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NATIONAL BUREAU OF STANDARDS REPORT

10 031

DEVELOPMENT OF METHODS OF TEST FOR QUALITY CONTROL OF PORCELAIN ENAMELS

Progress Report

January 1 through March 31, 1959

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS REPORT

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Progress Report

DEVELOPMENT OF METHODS OF TEST FOR QUALITY CONTROL OF PORCELAIN ENAMELS

by
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Sponsored by
Porcelain Enamel Institute

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

SUMMARY

Complete data are given for fifty-one porcelain enamels on aluminum after three years of exposure testing at five sites.

Data is given to show the degree of reproducibility which may be expected in determinations of a scratch-abrasion index. This index has permitted the comparison on a single scale of various materials with indices within the range of 1.0 to 22.5 and appears to significantly distinguish between values separated by approximately 0.3 index numbers.

PROGRESS REPORT

DEVELOPMENT OF METHODS OF TEST

FOR QUALITY CONTROL OF PORCELAIN ENAMELS

I. WEATHERING OF PORCELAIN ENAMELS

INTRODUCTION

In 1964 the Aluminum Council of the Porcelain Enamel Institute authorized an exposure test consisting solely of porcelain enamels on aluminum. Three specimens of each of fifty-one enamels included in the test were exposed at Kure Beach, North Carolina; Washington, D. C.; New York, New York; Los Angeles, California; and Montreal, Canada. In addition to the exposed specimens, three specimens of each enamel were kept in dry dark storage.

Seven Nature-Tone enamels on aluminum were added to the test program after one year's exposure. These Nature-Tone enamels have now been exposed for two years, while the fifty-one original enamels have been exposed for three years. The 3-year inspection of these enamels was completed during this report period with the examination of the enamels exposed at Montreal and Los Angeles. This report presents many observations relative to all exposure sites as well as data pertinent only to the enamels inspected during this report period.

INSPECTION PROCEDURE

A. Cleaning of Specimens

The specimens from the exposure sites were returned to the laboratory to be inspected. Before proceeding with the inspection, all specimens were cleaned by 1) scouring 30 strokes using a light pressure on a sponge that had been moistened with a one percent, by weight, solution of trisodium phosphate and sprinkled with calcium carbonate, 2) rinsing with tap water, 3) rinsing with distilled water, and 4) rinsing with alcohol. This procedure adequately cleaned the specimens exposed at Kure Beach, Washington, Los Angeles and Montreal, but the specimens exposed at New York City required much more vigorous scouring with the calcium carbonate to remove the tightly adherent dirt film from the specimens.

B. Visual Inspection

After the above cleaning process, the specimens were examined visually for spalling or any unusual color or gloss changes.

C. Gloss and Color

The 45° specular gloss of the specimens was measured at four orientations near the center of the specimen. The gloss is reported as percentage gloss retained after exposure.

The change in color was measured with a color difference meter. One of the three storage specimens of each enamel was used as the color standard to obtain the maximum efficiency with this type of instrument. The color change is reported as color retention which is 100 minus the color change in NBS units.

RESULTS AND DISCUSSION

A. Visual Inspection

A visual inspection of the enamels exposed at all sites indicated that only one enamel, AM-7, a nature-tone enamel showed objectionable spalling. "Fishscale" type spalling was noted on many enamels but this is not objectionable at this time since the spalled areas are very small and the base metal could not be seen except by extremely close observation.

Although some of the dark colored enamels exposed at Montreal and Los Angeles appeared to be a little lighter in appearance than new, unexposed enamels, the majority of the enamels exposed at these sites appeared to be quite stable in respect to gloss and color.

B. Gloss and Color

The percentage gloss retained and the color retention for the enamels included in this test are presented in Tables 1, 2, and 3 and Figure 1.

More emphasis is placed on color retention than on gloss retention because slight changes in gloss on matte or semi matte enamels have a large effect on the percentage gloss retained values. This is probably the cause of the dip in the gloss curves (Fig. 1) at 0.5-years exposure.

The average color retention for each color enamel included in the test is presented in Table 4. These data indicate that the red enamels had poor color retention at all sites. This was expected since all the red enamels in this program failed the nitric acid test for color retention. 1/ However, the large color changes that occurred on the black, dark green, and blue enamels exposed at Kure Beach was completely unpredicted.

1/ Specification for Porcelain Enamel on Aluminum for Weather Exposure. PEI: ALS - 105 (64)

C. Comparison of Exposure Sites

The 3-year color data in Table 1 was analyzed by a two-sided sign test to determine the significance of differing results at the different sites. The results of the sign test (95% confidence level) indicated that the enamels exposed at Kure Beach had significantly larger color changes than those exposed at any other site. The color changes occurring at New York and Washington were not significantly different from each other but they were less than those occurring at Kure Beach and greater than those occurring at Montreal and Los Angeles. The color changes at Montreal and Los Angeles were not significantly different from each other but were less than those occurring at any other site.

D. Correlation with Boiling Acid Solubility

The relationship between color retention and boiling acid solubility is illustrated in Figure 2. Here it can be observed that a fair correlation exists between boiling acid solubility and color retention at the milder sites such as Los Angeles and Montreal. However, the correlation is not as good at the more severe sites such as Washington, New York and Kure Beach. In fact a boiling acid solubility of 10 mg/in^2 resulted in color retentions ranging from 94-99 at New York and Washington and 74-98 at Kure Beach.

E. Development of a New Accelerated Test for Porcelain Enamels on Aluminum

Since the correlation between boiling acid solubility and the color retention of the enamels exposed at the more severe sites is not too good, some effort has been expended to develop a new accelerated test. The first test that offered promise consisted of subjecting unexposed enamels to a 25%, by weight, solution of boiling cupric chloride for one hour and measuring the color change caused by this treatment. The first tests thus conducted indicated a fair correlation between the laboratory test and the actual exposure data. Further work is now being conducted, varing time and concentration, and volume to see if the correlation can be improved.

PLANS FOR THE NEXT REPORT PERIOD

During the next report period it is planned to complete the work on the development of a new accelerated test to indicate the weatherability of porcelain enamels on aluminum and to prepare a report on the 3-year inspection of these enamels for publication.

II. CONTINUITY OF COATING

A test procedure for the continuity of coating for porcelain enamels and a paper describing the development of this test have been written and started through the editorial process at the National Bureau of Standards. One of the editorial readers has suggested that some more work be done to determine whether the method of calibrating the test instruments could be simplified. Arrangements have been made to borrow a new test instrument to see if this can be done.

III. RESISTANCE OF PORCELAIN ENAMELS TO SCRATCH ABRASION

INTRODUCTION

The previous report in this series described a method of test that might be used to evaluate the resistance of various materials to scratch abrasion. The goals of that program were two-fold: First, to determine and compare the resistance of various porcelain enamels to an abrasion which produced a type of damage intended to simulate that encountered in service. The second goal was to permit an intercomparison of a broad spectrum of materials against a common (abrasion) yardstick.

The example given illustrated the application of the test method to a series of porcelain enamels and organic finishes which appeared to be widely separated with respect to abrasion resistance.

The purpose of this report is two-fold: first to demonstrate the degree of repeatability that can be expected when the concept of a scratch abrasion index is used, and second to analyze the significance of small differences in these abrasion indices.

RESULTS AND DISCUSSION

Determinations of the scratch abrasion indices of three additional porcelain enamels are shown in Table 5 together with replicate tests on companion specimens. If determinations were made on only 6 specimens of each enamel (the recommended number) the indices for these would be: Enamel V, 1.01; Enamel P, 1.41; and Enamel F, 1.53. These indices were obtained as the ratio of the mean of six values of soil retained after abrasion to the mean soil retained before the abrasion treatment. The second group of six determinations for each enamel illustrates the degree of repeatability found between the first and second replicate sets. In all three enamels the scratch abrasion index obtained for the second replicate set did not differ significantly, at the 95 percent confidence level from the index for the first group of specimens.

The indices of scratch abrasion of nine porcelain enamels have been arranged in Table 6 to show the results of significance tests between the various pairs. The indices of sixteen pairs were shown to differ significantly. The average difference in indices for these sixteen pairs was 0.39 index numbers. In the remaining pairs the indices were not significantly different at the 95 percent level. The average values of these pair differences was 0.19 index numbers. Thus we may conclude that the scratch abrasion test can significantly distinguish between porcelain enamels whose indices differ by approximately 0.3 index numbers.

Table 1. Summary of Color Retention Data for Enamels Exposed for Three Years in the 1964 Exposure Test of Porcelain Enamels on Aluminum.

Enamel	Exposure Site														
	Kure Beach			New York			Washington			Los Angeles			Montreal		
	6-Mos.	1-Yr.	3-Yr.	6-Mos.	1-Yr.	3-Yr.	6-Mos.	1-Yr.	3-Yr.	6-Mos.	1-Yr.	3-Yr.	6-Mos.	1-Yr.	3-Yr.
AA-A	99.4	98.1	96.4	99.4	99.3	99.1	99.5	99.6	99.4	99.5	99.3	99.3	99.5	99.6	99.5
AA-B	99.3	98.7	96.4	99.7	99.4	98.9	99.5	99.3	99.2	99.3	99.0	99.3	99.4	99.4	99.3
AA-C	99.0	97.0	95.1	99.2	99.0	98.8	98.8	98.8	98.5	99.0	98.5	98.8	98.9	99.0	98.9
AA-D	98.3	97.0	96.4	97.9	97.4	95.8	97.8	97.9	97.2	98.2	98.8	97.6	97.8	97.8	96.2
AB-A	98.8	97.8	94.8	98.1	97.8	97.0	98.8	98.8	98.6	98.7	98.6	97.8	98.7	98.5	97.8
AB-C	99.6	99.1	99.2	99.2	99.0	98.7	99.5	99.5	99.5	99.4	99.3	99.3	99.4	99.4	99.2
AB-D	98.5	97.6	95.8	98.3	98.4	97.9	98.9	98.8	98.5	98.4	99.1	97.5	98.9	98.9	97.2
AC-A	99.4	98.7	96.5	99.3	99.3	99.0	99.3	99.2	99.1	99.1	98.7	99.0	98.6	99.3	99.2
AC-B	98.7	98.1	97.6	99.0	97.1	97.1	99.1	98.8	98.4	98.6	99.2	98.2	99.0	98.4	97.9
AC-C	98.3	96.9	95.1	98.7	98.4	98.3	98.6	98.6	98.7	98.9	98.8	98.2	98.9	98.9	98.0
AD-A	98.9	98.6	96.6	99.2	99.2	98.4	99.4	99.4	99.1	99.4	99.3	99.4	99.5	99.3	99.1
AD-B	99.4	98.3	95.1	99.1	99.2	99.0	99.6	99.6	99.6	99.4	99.3	99.4	99.5	99.5	99.2
AD-C	98.1	96.9	91.9	98.1	97.9	97.4	99.0	98.8	98.0	98.5	98.4	97.6	99.1	98.9	95.5
AD-D	98.1	97.3	96.0	98.1	96.7	96.6	96.9	98.1	97.4	98.4	98.9	99.0	98.8	99.1	98.1
AE-A	99.1	94.3	79.0	99.8	99.1	99.5	98.6	98.8	97.9	99.8	97.2	99.1	99.8	99.9	99.6
AE-B	98.6	89.1	73.4	99.6	99.4	99.6	99.8	99.8	98.7	99.7	99.1	99.4	99.5	99.0	99.0
AE-C	98.9	92.9	82.0	99.6	99.6	98.4	99.6	99.6	98.8	99.4	99.2	98.8	99.5	99.0	99.4
AE-D	98.6	76.6	50.3	98.9	98.2	96.4	98.0	96.4	94.3	99.4	97.2	99.0	99.7	98.4	98.1
AF-A	98.4	88.8	61.0	98.5	97.7	98.3	99.2	99.1	97.5	99.6	97.9	98.6	99.3	98.4	98.2
AF-B	99.1	88.7	84.7	99.4	98.4	95.3	98.8	99.0	96.9	99.3	99.4	99.4	99.4	99.7	99.4
AF-C	98.4	93.1	84.6	99.3	98.1	94.1	98.8	99.1	94.0	99.6	98.3	98.6	99.8	99.4	99.1
AG-B	97.6	88.2	81.7	98.4	98.5	97.0	98.6	98.7	97.2	99.3	98.1	98.0	98.9	98.5	98.9
AG-C	98.2	97.1	83.8	98.3	98.1	98.4	99.4	99.5	98.1	99.4	99.0	98.7	99.5	99.5	99.1
AH-A	97.5	93.5	85.9	97.6	97.1	95.7	98.1	97.6	96.9	97.4	96.9	95.3	97.5	97.4	95.5
AH-B	93.0	83.1	63.0	96.6	95.1	92.9	94.6	94.0	89.6	95.5	94.4	93.9	95.2	95.2	93.5
AH-C	90.1	86.3	71.0	91.5	90.7	90.1	91.9	91.5	73.4	91.9	91.4	92.7	92.8	91.8	90.1
AH-D	83.6	70.2	61.2	95.2	90.8	86.3	88.9	87.2	82.5	91.0	88.4	85.8	89.7	88.1	80.8
AO-A	95.4	91.7	83.0	99.7	99.0	99.0	99.1	99.0	97.6	99.9	99.2	98.3	99.3	99.0	99.2
AO-B	99.5	97.3	87.2	99.7	99.3	99.1	99.5	99.7	98.9	99.8	99.4	99.5	99.7	99.3	99.5
AO-D	97.8	92.0	80.9	99.4	98.6	97.6	98.5	98.0	95.8	98.9	98.6	96.6	99.4	99.0	98.2
AP-A	98.7	95.2	88.4	99.4	99.5	99.5	99.4	99.2	98.1	99.3	99.3	98.9	99.5	99.3	98.8
AP-B	99.4	98.7	96.3	99.6	99.4	99.5	99.4	99.4	99.2	99.6	99.6	99.4	99.6	99.4	99.1
AP-C	99.5	98.9	97.5	99.6	99.7	99.5	99.0	99.1	99.0	99.2	99.6	99.2	99.5	99.6	98.9
AP-D	99.1	97.1	91.7	99.5	99.3	99.2	99.0	99.0	98.8	99.2	99.3	98.8	99.3	99.3	98.7
AR-A	99.6	99.6	99.0	99.3	99.3	98.8	99.5	99.4	99.4	99.6	99.6	99.4	99.6	99.7	99.5
AR-B	99.4	98.8	95.9	98.8	98.7	97.9	99.6	98.7	97.9	99.6	99.6	99.6	99.7	99.7	99.3
AR-C	99.4	98.3	94.8	98.8	98.6	98.1	99.6	99.6	96.2	99.5	99.4	99.3	99.7	99.6	99.3
AS-A	98.7	96.2	91.2	99.4	99.3	99.5	99.4	99.0	97.0	99.5	99.6	98.8	99.5	99.4	98.7
AS-B	98.9	97.3	88.7	99.2	99.4	98.8	99.3	99.1	98.1	99.3	99.3	98.8	99.4	99.3	98.7
AS-C	99.8	99.6	96.2	99.6	99.5	99.7	99.6	99.7	99.3	99.8	99.6	99.6	99.8	99.6	99.6
AT-A	99.0	97.4	90.6	98.9	98.8	98.0	98.9	98.9	98.2	99.1	99.3	98.6	99.1	99.1	98.8
AT-B	98.6	94.9	87.9	98.6	98.8	98.2	98.9	99.0	98.1	97.9	97.8	98.2	99.3	99.1	98.6
AT-C	98.7	96.2	86.2	99.7	99.1	98.7	97.1	99.1	98.4	99.0	98.9	98.3	99.3	99.4	99.3
AU-A	99.3	99.4	98.1	99.7	99.8	98.0	99.7	99.7	99.4	99.7	99.7	99.6	99.8	99.7	99.6
AU-B	99.2	99.4	97.6	99.5	99.4	99.1	99.6	99.6	99.0	99.8	99.7	99.5	99.8	99.6	99.4
AU-C	99.8	99.6	97.8	99.6	99.6	99.6	99.5	99.4	99.3	99.8	99.8	99.6	99.8	99.8	99.2
AW-A	99.2	98.7	95.3	99.5	99.5	99.0	99.4	99.4	98.7	99.6	99.5	98.9	99.6	99.6	99.2
AW-B	99.3	97.3	93.9	99.3	99.2	98.8	99.2	99.0	98.8	99.3	99.3	98.8	99.2	99.3	99.2
AW-C	98.9	95.9	92.6	99.4	99.0	98.6	99.4	99.0	96.4	99.4	99.5	98.6	99.4	99.4	97.8
AZ-A	97.7	98.9	98.0	99.2	99.0	98.5	99.3	99.2	99.0	98.9	99.1	99.0	99.1	99.2	98.2
AZ-B	99.1	97.8	95.3	99.2	98.9	98.9	99.0	98.9	98.8	98.8	98.8	99.0	99.3	99.0	99.0
Ave.	98.2	95.1	88.7	98.8	98.4	97.8	98.6	98.6	97.2	98.9	98.7	98.2	98.9	98.8	98.1

Table 2. Summary of Percentage Gloss Retained Data for the Enamels Exposed for Three Years in the 1964 Exposure Test of Porcelain Enamels on Aluminum.

Enamel	Exposure Sites														
	Kure Beach			New York			Washington			Los Angeles			Montreal		
	6-Mos.	1-Yr.	3-Yr.	6-Mos.	1-Yr.	3-Yr.	6-Mos.	1-Yr.	3-Yr.	8-Mos.	1-Yr.	3-Yr.	6-Mos.	1-Yr.	3-Yr.
AA-A	85.5	95.2	46.9	98.3	96.5	96.3	93.2	91.6	96.9	95.6	97.8	94.1	93.8	90.4	92.6
AA-B	94.0	87.5	98.9	94.5	93.5	90.8	92.7	91.5	94.3	103.0	100.9	95.1	98.6	93.2	90.3
AA-C	90.7	107.4	94.6	92.3	89.6	90.6	90.7	90.8	102.1	96.0	96.8	90.9	92.0	87.6	90.8
AA-D	76.0	33.0	7.8	101.1	97.8	97.4	94.6	92.5	25.0	101.0	100.4	93.5	100.0	93.1	69.3
AB-A	81.2	88.4	42.6	95.9	94.2	102.5	82.8	80.9	75.3	84.5	88.3	84.8	83.9	95.7	81.5
AB-C	79.6	86.4	63.6	83.9	84.4	86.7	81.0	83.6	79.7	83.6	87.9	84.6	82.7	82.7	82.3
AB-D	75.3	80.2	25.8	100.5	112.1	118.6	93.3	92.0	94.2	79.6	98.1	99.1	80.0	95.9	100.8
AC-A	90.2	90.7	80.0	96.3	93.1	85.3	93.0	91.8	94.8	102.6	101.0	95.5	98.6	93.1	91.5
AC-B	85.8	37.3	8.2	103.4	98.4	95.9	92.8	90.2	49.7	102.1	101.3	98.7	101.3	97.1	87.0
AC-C	90.6	65.3	14.1	99.0	96.8	99.4	93.7	92.1	91.7	98.2	98.1	95.0	98.3	94.1	93.1
AD-A	87.6	96.9	43.4	100.9	99.9	101.9	91.7	91.1	94.9	90.3	95.7	94.6	90.3	91.1	92.3
AD-B	89.0	93.8	94.1	97.4	94.5	95.0	89.8	88.9	87.0	92.4	94.9	92.4	90.5	88.2	88.8
AD-C	82.8	91.3	27.6	105.3	106.4	116.3	90.9	90.3	92.2	87.5	95.4	94.7	88.6	94.5	95.5
AD-D	87.5	58.0	19.7	104.7	114.6	118.6	98.0	96.5	41.1	88.6	103.1	104.8	87.7	100.3	91.6
AE-A	76.4	68.4	49.7	82.1	80.3	80.8	81.3	80.5	78.8	80.5	80.5	78.5	82.1	80.2	80.3
AE-B	65.1	55.8	16.7	84.6	83.7	82.7	86.5	82.9	78.9	87.9	86.6	81.9	88.8	95.1	80.7
AE-C	72.6	68.2	36.4	86.7	83.7	83.8	89.4	85.6	80.8	91.1	89.9	84.7	91.9	85.1	83.0
AE-D	71.1	37.8	8.2	83.3	79.9	80.2	82.2	78.4	76.3	85.5	83.2	78.9	87.4	83.0	78.3
AF-A	65.6	67.9	23.5	82.1	82.1	98.0	85.7	80.0	76.3	85.7	84.3	81.9	90.4	84.3	79.5
AF-B	69.7	58.5	16.2	88.3	95.3	81.7	84.5	91.7	89.6	96.1	96.5	94.3	95.6	95.3	94.6
AF-C	72.2	76.8	42.0	84.4	83.3	79.7	84.5	82.6	77.2	87.5	86.6	81.4	88.2	85.4	81.2
AG-B	82.0	83.7	39.6	76.2	100.4	108.1	100.5	97.8	93.4	79.5	103.1	103.3	98.9	100.5	104.6
AG-C	46.9	112.8	78.4	35.9	101.0	127.2	105.7	100.8	85.3	33.2	103.8	109.8	31.8	97.0	107.5
AH-A	90.8	79.3	51.6	118.3	121.3	103.8	95.8	96.6	97.1	103.7	113.2	111.7	97.8	103.6	103.8
AH-B	64.3	44.8	8.5	81.7	75.6	76.8	72.3	70.0	65.4	76.8	77.6	73.3	75.4	75.7	71.5
AH-C	73.9	59.2	43.6	79.0	75.6	77.1	70.8	68.5	67.8	77.6	77.4	70.8	77.3	93.6	70.4
AH-D	59.7	37.8	6.5	79.0	77.0	77.6	74.7	70.6	64.5	83.2	81.8	75.2	82.8	77.6	66.5
AO-A	76.6	60.9	35.4	80.2	78.5	81.6	82.1	79.3	78.4	83.3	83.3	79.0	83.8	81.4	80.6
AO-B	72.5	67.0	34.3	83.0	83.1	80.4	84.0	82.7	76.4	84.6	86.0	81.3	83.4	83.1	80.0
AO-D	74.1	50.8	15.2	81.0	79.1	73.2	83.8	80.7	77.7	87.0	84.2	79.1	87.8	84.9	81.2
AP-A	82.2	80.4	16.3	102.3	104.9	113.0	95.5	93.4	84.1	90.2	97.4	95.2	92.1	98.3	95.0
AP-B	75.5	87.1	78.6	86.3	94.6	109.8	82.9	81.9	80.0	77.0	89.6	86.2	78.6	82.8	85.5
AP-C	73.9	84.1	84.3	85.8	98.9	116.6	85.7	83.9	82.7	72.5	91.3	88.2	85.7	83.9	90.0
AP-D	87.5	88.9	42.7	95.4	100.8	111.3	93.9	93.4	92.7	88.0	95.2	93.4	91.7	94.7	96.7
AR-A	47.0	128.2	109.4	54.2	138.4	174.5	111.8	104.8	95.7	25.5	122.2	128.8	62.4	106.5	118.1
AR-B	0.0	96.1	60.7	0.0	110.9	157.0	82.5	74.7	59.7	0.0	81.7	101.7	4.4	73.6	97.4
AR-C	0.0	105.9	70.0	0.0	84.6	117.0	85.7	81.6	58.2	0.0	81.6	109.0	0.0	69.6	105.3
AS-A	78.2	59.5	22.2	91.7	88.3	93.9	90.2	93.0	75.4	92.1	93.0	88.6	91.2	89.7	87.3
AS-B	83.7	86.4	33.6	85.0	84.5	92.6	83.0	82.3	81.3	82.5	84.6	82.8	83.0	82.3	81.9
AS-C	92.5	97.7	80.7	90.4	89.9	96.5	91.8	92.2	93.1	93.3	95.5	91.5	91.7	89.1	90.6
AT-A	75.2	93.8	82.2	80.4	94.1	116.0	83.8	83.2	72.9	71.4	91.0	87.3	68.3	83.1	87.4
AT-B	79.8	93.4	38.0	91.5	95.6	107.3	93.8	94.1	97.2	90.9	95.5	92.8	91.5	90.9	94.9
AT-C	81.5	82.0	32.4	83.3	83.0	89.5	78.8	79.2	76.2	82.0	84.0	80.8	80.9	79.9	77.5
AU-A	89.1	89.8	99.1	88.3	90.7	104.0	84.3	84.9	84.4	87.7	92.5	86.3	81.2	83.4	85.5
AU-B	75.7	93.4	70.1	98.0	108.1	121.5	92.4	91.8	86.4	80.3	94.9	94.6	79.9	89.7	94.2
AU-C	87.4	94.7	72.3	95.1	98.0	106.1	94.5	93.9	92.9	91.4	97.9	95.9	91.5	93.5	95.3
AW-A	81.4	80.1	98.0	86.2	85.1	87.8	82.7	81.5	77.9	85.3	85.8	83.2	85.7	83.5	81.7
AW-B	78.8	79.2	27.9	95.6	94.3	95.0	93.3	92.4	93.3	93.7	95.2	93.0	94.2	92.7	92.4
AW-C	72.1	47.6	17.7	91.4	85.4	86.4	84.6	81.4	66.3	91.7	90.3	85.8	90.3	86.3	74.7
AZ-A	100.9	50.1	9.5	103.4	99.2	102.2	93.5	91.5	82.4	104.1	102.1	99.9	102.4	98.0	94.5
AZ-B	94.2	11017	102.2	90.9	64.1	91.7	90.6	91.2	101.7	99.1	98.0	90.8	93.9	89.2	88.5
Average	75.8	77.9	47.5	85.7	93.2	99.6	88.8	86.7	80.7	82.9	92.9	91.0	81.7	88.3	88.5

Table 3. Summary of Gloss and Color Retention of Nature-Tone Enamels on Aluminum after Two-Years' Exposure.

Enamel	Color Retention					Percentage Gloss Retained				
	Kure Beach	New York	Wash-ington	Los Angeles	Mont-real	Kure Beach	New York	Wash-ington	Los Angeles	Mont-real
AM-2	92.9	98.9	97.1	98.8	97.5	76.8	119.2	91.5	85.7	87.3
AM-3	92.5	99.3	95.1	98.8	98.1	74.0	103.0	88.8	92.9	95.2
AM-4	95.2	99.3	98.9	99.1	99.2	79.9	108.3	82.4	103.0	105.6
AM-5	96.2	99.7	99.0	99.6	98.3	88.0	113.1	92.5	95.1	95.1
AM-6	96.4	99.5	98.9	98.9	99.7	77.3	110.7	89.9	85.2	91.4
AM-7	91.3	99.4	98.2	98.7	99.3	76.6	155.3	77.3	88.9	87.7
AM-8	93.9	98.7	97.8	98.6	97.7	65.0	84.9	93.0	82.2	84.9

Table 4. Color Retention for the Various colors of Porcelain Enamels on Aluminum after Three Years' Exposure.

Enamel Color	Exposure Site					Average
	Kure Beach	New York	Washing-ton	Los Angeles	Mont-real	
Red	70.3	91.3	85.6	91.9	90.0	85.8
Black	75.6	97.2	97.0	98.8	99.0	93.5
Dark Green	83.7	98.6	97.4	98.1	99.0	95.4
Blue	88.2	98.3	98.2	98.4	98.9	96.4
Gray	88.7	99.3	98.1	99.1	99.0	96.8
Yellow	93.9	98.8	98.0	98.8	98.7	97.6
White	96.0	98.1	98.7	98.5	98.3	97.9
Light Green	94.8	98.9	98.4	99.2	99.1	98.1
Brown	97.0	98.9	99.2	99.6	99.4	98.8

TABLE 5. Repeatability of Scratch Abrasion Index. $\text{S.A. Index} = \frac{\text{Soil retained after abrasion}}{\text{Soil retained before abrasion}}$

Enamel V			Enamel P			Enamel F		
Soil Retained, $\mu g/cm^2$			Soil Retained, $\mu g/cm^2$			Soil Retained, $\mu g/cm^2$		
Before Abrasion	After Abrasion	S.A. Index	Before Abrasion	After Abrasion	S.A. Index	Before Abrasion	After Abrasion	S.A. Index
13.84	12.53	0.90	2.46	3.45	1.40	1.53	2.11	1.38
16.03	16.03	1.00	1.97	2.72	1.38	1.36	2.00	1.47
24.34	20.40	0.84	1.76	2.89	1.64	1.47	2.29	1.56
13.84	16.47	1.19	3.27	3.19	0.98	1.42	1.94	1.37
18.22	23.03	1.26	1.73	2.78	1.61	1.62	2.90	1.79
35.78	32.65	0.92	1.73	3.16	1.83	1.53	2.43	1.59
20.03	20.18	1.01	2.15	3.03	1.41	1.49	2.28	1.53
			Second set of six specimens					
19.39	19.61	1.01	2.37	3.68	1.55	1.50	2.81	1.87
25.22	22.01	0.87	2.40	4.14	1.72	1.18	2.05	1.74
22.59	22.01	0.74	3.59	4.38	1.22	1.15	1.79	1.56
20.84	19.61	0.94	3.33	4.23	1.27	1.39	1.88	1.35
18.22	19.39	1.06	3.01	4.11	1.36	1.30	2.29	1.76
19.97	17.64	0.88	2.61	3.94	1.51	1.36	2.00	1.47
22.21	20.05	0.92	2.88	4.08	1.44	1.31	2.14	1.63

TABLE 6 Significance Tests on Differences in Scratch Abrasion Of Porcelain Enamels

Enamel		V	25	30	24	32	26	16	P	F
	SA Index	(0.96)	(0.97)	(1.01)	(1.14)	(1.22)	(1.28)	(1.35)	(1.42)	(1.58)
V	(0.96)	--								
25	(0.97)	x	--							
30	(1.01)	x	x	--						
24	(1.14)	2.46	x	x	--					
32	(1.22)	3.28	2.47	x	x	--				
26	(1.28)	3.14	2.51	x	x	x	--			
16	(1.35)	3.78	2.96	x	x	x	x	--		
P	(1.42)	6.07	4.72	2.40	2.71	x	x	x	--	
F	(1.58)	9.12	7.48	5.28	4.67	x	2.73	x	x	--

The statistic used to evaluate differences in scratch abrasion was:

$$t = \frac{(X_1) - (X_2)}{SP} \sqrt{\frac{N}{2}}$$

The critical value of t at the 95 percent confidence level is 2.23 when n is 6

Numbers in the body of the table are t values which exceed the critical value. A significant difference is indicated for this pair.

An x in the table indicates that no significance can be attached to the small difference in mean values compared.

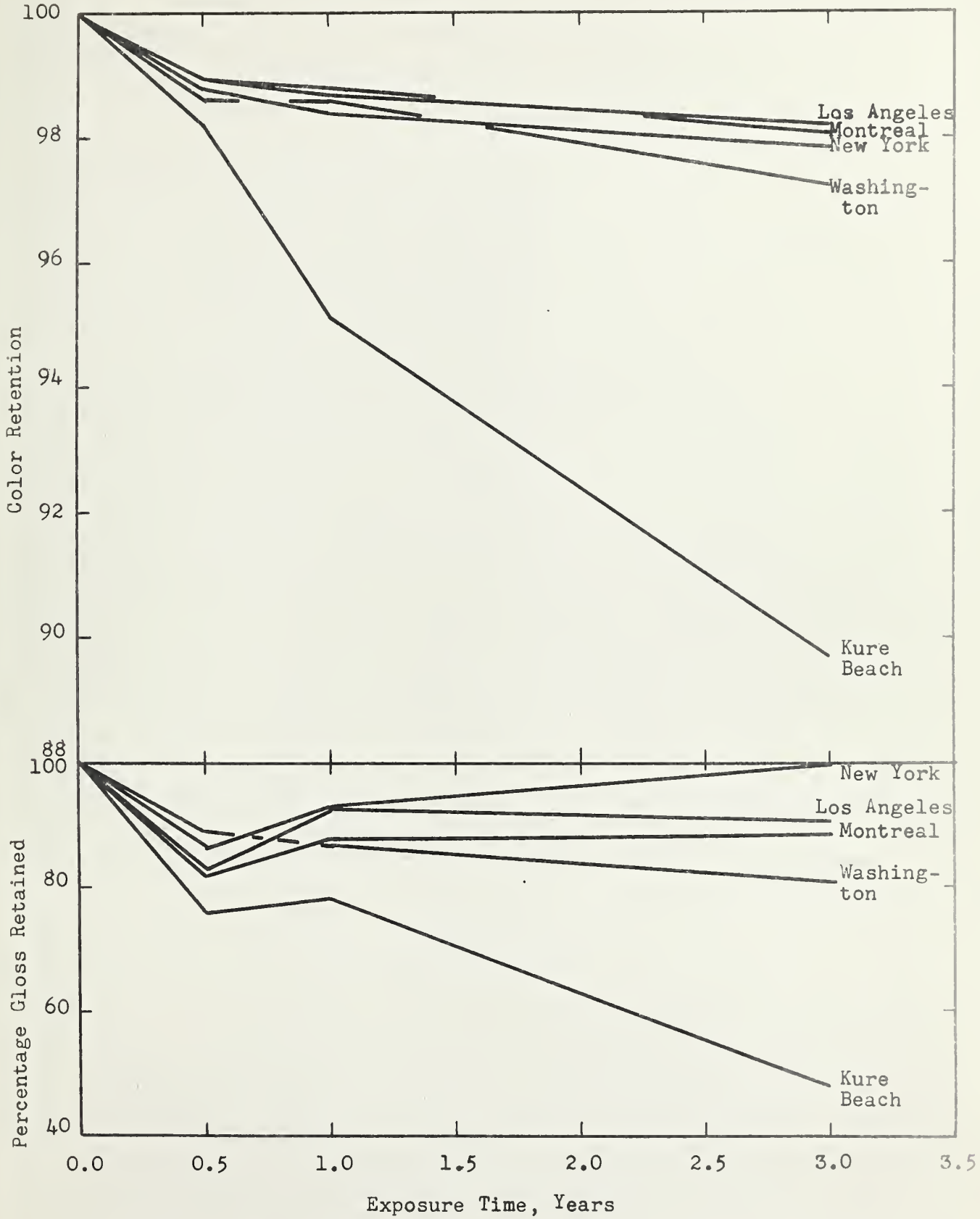

Figure 1. The Effect of Exposure Time on the Gloss and Color Retention of Porcelain Enamels on Aluminum

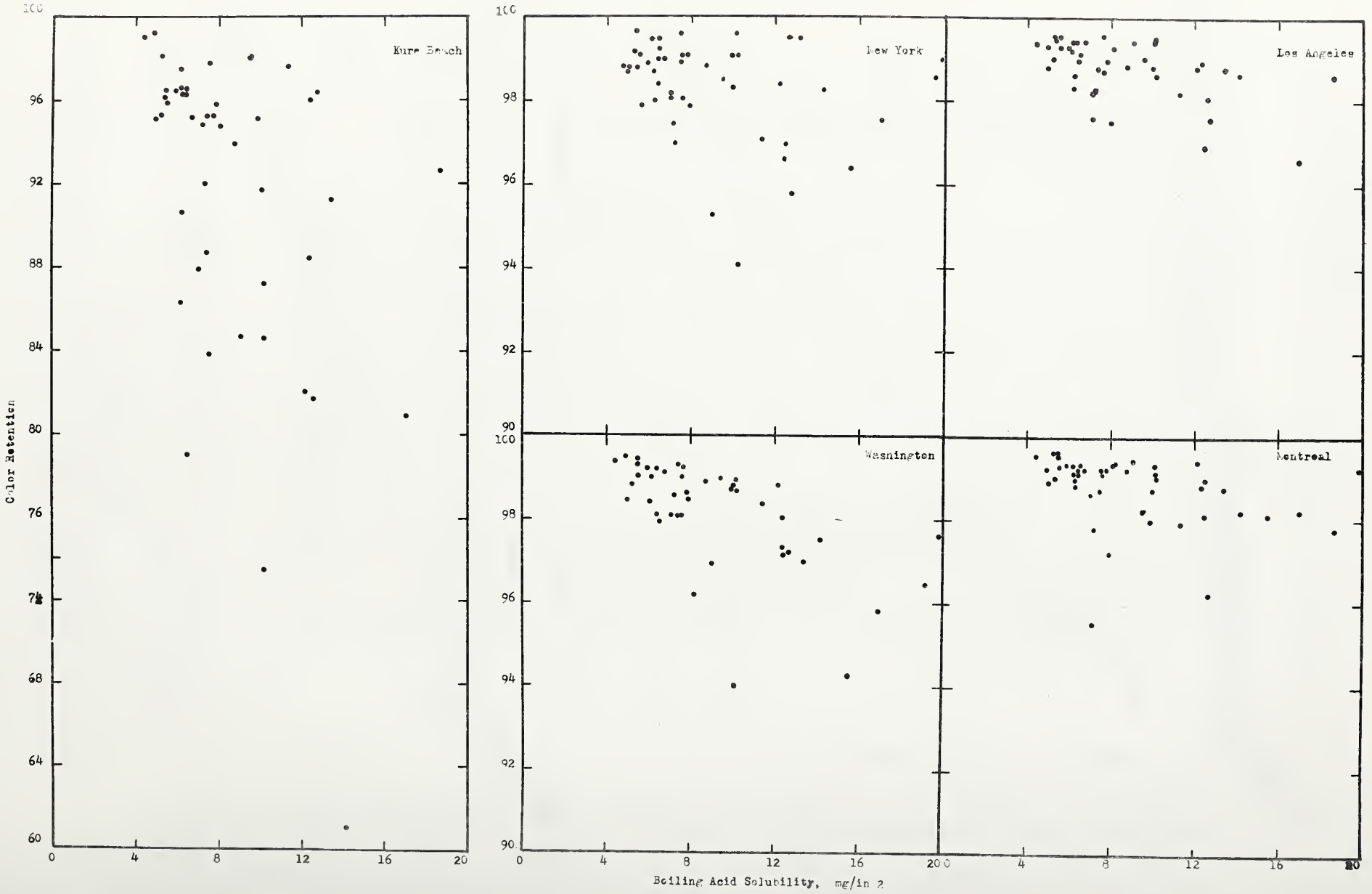

Figure 2. Correlation of Boiling Acid Solubility with Color Retention After Three Years' Exposure.


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