NATIONAL BUREAU OF STANDARDS REPORT

8347

PROGRESS REPORT

January 8, 1964 through March 31, 1964

PORCELAIN ENAMEL INSTITUTE RESEARCH ASSOCIATESHIP
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D. C.

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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1009-11-10190 | 8347

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SUMMARY

This report describes the progress during the report period on development of a standard alkali test, analysis of the five-and six-year weathering data, and plans for initiation of a new porcelain-enameled aluminum weathering test.

Several variables associated with alkali testing have been investigated, and modifications to the earlier PEI-NBS test equipment have been incorporated. Experiments established that the ratio of the solution volume to specimen area in the present equipment is such that typical alkali-resistant porcelain enamels can be satisfactorily tested at 96°C for 6 hours without the necessity of renewing the solution.

Specimens were tested in a heated and ultrasonically agitated alkaline solution in an attempt to accelerate the rate of corrosion. No significant effect was detected using a 40-watt ultrasonic generator, and no further ultrasonic tests are planned.

The PEI-Kirkpatrick alkali test apparatus was modified to accommodate six specimens. Tests showed that rate of attack was affected by position of the specimens. Additional equipment modifications intended to equalize rate of attack on specimens facing opposite directions will be checked. A low-cost commercial temperature controller was tested, and results showed it to be adequate for the intended use.

The five- and six-year weathering data for enamels exposed at Kure Beach and Washington were reduced and analyzed using new computer programs. On the basis of averages, good correlation existed between acid resistance and change in color and gloss. As a group, the acid-resistant glossy steel enamels showed the best resistance to weathering after six years' exposure.

The enamels exposed at the different sites lost gloss and changed color at different rates, depending upon severity of weathering conditions at the sites and on acid resistance of the enamels. The Kure Beach 80 site caused more severe changes in all specimens than either the Kure Beach 800 or Washington sites. The seven-year inspection will be completed and reported next quarter.

Detailed planning of the new weathering test of aluminum porcelain enamels consisted of (a) arrangements for new sites, (b) studying methods of cutting specimens from large panels, (c) providing new racks, and (d) making the necessary arrangements for procuring and labeling specimens.

Photomicrographs of sheared and sawed edges are presented showing the extent of coating damage for each type of cutting.

I. STANDARD ALKALI TEST

Introduction

The extensive use of automatic laundry and dishwashing equipment, together with increasing water temperatures and more aggressive detergents, have intensified the need for greater alkali resistance in porcelain enameled products. Various testing procedures[1-12] are being used to evaluate alkali resistance. These employ different testing temperatures, testing times, alkaline solutions, and ratios of solution volume to exposed specimen surface.

Many of these test methods are satisfactory for development of improved porcelain enamel compositions. However, there is an urgent need for a standard or referee method which permits all laboratories to obtain equivalent test results for any given enamel. Such a method must recognize and control the many test variables that influence results. While simulating service conditions insofar as possible, the selected test method should also accelerate the rate of attack so that appreciable attack can be obtained in relatively short time periods. Finally, the test must rank porcelain enamels in the same order of merit as experienced in field performance.

One of the most important variables that affect the rate of attack is the testing temperature, the higher the temperature, the greater the rate. It has been shown that, for a titania-opacified sheet steel enamel, a change from 90° to 91°C in solution temperature changes the weight loss by about 12%.[10] This extreme temperature dependence requires that a standard test be performed at a carefully controlled temperature. The boiling temperature utilized by most present testing methods, while roughly constant, is influenced by rate of boil, elevation above sea level and atmospheric pressure. Thus, temperature control associated with boiling is insufficient to achieve reproducible results among different laboratories.

Several years ago an ad hoc committee headed by John T. Roberts recommended a test procedure based largely on the work of Kirkpatrick, et al., at NBS. Five laboratories purchased the necessary equipment and participated in a round-robin test. Analysis of the resulting data showed that the recommended test procedure was reproducible to within three percent. However, the equipment was not considered acceptable because of a design deficiency, relatively high cost, and low capacity (three specimens per test).

Our current work on equipment modifications is an attempt to overcome these objections.

Results and Discussion

1. Solution Renewal

There has been some question as to whether or not addition of fresh alkali solution after each testing interval would affect the weight loss. If the solution is not refreshed it may become sufficiently comtaminated or diluted by reaction products to give a lower rate of attack.

In order to seek a partial solution to this question, a series of tests were made with specimens coated with the same alkali-resistant porcelain enamel. Results are given in Table 1. Under the selected conditions, there was no statistically significant difference between the results for specimens tested in solutions that were refreshed each two hours and those tested for the entire six hours in a solution that was not refreshed. This type of result implies that the testing of enamels with high alkali resistance cannot be accelerated with the present equipment through use of fresh alkali solution at periodic intervals. However, for enamels of poor resistance, or for longer testing times, refreshing of the solution might well cause a significant effect.

2. Effect of Ultrasonic Agitation on Rate of Attack

The mechanism of corrosion of porcelain enamel by alkali solutions is not well understood. Kirkpatrick and co-workers[10] have discussed several possibilities. These involve preferential adsorption of foreign ions at the glass-solution interface, the rate-controlling effects of dissolved glass in the solution, and the presence at the interface of a layer of hydrolized glass. If such a layer does tend to form, then a strong ultrasonic agitation of the solution should inhibit its growth and accelerate the rate of attack.

In order to explore this possibility, tests were made in which a 40-watt ultrasonic generator was used to agitate a heated 5% sodium pyrophosphate solution. The bath temperature was controlled at 78°C (172°F), the maximum temperature at which the ultrasonic equipment could be used. A constant level device was incorporated to replace water that evaporated from the solution, and a motor driven stirrer was used to inhibit thermal stratification and thus to improve temperature control.

The weight-loss data after 6 hours of treatment is given in Table 2. Although the average weight loss was approximately 5% greater when the solution was agitated ultrasonically, this increase was not statistically significant. While this test does not preclude the possibility of a real effect of ultrasonic agitation on the rate of attack, the results do suggest that the effect is not a large one. No further work is planned on acceleration of corrosion with ultrasonic generators.

3. Increasing Specimen Capacity

The specimen holder boxes were altered by cutting an opening in the back side of the box and inserting an "O" ring seal so as to permit two specimens rather than one to be tested in each box.

With the stirring arrangement that is used in the present apparatus, there is no assurance that attack on specimens facing toward the center of the container will be the same as that on specimens facing the container wall. To determine if such a difference exists, determinations were made with a series of specimens prepared from the same white porcelain enamel. The tests were made at 96°C ± 0.15°C for six hours in a 5% sodium pyrophosphate solution.

The results are given in Table 3. The average weight loss for specimens facing the center was approximately 12% greater than those facing the container wall.

A "t" test based on differences between specimen pairs was calculated as follows:

$$t = \frac{(\bar{d} - 0)\sqrt{n}}{s_d} = \frac{\bar{d}\sqrt{n}}{s_d}$$

where $\bar{d}$ = mean of the differences,

n = number of differences,

s_d = standard deviation of the difference, and is obtained from

$$(s_d)^2 = \frac{1}{n-1}(d_1^2 + d_2^2 + \ldots d_n^2 - n\bar{d}^2)$$

The "t" value obtained was 8.41. Comparison with a critical value of 2.31 at the 95% confidence level indicates that the difference between inside and outside positions is significant.

An analysis of variance of the data in Table 3 confirmed the significance of this difference and also showed that the specimens did not differ significantly one from another.

4. Temperature Controller

A commercially available temperature controller is under test as a possible substitute for the more expensive controller previously used with the alkali test equipment. Tests were made to determine the degree of control obtainable and its dependence on rate of stirring. The data are given in Table 4. For the speeds so far explored, 1400 rpm provides ± 0.15°C control at a mean temperature of 96°C. Although this is considered acceptable, there is good likelihood that it may be further improved by use of more powerful heaters and/or higher stirrer speeds.

Plans for Next Report Period

Additional equipment modifications will be investigated in an attempt to equalize the rate of attack on specimens facing the container wall and those facing the center. These include:

(1) Changing the stirrer speed

(2) Inserting vanes or baffles to equalize the rate of flow of solution past the two positions

(3) Raising the box height in the container to permit a greater flow of solution under the boxes

(4) Reversing the specimen boxes at uniform intervals so as to equalize the attack on the two specimens.

Of the four alternatives the latter, while easiest to incorporate, is the least attractive because of the extra attention required of the operator. Therefore, the greatest emphasis will be placed on the first three possibilities.

The effect of higher stirrer speeds and more powerful heaters on the degree and reliability of temperature control will also be determined.

It is expected that a decision on the suitability of the modified version of the alkali test equipment will be reached during the next quarter.

II. PEI-NBS WEATHERING TEST

Introduction

The present weathering test was initiated in 1956, and included 94 different enamels which were divided into eight types:

1. Regular glossy steel- acid-resisting
2. Mat aluminum
3. 1300°F steel
4. Mat steel
5. Regular glossy steel - non-acid resisting
6. Glossy aluminum
7. 1000°F steel
8. Red and yellow screening pastes.

The weathering test has seven exposure sites: Kure Beach, North Carolina - 80 feet from the ocean; Kure Beach, North Carolina - 800 feet from the ocean; New Orleans, Lousiana; Los Angeles, California; Dallas, Texas; Pittsburgh, Pennsylvania; and Washington, D. C. The enamels exposed at Washington and the two Kure Beach sites have been inspected annually, those at Pittsburgh and Los Angeles have been inspected after 1, 2, 3 and 7 years' exposure, while those at Dallas and New Orleans have been inspected after 1, 3, and 7 years' exposure. A report entitled "Effect of Exposure Site on the Weather Resistance of Porcelain Enamels Exposed for Three Years" has been published.[13/]

Two quantitative measures of the effect of weathering on porcelain enamels are changes in gloss and color. The 45-degree specular gloss is measured with a Hunter Precision Glossmeter, calibrated and operated in accordance with the ASTM Designation C-346 "Standard Method of Test for 45° Specular Gloss of Ceramic Materials." The measurements are made at four fixed orientations at the center of each specimen and are compared to similar measurements made before exposure. The results are reported as the percent of the initial specular gloss retained.

The changes in color are measured with a Hunter Color Difference Meter. Measurements are made at the beginning of the investigation and after exposure. The color change is expressed as the color stability index, which is equal to 100 minus the color difference in NBS units.

The weathering characteristics have also been correlated with the spot-test acid resistance of the enamels. The acid resistance rating was made in accordance with the "Test for Acid Resistance of Enamels, Part I, Flatware"[14/], except that the grading of Class A and Class B enamels was modified to conform with the "Specification for Architectural Porcelain Enamel on Steel for Exterior Use."[15/]

After three years' exposure three of the experimental screening paste enamels had become so badly weathered that they were withdrawn from the test. The 91 remaining enamels were evaluated after five and six years' exposure.

Results and Discussion

1. Computer Programs for Data Reduction

The five- and six-year weathering data for three exposure sites had been collected earlier but it had not been reduced. Before the data could be processed on the Bureau's new 7094 computer, the old 704 computer program needed to be converted to a Fortran program. This conversion was completed during the quarter. The new program computes the color stability index and the percent gloss retained for each of the exposed specimens. It then calculates the average, sum of the squares, and standard deviation for the three specimens of each enamel at one site and for each enamel at all sites.

One of the features of the Fortran program is that it enables the computer to punch cards with summary data including specimen number, average percent gloss retained, average color stability index, acid rating, and type of enamel. An Omnitab program then instructs the computer to sort the data on the cards by (1) type and (2) acid rating. Once these data are sorted, the computer plots the color stability index and the percent gloss retained against acid rating for each type of enamel in the test. An example of the type of data the computer plots is shown in Figure 1. After each plot the computer prints a statistical summary which includes the number of specimens, sum, sum of the squares, average, maximum, and minimum values of the data plotted. When the data are sorted by acid rating, the statistical summary is given for each acid rating and the plot is omitted.

Although these new programs cannot reduce the time necessary to take the actual gloss and color measurements, they have greatly reduced the time required to process and analyze the data, thus saving a large portion of the Research Associate's time. Once the five- and six-year data were collected, it took only fifteen minutes of computer time to calculate, plot, and summarize the gloss retention and the color stability results.

2. Weather Resistance of Different Types of Enamel

Table 5 gives the average color stability index and percent gloss retained for each type of enamel after five and six years' exposure. In all cases, the changes in gloss and color for the additional year of exposure (from 5 to 6 years) are small and are not statistically significant. Analysis of the data in Table 5 shows that, as a group, the glossy acid-resistant steel porcelain enamels are the most resistant to changes in color. This result is in agreement with the 3-yr analysis[13]. It is important to point out, however, that individual enamels of any type deviate from the average.

3. Correlation Between Acid Resistance and Weather Resistance

As was expected, the weather resistance of enamels in this test correlated with the citric acid spot test rating when averages were considered. This is illustrated in Figures 2, 3, and 4. Many individual specimens of low acid ratings have good gloss retention and a high color stability, and some AA and A enamels have low gloss retention and color stability. This scatter in the data for glossy steel enamels is illustrated in Figure 1.

The high weather resistance of Class AA and Class A glossy steel porcelain enamels is illustrated in Figure 2. These two classes of enamel drop to between 78 and 80 percent gloss retention after two years' exposure at Washington, after which they decrease only very slowly with additional exposure time. The average gloss retention of these two classes of enamels differ from each other by not more than five percent during the six-year weathering period.

The Class B enamels have a slightly larger gloss loss, retaining only 73 percent of their initial gloss after two years' exposure. They also show only a slight change in gloss between two and six years' exposure.

The change in gloss is much greater for the Class C and D enamels. They retain only 62 and 59 percent of their initial gloss at two years and 61 and 53 percent gloss at the end of six years' exposure.

The differences in the color stability index (see Figure 3) of the Class AA and A and the Class C and D glossy steel enamels is noted by the decrease in the rate of color change of the AA and A enamels after two years' exposure while the C and D enamels continue to change color at about the same rate from two to six years as they did during the first two.

As there were no colored glossy steel enamels with a B acid rating in the test, the color retention of this class of enamels cannot be evaluated.

The averages for all enamels of the different acid ratings after five years' exposure are given in Fig. 4 and after five and six years in Table 6. It can be seen that there is not much difference in the weathering behavior of the Class AA, A and B enamels at the moderate site (Washington) but that the differences between these same enamels are significant at the severe site (Kure Beach, 80 feet).

4. Comparison of Exposure Sites

The gloss data for the enamels exposed at Kure Beach - 80 feet, Kure Beach - 800 feet, and Washington indicate a significant difference (95 percent confidence level) between Kure Beach - 80 feet and Kure Beach - 800 feet, and Kure Beach - 80 feet and Washington, while there is no significant difference between Kure Beach - 800 feet and Washington. The Kure Beach - 80 feet site was ranked as severe, and the other two as moderate at the end of three years' exposure [13/]. After three additional years of exposure Kure Beach - 80 feet remains a severe site, while Washington and Kure Beach - 800 feet remain as moderate sites.

5. The Effect of Exposure Time

The changes in gloss and color of the glossy steel acid resistant enamels (AA, A, and B) are illustrated in Figure 5. The enamels exposed at Washington lose gloss rapidly during the first two years' exposure with little further loss during the next four years. These same enamels lose about two NBS units of color during the first year's exposure. The color loss remains near this level with exposure up to six years. The enamels exposed at Kure Beach - 80 feet did not follow this type of curve inasmuch as the specimens at this site continued to change gloss and color throughout the six years' exposure.

Plans for Next Report Period

The seven-year exposure data have been collected for all sites except the two at Kure Beach. These data will be reduced. Also, measurements will be made on the Kure Beach specimens. It is hoped that the preparation of the 7-yr report can be started during the next quarter with a view to publication late in 1964 or early 1965.

Boiling acid solubility tests have been made on storage specimens of the aluminum enamels. In the next quarter the test will be made on some of the storage specimens of glossy steel enamels to determine if the resulting weight loss correlates better with the weathering characteristics of the enamels than does the spot test rating.

III. NEW ALUMINUM WEATHERING PROGRAM

Introduction

On January 9, 1964 the Porcelain Enameled Aluminum Council's Weathering Test Committee voted to initiate a weathering test of porcelain enameled aluminum.

The tentative plans are to include the following colors in the test:

White: semi gloss and full gloss, one and two coats

Black: mat, semi gloss and full gloss, one coat

Red: full gloss, one coat

Green: full gloss, one coat

Pastel Green: mat and semi gloss, two coats

Pastel Blue: semi gloss, two coats

Pastel Grey: semi gloss, two coats

Pastel Brown: semi gloss, two coats

Pastel Yellow: semi gloss, two coats .

In addition to studying the effect of weathering on coloring oxides with the frit commonly used to produce that color, it was decided to use five different production frits with the same color. Light and dark green were chosen for this part of the investigation.

To achieve better uniformity among specimens of the same enamel, it was decided to cut the 4½ by 4½-inch test specimens from a 3 by 5-foot sheet of enameled aluminum rather than to fabricate each specimen individually. To determine how the large sheet could best be prepared into specimens with minimum damage to the enamel, cuts were made with a band saw, a radial saw, and a shear. The band saw used had a ½-inch wide blade with a 12-8 broach tooth set. The radial saw had a 16-inch diameter, carbide tip blade which was revolving at 3524 rpm, and the shear was a hand shear. The specimen edges, after cutting, were examined with a metallographic microscope. Photomicrographs are shown in Figures 6, 7 and 8. It can be seen that the band saw cuts with minimum chipping damage to the enameled surface. The radial saw gives a smoother edge but the chipped enamel surface is much wider and in some places the bare metal is visible. The shear not only chips a wide area of the enamel from the metal, but it also causes cracks which extend into the unchipped enamel surface. On the basis of this information, it has been decided to cut the enameled sheets with a band saw.

The specimens are to be exposed at Kure Beach, Los Angeles, New York City, and Washington. Permission has been obtained to put exposure racks on a government building in New York City, and arrangements are being made to place exposure racks on roof tops in Washington and Los Angeles, as well as at the International Nickel Company's exposure site at Kure Beach, North Carolina. There is also an excellent possibility of establishing a fifth exposure site in Canada.

Plans for Next Report Period

Procurement of the 36 by 60 by 0.064-inch sheets of porcelain enameling grade 6061 aluminum alloy with an H-12 temper has been arranged. These will be sent to the Research Associate who will divide the sheets into small lots for shipment to the fabricators. Current planning calls for the sheets, coated with the selected enamels, to be in the hands of the Research Associate by the end of the next quarter.

IV. STANDARD REFERENCE MATERIALS

The following stock of standards was on hand April 1, 1964:

Corundum abrasive, March 1960 issue, for subsurface abrasion test - 249 lbs., 83 jars

Standard Pennsylvania Glass Sand for surface abrasion test, July 1963 issue,-342 lbs., 114 jars

Distinctness-of-Image Gloss Standards - 20 sets

Calibrated Glass Plates for Abrasion Testing - 5 dozen.

A new supply of glass plates has been ordered and will be calibrated next quarter.

Respectfully submitted,

M. D. Burdick
M. A. Rushmer
Research Associates

TABLE 1. Effect of Refreshment of Alkali Solution on Weight Loss.

Test Period	REFRESHED SOLUTION[a]		SOL. NOT REFRESHED[b]		
	Specimen Number	Weight Loss[c] (mg.)	Specimen Number	Weight Loss[c] (mg.)	Difference in Wt. Loss (mg.)
First two hours	B-12	0.0281	B-11	0.0367	+ 0.0086
	B-24	.0145	B-31	.0155	+ .0010
	B-36	.0154	B-42	.0169	+ .0015
Average		0.0193		0.0230	
Second two hours	B-12	0.0377	B-11	0.0417	+ 0.0040
	B-24	.0180	B-31	.0191	+ .0011
	B-36	.0188	B-42	.0224	+ .0036
Average		0.0248		0.0277	
Third two hours	B-12	0.0560	B-11	0.0469	- 0.0091
	B-24	.0218	B-31	.0206	- .0012
	B-36	.0233	B-42	.0235	+ .0002
Average		0.0337		0.0303	

Average difference in wt. loss after 6 hrs = 0.00107 mg.

a/ Fresh solution added after each 2-hr test period.

b/ Same solution used for the entire 6-hr test period

c/ Total wt. loss for 3 5/16 in. diam. test area.

TABLE 2. Comparison of Corrosion Rates of Porcelain Enamel With and Without Ultrasonic Agitation

(A) With Ultrasonic Agitation of Alkali Solution

Specimen No.	Weight Loss	
	mg.	mg/in^2
F-19	0.0179	0.0005594
F-20	.0177	.0005531
F-21	.0176	.0005530
F-22	.0205	.0006046
F-23	.0197	.0006156
F-24	.0188	.0005875
Average	.0187	.000585
Std.Dev.	.00119	
Coef.of var.	6.4%	

(B) Without Ultrasonic Agitation of Alkali Solution

Specimen No.	Weight Loss	
	mg.	mg/in^2
F-25	0.0169	0.0005281
F-26	.0157	.0004906
F-27	.0173	.0005406
F-28	.0182	.0005687
F-29	.0193	.0006031
F-30	.0190	.0005938
Average	.0177	.000554
Std.Dev.	.00136	
Coef.of var.	7.7%	

TABLE 3. Effect of Specimen Position in Holder on Weight Loss

Inside			Outside			
Specimen No.	Weight Loss		Specimen No.	Weight Loss		Weight Loss Difference
	mg.	mg/in^2		mg.	mg/in^2	mg/in^2
F-2	0.0282	0.003272	F-1	0.0294	0.003411	0.000139
F-3	.0288	.003342	F-4	.0251	.002912	.000430
F-5	.0259	.003005	F-6	.0241	.002796	.000209
F-7	.0286	.003318	F-8	.0249	.002889	.000429
F-10	.0290	.003365	F-9	.0248	.002878	.000487
F-11	.0279	.003237	F-12	.0238	.002762	.000475
F-32	.0265	.003075	F-31	.0237	.002750	.000325
F-33	.0277	.003214	F-34	.0230	.002669	.000545
F-36	.0260	.003017	F-35	.0230	.002669	.000348
Average	.0276	.003256	Average	.0246	.002941	.000376
Std.Dev.	.0012	.0001317	Std.Dev.	.0019436	.0002373	.0001342
Coef.of var.	4.35%	4.34%	Coef.of var.	7.87%	7.88%	

TABLE 4. Effect of Stirrer Speed on Temperature Control

Speed of Stirrer	Heating Time	Cooling Time	Solution Maximum	Temperature Minimum	Total Length of Control Cycle	Control Range
R.P.M.	Min.	Min.	°C	°C	Min.	°C
800	4.73	0.80	97.3	96.9	5.52	0.40
1000	4.60	.83	96.5	96.1	5.44	.40
1200	7.00	1.12	96.2	95.7	8.25	.50
1400	3.07	0.60	96.2	95.9	3.67	.30

Table 5. Average Gloss and Color Stability Index for the Types of Enamels Tested

Type of Enamel	Number of Enamels	Exposure Site	Ave.% Gloss Retention at 5 yrs	Ave.% Gloss Retention at 6 yrs	Ave.Color Stab.Index at 5 yrs	Ave.Color Stab.Index at 6 yrs
Glossy Steel	24	Kure Beach 80 ft.	53.5	52.2	94.3	95.6
Acid Resistant		Kure Beach 800 ft.	70.1	61.3	98.2	98.0
		Washington	76.4	77.1	98.4	98.4
Mat Aluminum	4	Kure Beach 80 ft.	63.3	57.1	93.8	93.3
		Kure Beach 800 ft.	92.8	87.3	93.5	94.1
		Washington	62.0	66.5	97.3	96.9
1300°F Steel	4	Kure Beach 80 ft.	57.2	55.9	93.0	93.2
		Kure Beach 800 ft.	73.9	70.6	96.1	96.6
		Washington	81.3	80.5	96.8	97.1
Mat Steel	18	Kure Beach 80 ft.	46.0	45.3	95.6	95.0
		Kure Beach 800 ft.	62.1	58.4	94.7	95.4
		Washington	61.3	59.9	94.8	94.3
Regular Glossy	16	Kure Beach 80 ft.	30.9	30.8	91.5	93.2
Steel		Kure Beach 800 ft.	49.1	38.3	95.6	94.9
Non-acid Resisting		Washington	58.0	57.4	92.7	92.0
Glossy Aluminum	10	Kure Beach 80 ft.	14.0	13.0	86.3	84.7
		Kure Beach 800 ft.	50.7	46.5	88.2	86.6
		Washington	58.4	57.3	94.4	94.9
1000°F Steel	2	Kure Beach 80 ft.	27.6	25.5	69.6	66.5
		Kure Beach 800 ft.	76.5	75.6	71.2	71.1
		Washington	68.0	67.4	87.1	87.5
Red and Yellow	13	Kure Beach 80 ft.	30.6	28.7	76.0	76.2
Screening Paste		Kure Beach 800 ft.	69.3	59.6	78.1	77.8
		Washington	63.6	61.7	81.8	82.1
All Types	91	Kure Beach 80 ft.	40.5	39.2	89.5	89.7
		Kure Beach 800 ft.	63.7	56.7	91.5	91.3
		Washington	65.8	65.3	93.0	92.9

Table 6. Effect of Acid Resistance on the Average Gloss and Color Retention of All Enamels Tested

(A) PERCENT GLOSS RETENTION

Exposure Site	Class AA		Class A		Class B		Class C		Class D	
	5 yr	6 yr	5 yr	6 yr	5 yr	6 yr	5 yr	6 yr	5 yr	6 yr
Kure Beach 80 ft.	48.9	46.9	43.0	41.1	39.2	39.3	37.0	35.2	26.2	26.5
Kure Beach 800 ft.	75.0	68.8	64.5	57.1	66.9	62.6	56.7	49.6	48.2	35.5
Washington	67.6	68.5	72.2	72.9	68.6	67.0	57.7	55.6	55.5	54.7

(B) COLOR STABILITY INDEX

Exposure Site	Class AA		Class A		Class B		Class C		Class D	
	5 yr	6 yr	5 yr	6 yr	5 yr	6 yr	5 yr	6 yr	5 yr	6 yr
Kure Beach 80 ft.	92.7	93.1	88.8	88.9	87.8	86.7	89.6	90.3	89.8	91.5
Kure Beach 800 ft.	95.4	95.0	90.9	90.0	88.8	89.3	91.5	91.3	94.8	93.9
Washington	96.0	96.3	93.3	93.2	93.9	93.7	91.1	90.8	89.9	89.7

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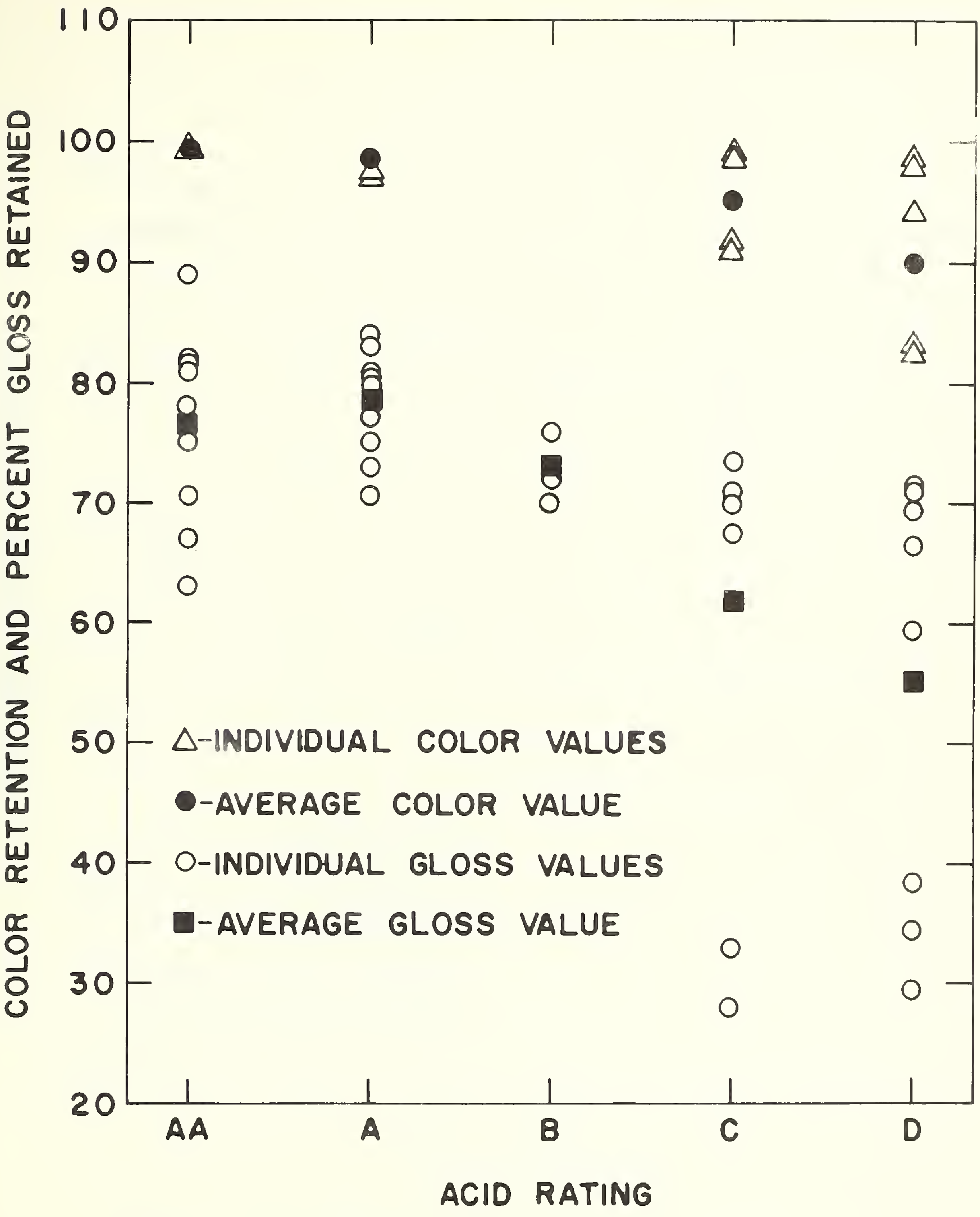

Figure 1. Five-year weathering data for glossy steel enamels with different citric acid spot test ratings, exposed at Washington. Gloss data for all enamels; color data for non-white enamels only.

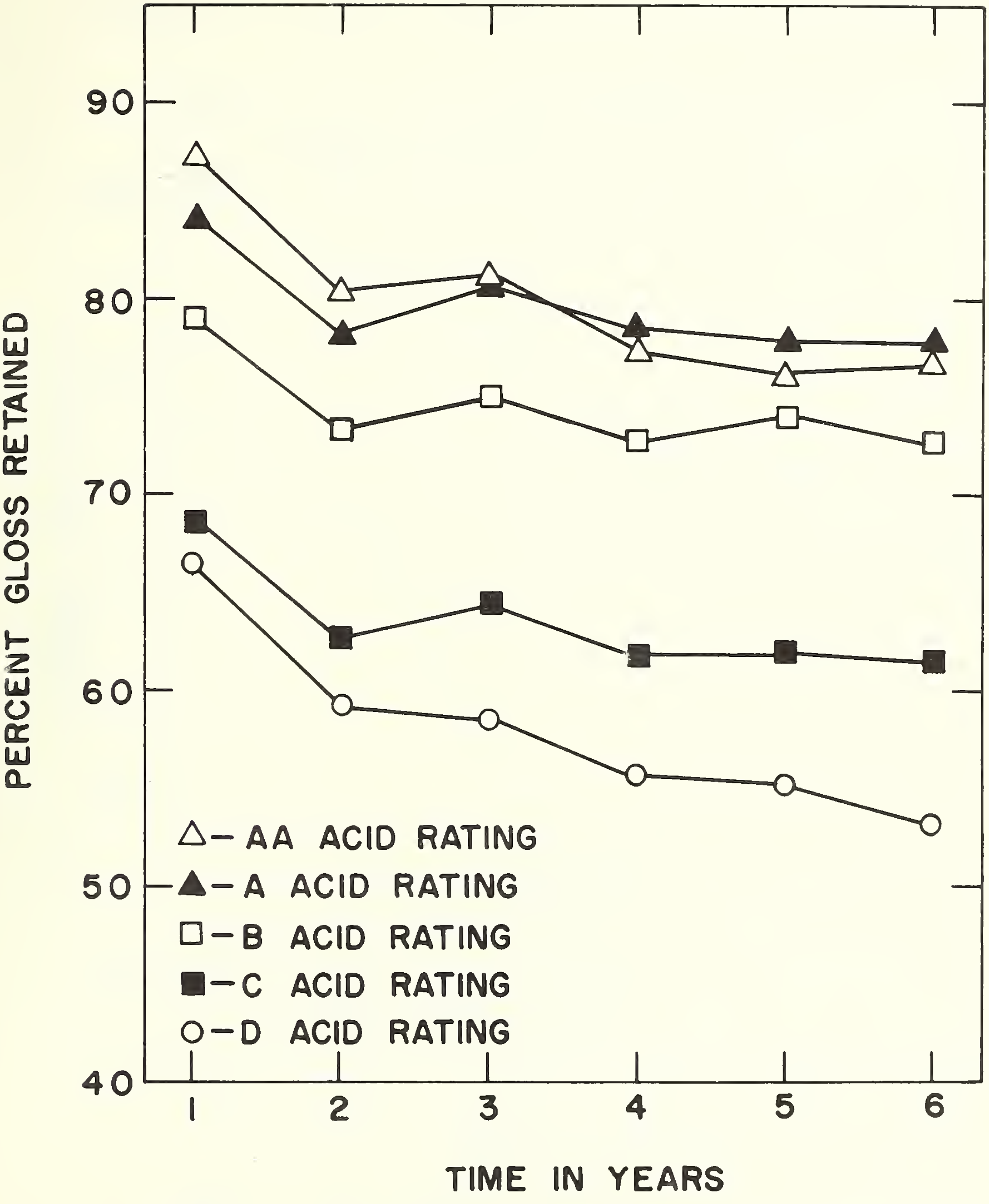

Figure 2. The effect of time on the gloss retention of all glossy steel enamels exposed at Washington.

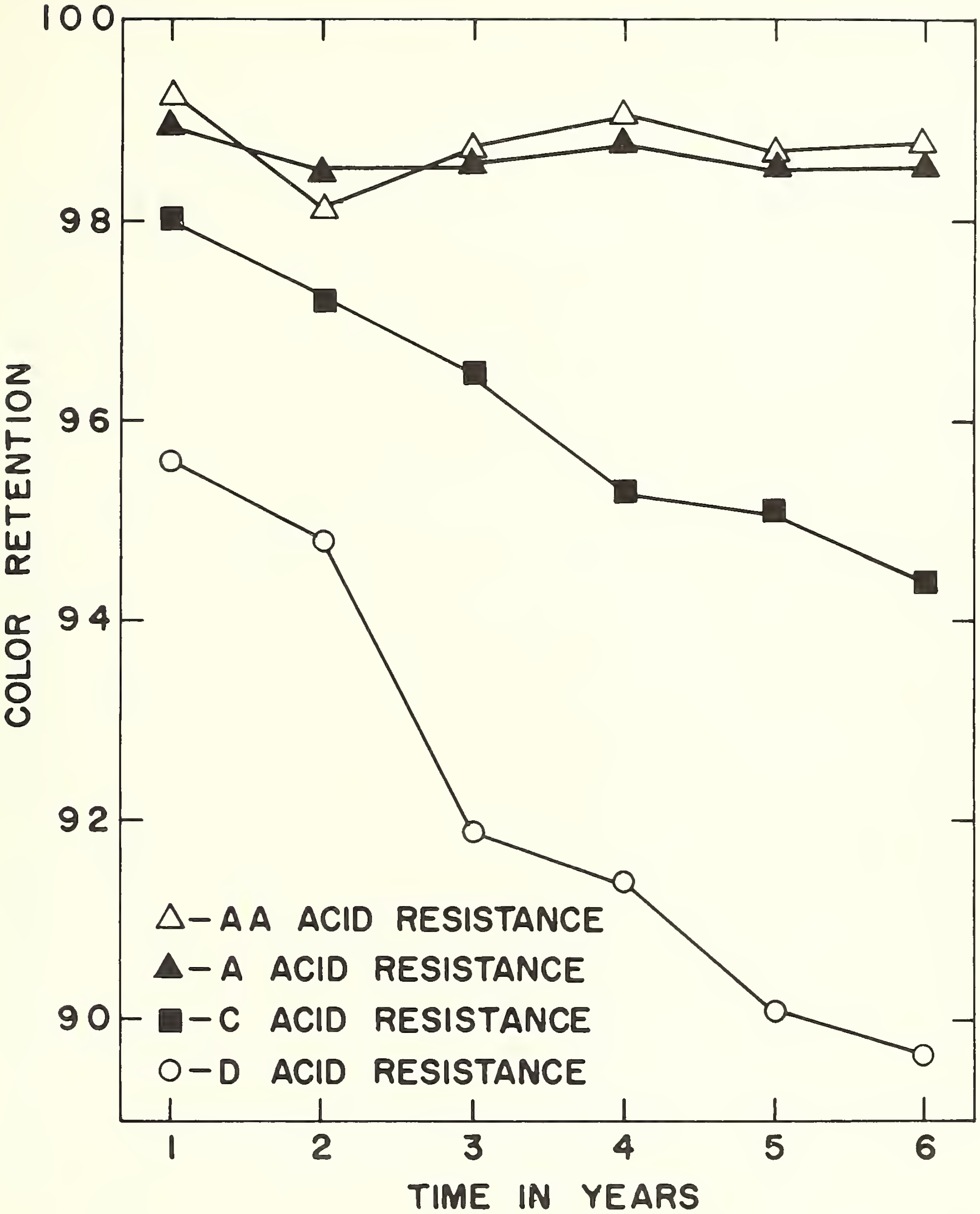

Figure 3. The effect of time on the color retention of all non-white gloss steel enamels exposed at Washington.

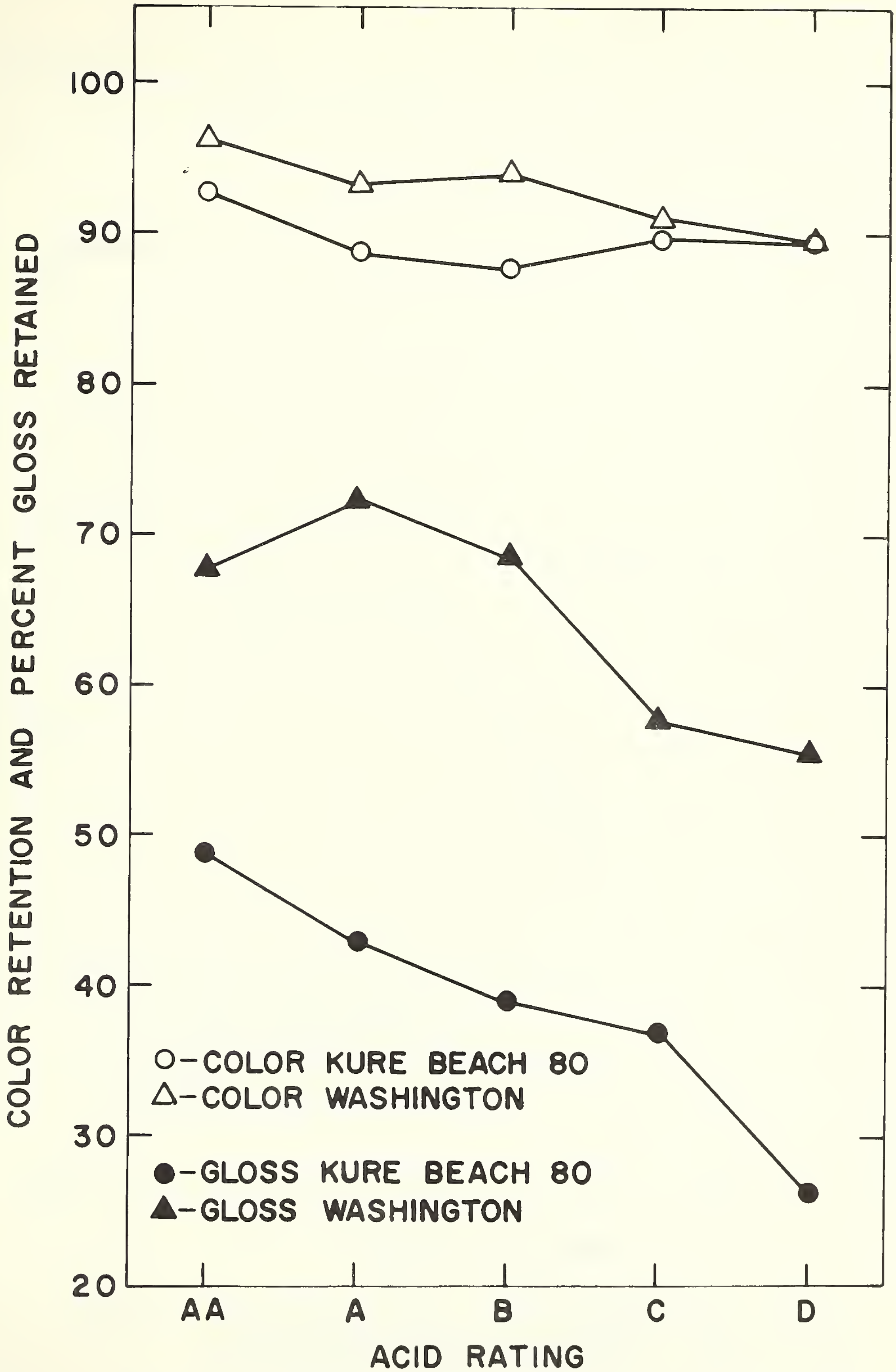

Figure 4. Five-year weathering data for all enamels tested with different spot test ratings. Gloss data for all enamels, color data for non-white enamels only.

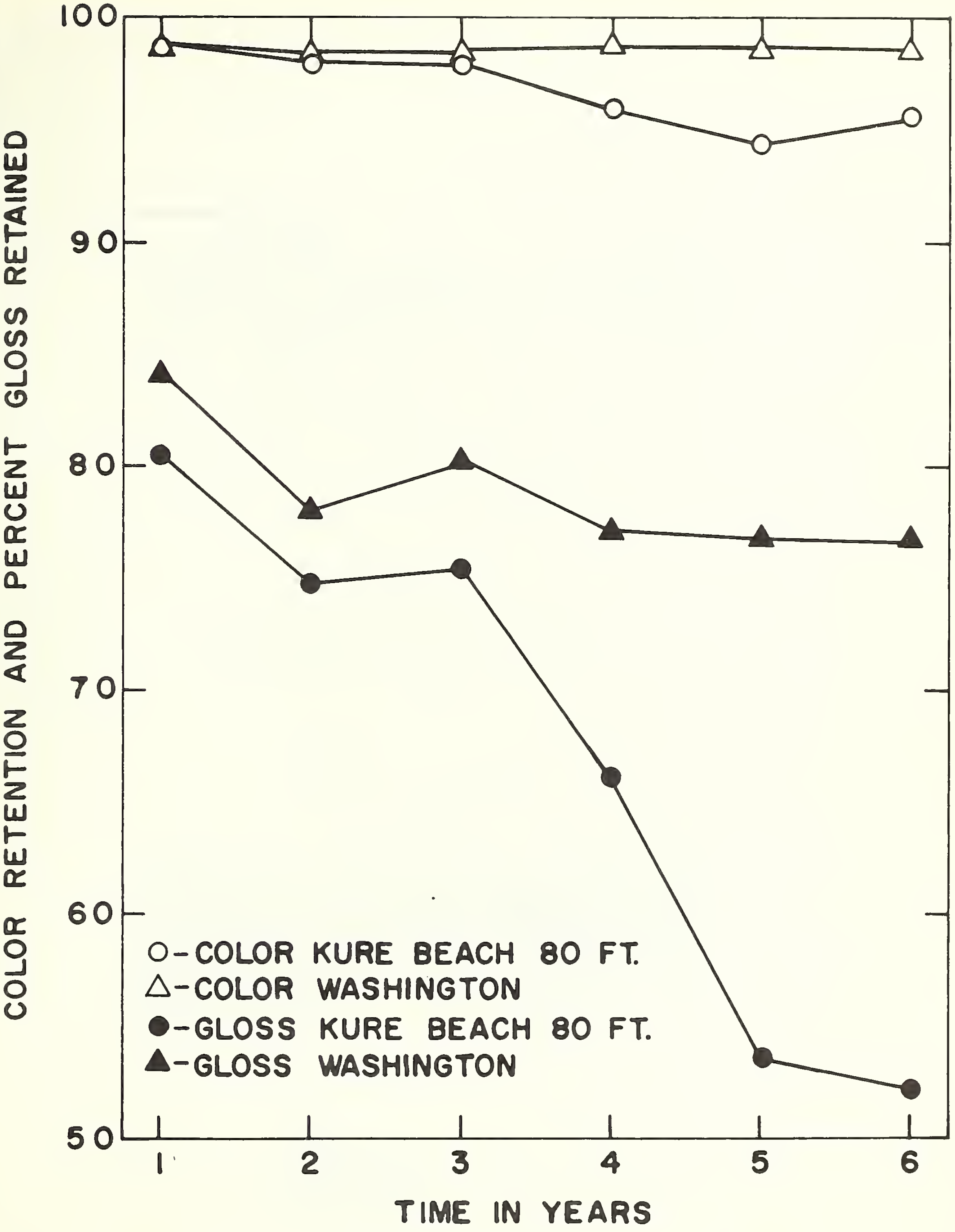

Figure 5. The effect of time on gloss and color retention of glossy steel enamels - acid-resisting type, exposed at Washington, and Kure Beach-80 ft. Gloss data for all enamels, color data for non-white enamels only.

Edge of Specimen

Chipped Enamel Surface

Original Enamel Surface

Fig. 6

Photomicrograph Illustrating Chipping of Porcelain Enameled Aluminum Surface After Cutting Specimen with a Band Saw

Edge of Specimen

Chipped Enamel Surface

Original Enamel Surface

Fig. 7

Photomicrograph Illustrating Chipping of Porcelain Enameled Aluminum Surface after Cutting Specimen with a 16 inch Radial Saw

Fig. 8

Photomicrograph Illustrating Chipping and Cracking of Porcelain Enameled Aluminum Surface after Cutting Specimen with a Shear

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