EFFECT OF DEPOSIT COMPOSITION AND QUALITY ON CORROSION OF ELECTROLESS NICKEL COATINGS

The corrosion resistance of an Electroless Nickel coating is a function of two factors, alloy passivity and deposit quality. Passivity is an electrochemical term which describes a metal's or alloy's loss of chemical reactivity (its reduced corrosion) under specific environmental conditions. This is normally due to the formation of a protective film only a few atoms thick, on the surface of the metal.

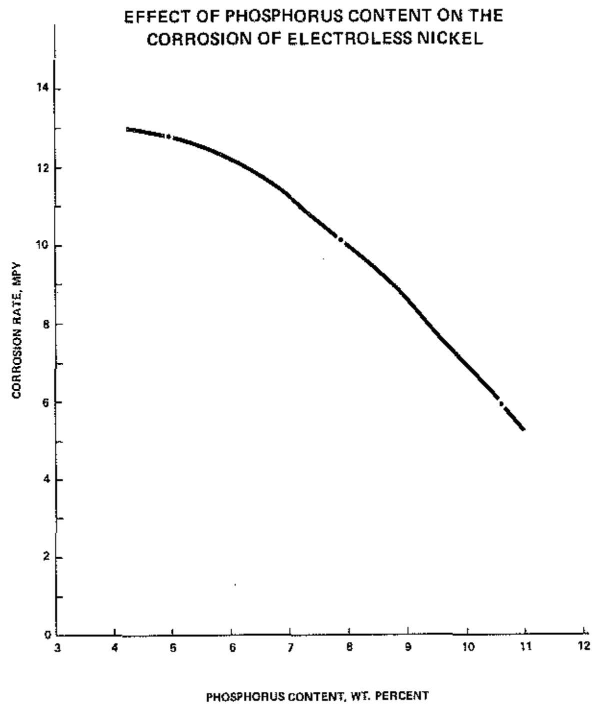
Whether a metal is passive, and the degree of its passivity, is a function of the metal's composition and its environment. For example, Type 300 stainless steels are passive and do not appreciably corrode in oxidizing media such as nitric acid or aerated seawater. If, however, these stainless steels are placed in a reducing environment, such as hydrochloric acid or deaerated seawater, they will be rapidly attacked.

ALLOY PASSIVITY

Most Electroless Nickel coatings display natural passivity and are very resistant to reducing, neutral, and most oxidizing environments. Their degree of passivity, however, is greatly affected by their phosphorus content; higher phosphorus alloys are more easily passivated and are more corrosion resistant than those with lower phosphorus concentration. This is illustrated by Figure 1, which compares the corrosion experienced by Electroless Nickel coatings containing 4½ to 10½ percent phosphorus in aerated citric acid at 122°F (50°C)[1].

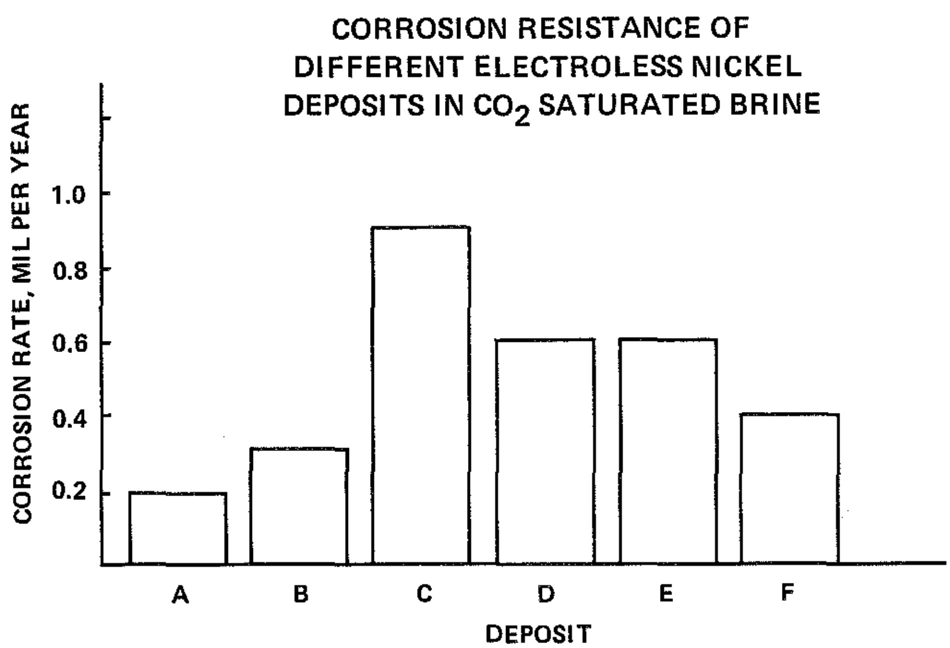
In this test, corrosion of the 10½ percent phosphorus Electroless Nickel was only about one half of that of lower phosphorus coatings. Unfortunately, most of the Electroless Nickel sold today is of the latter type, and typically contains only 7 to 9 percent phosphorus.

FIGURE 1



Often, the contaminants present in the coating are even more important to an Electroless Nickel's corrosion resistance. Most coatings are applied from baths stabilized with lead, cadmium or sulfur. Codeposition of these elements with an Electroless Nickel coating will cause a severe reduction in its passivity and corrosion resistance. This is illustrated by Figure 2, which shows the results of corrosion tests with 6 different commercial Electroless Nickel deposits in CO_2 saturated, 3½ percent salt brine at 200°F (95°C)[2].

FIGURE 2



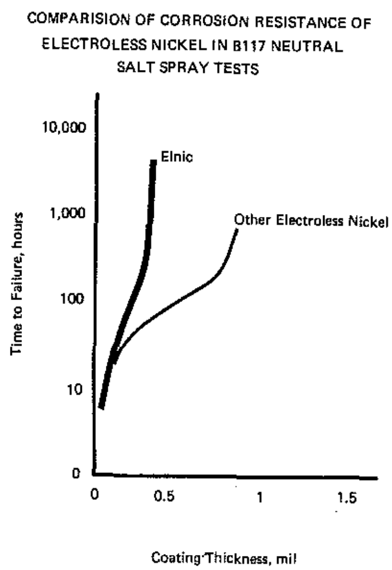
These tests showed hugh differences between the coatings. The deposit (A) had a loss of 0.2 mpy (5 μm/y) while that of the other deposits was 50 to 450 percent higher. Similar tests in 10 percent HCl at ambient temperature showed even larger differences; [illegible] and Deposit B had corrosion rates of 0.6 and 0.8 mpy (15 and 20 μm/y) respectively, while Deposits C through F were 8 to 26 mpy (200 to 600 μm/y).

The primary differences between these deposits was not their phosphorus content, but rather their baths' stabilizing system. ELNIC is applied from an organically stabilized bath, and contains only trace amounts of contaminants. Deposits B, C, D, E and F, however, were found to contain 500 to 1500 ppm of either lead, cadmium, tin or sulfur.

DEPOSIT QUALITY

The second factor controlling an Electroless Nickel coating's corrosion resistance is the deposit's quality. Electroless Nickel is free of defects. The coating is continuous. Unfortunately, the structure of most other coatings is not like this; instead they consist of many small islands of Electroless Nickel separated by cracks or pores. Since Electroless Nickel is a barrier coating and protects the underlying metal by sealing it off from the environment, these coatings offer only limited protection. Each crack and pore serves as a tunnel to allow the corrodent through the coating and to the substrate. This effect is illustrated by Figure 3, which compares the resistance of Electroless Nickels to an ASTM B117 neutral salt spray test.

FIGURE 3



While a 0.4 mil thickness of] Electroless Nickel will provide 1000 hours of salt spray resistance, with other coatings thicknesses greater than one mil may be needed to provide the same level of protection.

Defects form in most Electroless Nickel coatings for two reasons. First, the level of internal stress of low phosphorus coatings is quite high. Electroless Nickel coatings, containing only 7 to 9 percent phosphorus, develop internal tensile stresses of 3000 to 5000 psi (20 to 35 MPa). These coatings are like rubber bands tightly stretched across the surface of the part; they want to crack and open up in order to make themselves more stable.

Second, the brightening agents and heavy metal stabilizers in most Electroless Nickel baths codeposit with the coatings producing defect nucleation sites. These are zones where the metal is locally stretched and weak; they are like nicks in the edge of a rubber band. Because of the stress in the coating, the weak zone tears and pores are formed.

CONCLUSION

To provide maximum corrosion protection, both phosphorus and contaminant content must be carefully controlled. This can only be obtained by proper bath formulation and by careful bath control.

GUIDE TO THE CORROSION RESISTANCE OF ELECTROLESS NICKEL

ENVIRONMENT	CONCENTRATION WT. %	TEMPERATURE °C	°F	CORROSION RESISTANCE
Acacia	1	20	70	A
Acetic Acid	2-90	20	70	C
Acetone	100	54	130	A
Aluminum Chloride	41	20	70	D
Aluminum Sulfate (Alum)	5-27	20	70	B
Ammonium Bicarbonate	14	20	70	B
Ammonium Chloride	5-27	20	70	B
Ammonium Hydroxide	5-28	20	70	C
Ammonium Nitrate	5-66	20	70	B
Ammonium Phosphate	35	20	70	B
Ammonium Sulfate	43	20	70	A
Amyl Alcohol	100	20	70	A
Amyl Chloride	100	20	70	A
Ascorbic Acid	5	20	70	B
Atmosphere, Industrial	--	20	70	A
Atmosphere, Marine	--	20	70	A
Atmosphere, Rural	--	20	70	A
Barium Chloride	2-40	20	70	A
Barium Hydroxide	2-50	60	140	A
Beer	Product	Chilled		A
Beet Sugar Liquor	Product	20	70	A
Benzene	100	20	70	A
Benzoic Acid	1	20	70	C
Benzyl Alcohol	100	20	70	A
Borax	3	20	70	B
Boric Acid	1-5	20	70	B
Bromine, Dry	100	20	70	A
Bromine, Wet	100	20	70	B
Butadiene	100	26	80	A
Butane	100	26	80	A
Butyl Alcohol	100	20	70	A
Brine, Oil Field	--	60	140	A
Calcium Chloride	40	20	70	A
Calcium Nitrate	50	20	70	A
Calcium Hydroxide	1	60	140	A
Cane Sugar Liquor	100	95	200	A
Caprolactam	Product	82	180	A
Carbon Black	20	20	70	A
Carbon Dioxide, Dry	100	400	750	A
Carbon Dioxide, Wet	100	20	70	B
Carbon Disulfide	100	20	70	A
Carbon Tetrachloride	100	Boiling		A
Chlorine, Dry	100	20	70	A
Chlorine, Wet	100	20	70	B
Chlorobenzene	100	20	70	A
Chloroform	100	20	70	A
Chloroform	100	Boiling		B
Chrome Plating Solution	Standard	20	70	B
Chromic Acid	2-100	20	70	D
Citric Acid	5-50	20	70	C
Coffee	Product	Boiling		A
Corn Syrup Liquor	Product	20	70	B

GUIDE TO THE CORROSION RESISTANCE OF ELECTROLESS NICKEL

ENVIRONMENT	CONCENTRATION WT. %	TEMPERATURE °C	TEMPERATURE °F	CORROSION RESISTANCE
Copper Chloride	5-40	20	70	D
Copper Nitrate	5	20	70	B
Copper Plating Solution	Standard	20	70	A
Copper Sulfate	5-30	20	70	C
Cresylic Acid	1-100	20	70	A
Crude Oil	100	20	70	A
Detergent	1	20	70	A
Dextrin	1	20	70	A
Dichloroethene	100	20	70	A
Diethanolamine	30	95	200	A
EDTA	1	20	70	C
Ethyl Alcohol	100	20	70	A
Ethylene	100	20	70	A
Ethylene Dichloride	100	Boiling		A
Ethylene Glycol	100	20	70	A
Fatty Acids	100	20	70	B
Ferric Chloride	1-48	20	70	D
Ferric Nitrate	5	20	70	D
Ferric Sulfate	21	20	70	D
Flue Gas, Oxidizing	--	540	1000	A
Flue Gas, Reducing	--	260	500	D
Fluoroboric Acid	48	20	70	D
Formaldehyde	37	20	70	B
Formic Acid	10-88	20	70	B
Fruit Juices	Product	20	70	A
Fuel Oil	100	20	70	A
Gasoline	100	20	70	A
Gin	Product	20	70	A
Glucose	45	20	70	A
Glycerine	100	20	70	A
Hydrochloric Acid	1-36	20	70	C
Hydrofluoric Acid	2-49	20	20	D
Hydrogen Chloride, Dry	100	20	70	A
Hydrogen Sulfide, Dry	100	20	70	A
Hydrogen Sulfide, Wet	100	20	70	A
Iodine	0.1N	20	70	D
Isopropyl Alcohol	100	20	70	A
Jet Fuel	100	20	70	A
Kerosene	100	20	70	A
Lactic Acid	10-50	20	70	C
Lactic Acid	85	20	70	A
Lead Acetate	35	20	70	B
Lead Nitrate	36	20	70	A
Lemon Juice	Product	20	70	A
Linseed Oil	100	20	70	A
Lithium Chloride	46	20	70	A

ENVIRONMENT	CONCENTRATION WT. %	TEMPERATURE °C	°F	CORROSION RESISTANCE
Magnesium Chloride	2-50	20	70	A
Magnesium Hydroxide	2-100	20	70	A
Maleic Acid	44	20	70	A
Malic Acid	10-50	20	70	B
Mercurous Chloride	1	20	70	B
Methyl Alcohol	100	20	70	A
Methyl Cellulose	10	20	70	A
Methyl Chloride	100	20	70	C
Methyl Ethyl Ketone	100	20	70	A
Milk	Product	20	70	A
Mine Water, Acid	--	20	70	B
Molasses, Raw	Product	20	70	A
Molasses, Raw	Product	104	220	B
Monoethanolamine	20	95	200	A
Naphtha	100	20	70	A
Naphthenic Acid	100	20	70	B
Nickel Chloride	72	20	70	A
Nickel Sulfate	38	20	70	C
Nitric Acid	10-70	20	70	D
Nitrobenzene	100	20	70	A
Oil, Petroleum	100	20	70	A
Oil, Mineral	100	20	70	A
Oil, Palm	100	20	70	A
Oil, Peanut	100	20	70	A
Oil, Vegetable	100	20	70	A
Oleic Acid	100	20	70	A
Oleum	20	20	70	D
Orange Juice	Product	20	70	A
Oxalic Acid	10	20	70	C
Palmitic Acid	100	20	70	C
Paraffin	100	Molten		A
Perchloroethylene	100	20	70	A
Phenol	25-100	95	200	A
Phosphoric Acid	10-85	20	70	B
Phthalic Anhydride	10	20	70	A
Picric Acid	1	20	70	D
Polymers	100	200	400	A
Potassium Carbonate	27	95	200	A
Potassium Chloride	25	20	70	A
Potassium Ferricyanide	5-25	20	70	A
Potassium Hydroxide	2-50	20	70	A
Potassium Nitrate	24	20	70	A
Propane	100	20	70	A
Resins	100	50	120	A
Rochelle Salts	35	20	70	B
Rosin	100	Boiling		A
Rum	Product	20	70	A
Soap Wash Liquor	Product	95	200	A
Sodium Bicarbonate	2-14	20	70	B
Sodium Carbonate	18	20	70	A
Sodium Chloride	5-26	20	70	A

ENVIRONMENT	CONCENTRATION WT. %	TEMPERATURE °C	°F	CORROSION RESISTANCE
Sodium Cyanide	5-10	20	70	B
Sodium Hydroxide	2-50	120	250	A
Sodium Hypochlorite	1-5	20	70	A
Sodium Nitrate	10	20	70	A
Sodium Nitrite	42	20	70	B
Sodium Phosphate	46	20	70	A
Sodium Silicate	10	20	70	A
Sodium Sulfate	31	20	70	A
Sodium Sulfide	14	20	70	A
Soup	Product	95	200	A
Steam	--	430	800	A
Steam Condensate	--	82	180	A
Stearic Acid	2	20	70	A
Sugar Liquor	Product	20	70	A
Sulfuric Acid	1-85	20	70	C
Sulfuric Acid	85-98	20	70	D
Sulfurous Acid	2-60	20	70	D
Tall Oil	100	20	70	A
Tanning Solution	100	20	70	A
Thiourea	8	20	70	D
Toluene	100	95	200	A
Trichloroethylene	100	95	200	A
Turpentine	100	20	70	A
Urea	58	20	70	D
Varnish	100	20	70	A
Vinegar	Product	20	70	B
Vinyl Chloride	100	38	100	A
Vodka	Product	20	70	A
Water, Boiler Feed	--	200	400	A
Water, Cooling	--	38	100	A
Water, Deionized	--	82	180	A
Water, Distilled	--	20	70	A
Water, Fresh	--	20	70	A
Water, Acid Mine	--	20	70	C
Water, Sea	--	20	70	A
Wine	Product	20	70	B
Whiskey	Product	20	70	A
Xylenes	100	20	70	A
Zinc Chloride	5-10	20	70	B
Zinc Nitrate	35	20	70	B
Zinc Sulfate	50	20	70	D

NOTES:

1. Code:
   - A = Satisfactory, corrosion rate generally less than 0.1 mpy (2½ µm/y).
   - B = Usually satisfactory, corrosion rate generally less than 0.5 mpy (12½ µm/y).
   - C = Sometimes useful, corrosion rate generally less than 1 mpy (25 µm/y).
   - D = Usually unsatisfactory for long term exposure, corrosion rate greater than 1 mpy (25 µm/y).

2. All solution concentrations are shown in percentage by weight in water except where otherwise indicated.

3. The information presented in this listing is as complete and accurate as possible at the time of publication. It is intended as a guide only, and not as an implied recommendation. Variations in environments and their contaminants as well as, processing techniques, can effect corrosion resistance and must be considered.

RND: js
April 10, 1981

Revised
December 2, 1982