula No.	Exposure Time (Hrs.)	Field	Scribe
Treated CRS			
MAJ-1374-1	500	8M Blisters	6MD Blisters, 2 mm creepage
	675	6D Blisters	2D Blisters, 10 mm creepage
MAJ-1374-2	500	8F Blisters	8MD Blisters,<1 mm creepage
	675	8MD Blisters	2D Blisters, 8 mm creepage
MAJ-1374-3	500	No Blisters	8VF Blisters, <1 mm creepage
	675	8F Blisters	8F Blisters, 1 mm creepage
	1000	6-8D Blisters	4F Blisters, 2 mm creepage
MAJ-1374-4	500	No Blisters	No Blisters, 1-2 mm creepage
	675	No Blisters	No Blisters, 2 mm creepage
	1000	8VF Blisters	8VF Blisters, 3-4 mm creepage
MAJ-1374-5	500	No Blisters	No Blisters, 1-2 mm creepage
	675	8VF Blisters	No Blisters, 2 mm creepage
	1000	8VF Blisters	No Blisters, 4 mm creepage

APPENDIX 2

Primer Coating Formulations

SCS Formula No. **MAJ-1374-1**

Water-Borne Anti-Corrosive Epoxy Primer
Based on Erisys GA-240 Epoxy Resin

Stoichiometry: 1.50 : 1.0 epoxy to amine based on equivalents

Material	Pounds	Gallons	NV Pounds	NV Gallons	Gallons Water	Lbs. VOM
- Part A -						
Erisys Ga-240 Epoxy Resin	138.3	14.44	138.3	14.44	--------	--------
- Part B -						
Anquamine 419 Curing Agent	175.0	19.36	105.0	14.48	3.15	43.75
Glycol Ether PM	18.0	2.35	--------	--------	--------	18.00
De-Ionized Water	152.8	18.34	--------	--------	18.34	--------
Surfynol DF-62 Defoamer	3.0	0.36	3.0	0.36	--------	--------
Red Iron Oxide	70.0	1.75	70.0	1.75	--------	--------
10ES Wollastokup	125.4	5.18	125.4	5.18	--------	--------
Zeeosphere 400	84.8	4.29	84.8	4.29	--------	--------
Barium Sulfate	84.8	2.32	84.8	2.32	--------	--------
Halox SW-111	100.0	4.20	100.0	4.20	--------	--------
** HSD to a Texture of 5-6 N.S., then add: **						
Anquamine 419 Curing Agent	69.5	7.69	41.7	4.17	1.25	17.38
Glacial Acetic Acid	0.6	0.07	--------	--------	--------	0.60
De-Ionized Water	163.7	19.65	--------	--------	19.65	--------
	1047.6	85.56	614.7	36.75	42.39	79.73
Total A+B	**1185.9**	**100.00**	**753.0**	**51.19**	**42.39**	**79.73**

SCS Formula No. **MAJ-1374-1**

Water-Borne Anti-Corrosive Epoxy Primer
Based on Erisys GA-240 Epoxy Resin

Stoichiometry: 1.50 : 1.0 epoxy to amine based on equivalents

Typical Coating Constants	As Formulated	Reduced to 80-85 K.U.	Reduced to 65-70 K.U.
• Total Weight Solids	63.5 %	59.6 %	58.4 %
• Total Volume Solids	51.2 %	46.8 %	45.5 %
• PVC	34.7 %	34.7 %	34.7 %
• Pigment/Binder Ratio	1.63 : 1.0	1.63:10	1.63 : 1.0
• VOC Pounds per Gallon	1.38	1.38	1.38
Grams per Liter	166.0	166.0	166
• A+B Viscosity	127 K.U.	83 K.U.	68 K.U.

SCS Formula No. **MAJ-1374-2**

Water-Borne Anti-Corrosive Epoxy Primer
Based on Erisys GA-240 Epoxy Resin

Stoichiometry: 1.25 : 1.0 epoxy to amine based on equivalents

Material	Pounds	Gallons	NV Pounds	NV Gallons	Gallons Water	Lbs. VOM
- Part A -						
Erisys Ga-240 Epoxy Resin	125.5	13.10	125.5	13.10	--------	--------
- Part B -						
Anquamine 419 Curing Agent	175.0	19.36	105.0	14.48	3.15	43.75
Glycol Ether PM	18.0	2.35	--------	--------	--------	18.00
De-Ionized Water	152.8	18.34	--------	--------	18.34	--------
Surfynol DF-62 Defoamer	3.0	0.36	3.0	0.36	--------	--------
Red Iron Oxide	70.0	1.75	70.0	1.75	--------	--------
10ES Wollastokup	125.4	5.18	125.4	5.18	--------	--------
Zeeosphere 400	84.8	4.29	84.8	4.29	--------	--------
Barium Sulfate	84.8	2.32	84.8	2.32	--------	--------
Halox SW-111	100.0	4.20	100.0	4.20	--------	--------
** HSD to a Texture of 5-6 N.S., then add: **						
Anquamine 419 Curing Agent	90.9	10.06	54.5	5.45	1.64	22.73
Glacial Acetic Acid	0.6	0.07	--------	--------	--------	0.60
De-Ionized Water	155.1	18.62	--------	--------	18.62	--------
	1060.4	86.90	627.5	38.03	41.75	90.08
Total A+B	**1185.9**	**100.00**	**753.0**	**51.13**	**41.75**	**90.08**

SCS Formula No. **MAJ-1374-2**

Water-Borne Anti-Corrosive Epoxy Primer
Based on Erisys GA-240 Epoxy Resin

Stoichiometry: 1.25 : 1.0 epoxy to amine based on equivalents

Typical Coating Constants	As Formulated	Reduced to 80-85 K.U.	Reduced to 65-70 K.U.
• Total Weight Solids	63.5 %	54.4 %	53.0 %
• Total Volume Solids	51.1 %	41.4 %	39.9 %
• PVC	34.7 %	34.7 %	34.7 %
• Pigment/Binder Ratio	1.63 : 1.0	1.63 : 1.0	1.63 : 1.0
• VOC Pounds per Gallon	1.55	1.55	1.55
Grams per Liter	185.5	185.5	185.5
• A+B Viscosity	>141 K.U.	84 K.U.	68 K.U.

SCS Formula No. **MAJ-1374-3** **April 13, 2006**

Water-Borne Anti-Corrosive Epoxy Primer
Based on Erisys GA-240 Epoxy Resin

Stoichiometry: 1.0 : 1.0 epoxy to amine based on equivalents

Material	**Pounds**	**Gallons**	**NV Pounds**	**NV Gallons**	**Gallons Water**	**Lbs. VOM**
- Part A -						
Erisys Ga-240 Epoxy Resin	110.1	11.49	110.1	11.49	--------	--------
- Part B -						
Anquamine 419 Curing Agent	175.0	19.36	105.0	14.48	3.15	43.75
Glycol Ether PM	18.0	2.35	--------	--------	--------	18.00
De-Ionized Water	152.8	18.34	--------	--------	18.34	--------
Surfynol DF-62 Defoamer	3.0	0.36	3.0	0.36	--------	--------
Red Iron Oxide	70.0	1.75	70.0	1.75	--------	--------
10ES Wollastokup	125.4	5.18	125.4	5.18	--------	--------
Zeeosphere 400	84.8	4.29	84.8	4.29	--------	--------
Barium Sulfate	84.8	2.32	84.8	2.32	--------	--------
Halox SW-111	100.0	4.20	100.0	4.20	--------	--------
** HSD to a Texture of 5-6 N.S., then add: **						
Anquamine 419 Curing Agent	116.5	12.89	69.9	6.98	2.10	29.13
Glacial Acetic Acid	0.6	0.07	--------	--------	--------	0.60
De-Ionized Water	145.8	17.50	--------	--------	8.64	--------
	1076.7	88.51	642.9	39.56	32.23	91.48
Total A+B	**1186.8**	**100.00**	**753.0**	**51.05**	**32.23**	**91.48**

SCS Formula No. **MAJ-1374-3**

Water-Borne Anti-Corrosive Epoxy Primer
Based on Erisys GA-240 Epoxy Resin

Stoichiometry: 1.0 : 1.0 epoxy to amine based on equivalents

Typical Coating Constants	As Formulated	Reduced to 80-85 K.U.	Reduced to 65-70 K.U.
• Total Weight Solids	63.5 %	52.0 %	50.0 %
• Total Volume Solids	51.1 %	38.9 %	36.9 %
• PVC	34.8 %	34.8 %	34.8 %
• Pigment/Binder Ratio	1.63 : 1.0	1.63 : 1	1.63 : 1.0
• VOC Pounds per Gallon	1.55	1.55	1.55
Grams per Liter	186.3	186.3	186.3
• A+B Viscosity	> 141 K.U.	84 K.U.	70 K.U.

SCS Formula No. **MAJ-1374-4 (APC Starting Formula WB419P2)**

Red Iron Oxide Primer Based on Air Products' Anquamine 419 Water-Borne Epoxy Curing Agent and Hexion's Epi-Kote 5522-WY55 Epoxy Resin Dispersion

Material	**Pounds**	**Gallons**	**Pounds**	**Gallons**	**Water**	**VOM**
- Part A -						
Epi-Kote 5522WY55 Epoxy Resin	388.4	42.50	207.8	21.47	17.97	30.88
Glycol Ether PM	4.3	0.54	---------	---------	---------	4.30
Benzyl Alcohol	8.7	0.99	---------	---------	---------	8.70
Dee-Fo PI-4 Conc. Defoamer	3.3	0.40	3.3	0.40	---------	---------
De-Ionized Water	87.6	10.50	---------	----------	10.50	---------
325 mesh WG Mica	8.3	0.35	8.3	0.35	---------	---------
10ES Wollastocoat	108.1	4.47	108.1	4.47	---------	---------
Halox SW-111	101.6	4.27	101.6	4.27	---------	---------
Kroma Red Iron Oxide RO-4097	72.1	1.80	72.1	1.80	---------	---------
Zeeosphere 400G	72.1	3.60	72.1	3.60	---------	---------
Barium Sulfate (Sparmite)	72.1	1.96	72.1	1.96	---------	---------
** High Speed Disperse to A Texture of 5-7 N.S., then add : **						
Epi-Kote 5522WY55 Epoxy Resin	61.2	6.70	32.7	3.38	2.83	4.87
De-Ionized Water	16.0	1.92	---------	---------	1.92	---------
	1003.8	80.00	678.1	41.70	33.22	48.75

SCS Formula No. **MAJ-1374-4 (APC Starting Formula WB419P2)**

Red Iron Oxide Primer Based on Air Products' Anquamine 419 Water-Borne Epoxy Curing Agent and Hexion's Epi-Kote 5522-WY55 Epoxy Resin Dispersion

- Part B -						
Anquamine 419	70.3	7.75	42.2	4.28	2.11	10.55
Glycol Ether PM	17.9	2.31	---------	---------	---------	17.90
Glacial Acetic Acid	0.4	0.06	---------	---------	---------	0.40
De-Ionized Water	82.3	9.88	---------	---------	9.88	---------
	170.9	20.00	42.2	4.28	11.99	28.85
Total A+B	**1174.7**	**100.00**	**720.3**	**45.98**	**45.21**	**77.60**

Typical Coating Constants	**As Formulated**
• Total Weight Solids	61.3 %
• Total Volume Solids	46.0 %
• PVC	35.7 %
• Pigment/Binder Ratio	1.54 : 1.0
• VOC Pounds per Gallon	1.42
Grams per Liter	169.9
• A+B Viscosity	68 K.U.

SCS Formula No. **MAJ-1374-5** **(APC starting formula AR550MP4101-419)**

Red Iron Oxide Primer Based on Air Products' Anquamine 419 Water-Borne Epoxy Curing Agent and Ancarez AR-550 Epoxy Resin Dispersion

Material	Pounds	Gallons	Pounds	Gallons	Water	VOM
- Part A -						
De-Ionized Water	123.6	14.80	---------	---------	14.80	---------
Disperbyk 190	13.5	1.48	5.5	0.51	0.97	---------
Surfynol DF-62 Defoamer	2.9	0.35	2.2	0.27	---------	0.67
Surfynol 420	1.0	0.13	0.7	0.09	---------	0.28
Red Iron Oxide	72.4	1.68	72.4	1.68	---------	---------
Zeeosphere 400G	62.7	3.42	62.7	3.43	---------	---------
Barium Sulfate (Sparmite)	62.7	1.71	62.7	1.71	---------	---------
10ES Wollastocoat	62.7	2.59	62.7	2.59	---------	---------
Halox SW-111	96.5	4.00	96.5	4.00	---------	---------
325 mesh WG Mica	9.7	0.41	9.7	0.41	---------	---------
** High Speed Disperse to A Texture of 5-7 N.S., then add : **						
Ancarez AR-550 Epoxy Resin	415.1	45.62	228.3	23.16	22.42	---------
Rheolate 310 (15 % sol'n in water)	32.2	3.81	1.6	0.16	3.67	---------
	955.0	80.00	605.0	38.01	41.86	0.95

<u>SCS Formula No.</u> **MAJ-1374-5** **(APC starting formula AR550MP4101-419)**

Red Iron Oxide Primer Based on Air Products' Anquamine 419 Water-Borne Epoxy Curing Agent and Ancarez AR-550 Epoxy Resin Dispersion

- Part B -						
Anquamine 419	113.4	12.53	68.0	6.79	2.04	28.35
Glycol Ether PM	32.8	3.75	---------	---------	---------	32.80
De-Ionized Water	31.1	3.72	---------	---------	3.72	---------
	177.3	20.00	68.0	6.79	5.76	61.15
Total A+B	**1132.3**	**100.00**	**673.0**	**44.80**	**47.62**	**62.10**

Typical Coating Constants	As Formulated
• Total Weight Solids	59.4 %
• Total Volume Solids	44.8 %
• PVC	30.9 %
• Pigment/Binder Ratio	1.24 : 1.0
• VOC Pounds per Gallon	1.19
Grams per Liter	142.2
• A+B Viscosity	61 K.U.

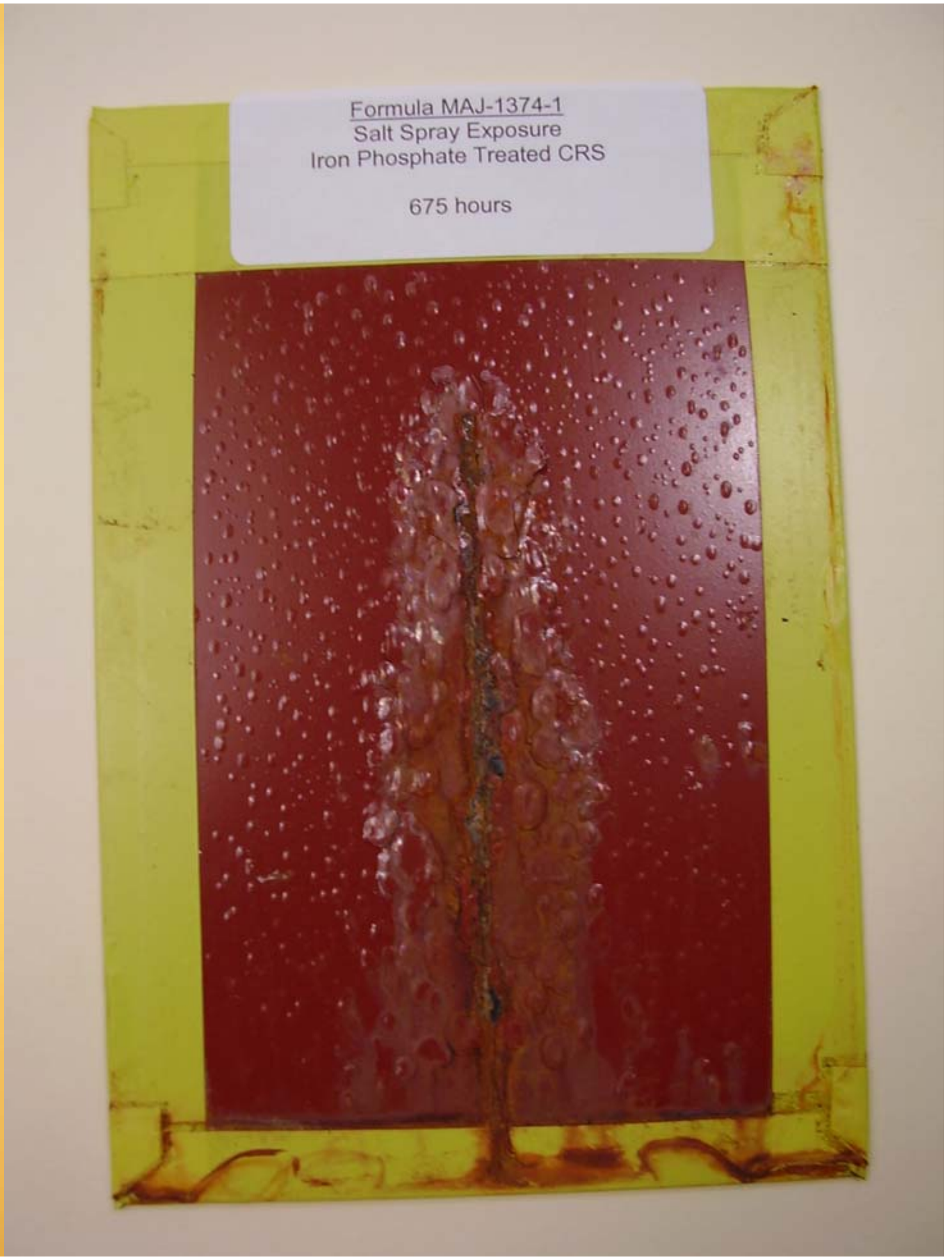
APPENDIX 3

Photographs of Panels Tested for Salt Spray and Condensing Humidity


Formula MAJ-1374-1
Salt Spray Exposure
Bare Cold Rolled Steel
675 hours

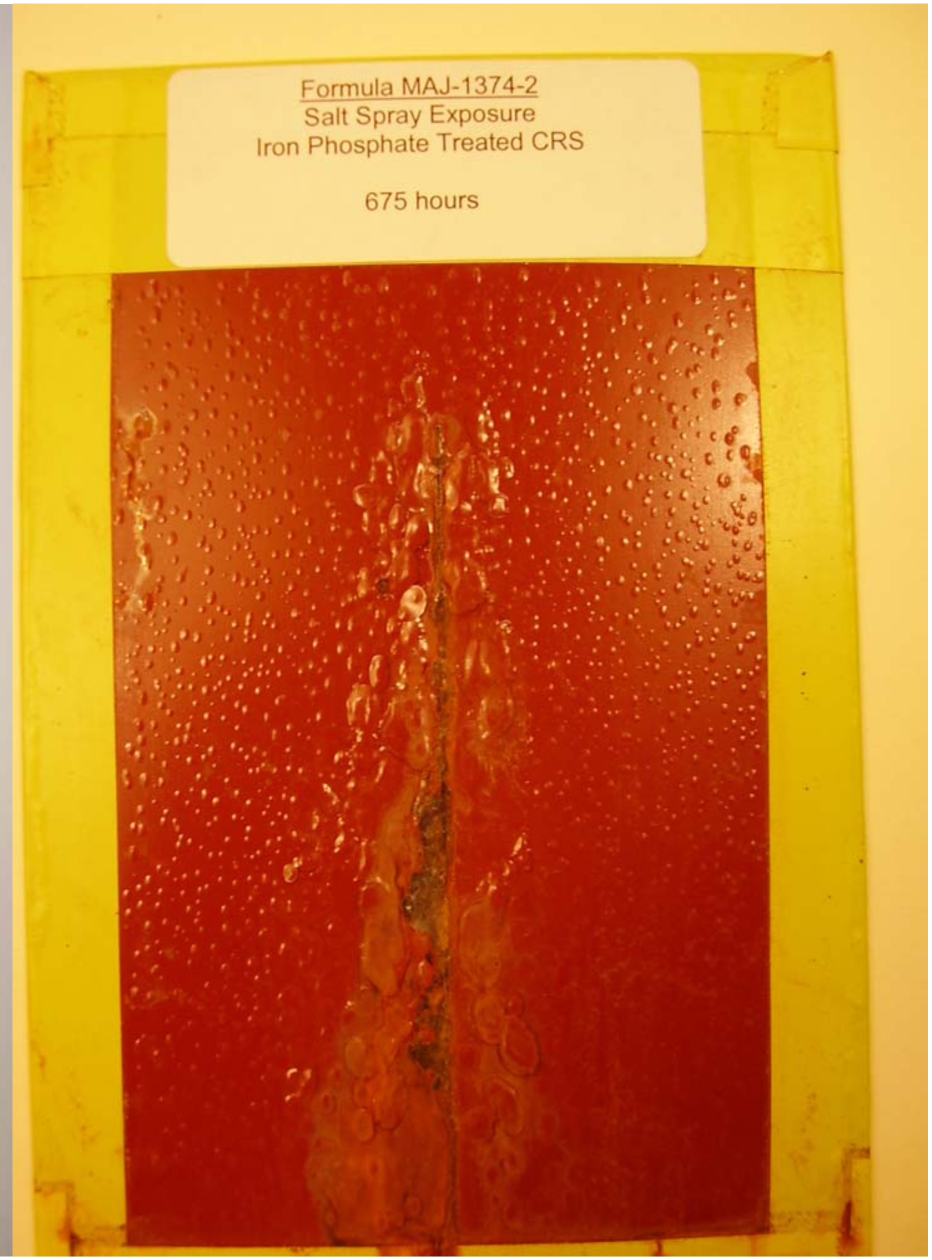

Formula MAJ-1374-1
QCT Condensing Humidity
Bare Cold Rolled Steel
168 hours


Formula MAJ-1374-1
QCT Condensing Humidity
Iron Phosphate Treated CRS
1000 hours


Formula MAJ-1374-1
Salt Spray Exposure
Iron Phosphate Treated CRS
675 hours


Formula MAJ-1374-2
QCT Condensing Humidity
Bare Cold Rolled Steel
168 hours


Formula MAJ-1374-2
QCT Condensing Humidity
Iron Phosphate Treated CRS
1000 hours


Formula MAJ-1374-2
Salt Spray Exposure
Bare Cold Rolled Steel
675 hours

Formula MAJ-1374-2
Salt Spray Exposure
Iron Phosphate Treated CRS
675 hours


Formula MAJ-1374-3
QCT Condensing Humidity
Bare Cold Rolled Steel
168 hours


Formula MAJ-1374-3
QCT Condensing Humidity
Iron Phosphate Treated CRS
168 hours


Formula MAJ-1374-3
Salt Spray Exposure
Bare Cold Rolled Steel
1000 hours


Formula MAJ-1374-3
Salt Spray Exposure
Iron Phosphate Treated CRS
1000 hours

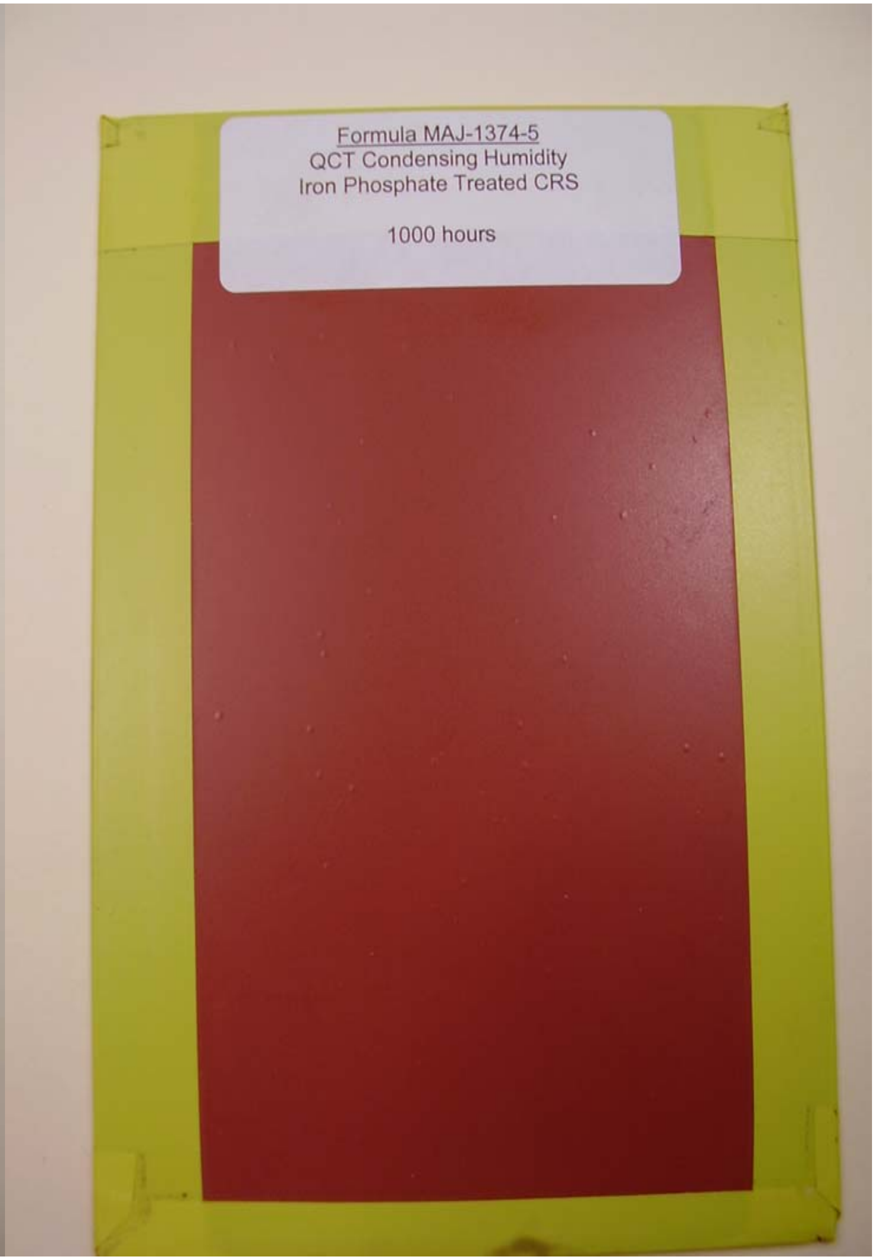

Formula MAJ-1374-4
QCT Condensing Humidity
Bare Cold Rolled Steel
1000 hours


Formula MAJ-1374-4
QCT Condensing Humidity
Iron Phosphate Treated CRS
1000 hours


Formula MAJ-1374-4
Salt Spray Exposure
Bare Cold Rolled Steel
1000 hours


Formula MAJ-1374-4
Salt Spray Exposure
Iron Phosphate Treated CRS
1000 hours

Formula 1374-5




Formula MAJ-1374-5
Salt Spray Exposure
Bare Cold Rolled Steel
1000 hours


Formula MAJ-1374-5
Salt Spray Exposure
Iron Phosphate Treated CRS
1000 hours