NATIONAL BUREAU OF STANDARDS REPORT

8587

PROGRESS REPORT

July 1 through September 30, 1964

Development of Methods of Test
For Quality Control of Porcelain Enamels

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

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT	NBS REPORT
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SUMMARY

Data on abrasion resistance, alkali resistance, and cleanability were obtained on sanitary ware-type specimens to serve as a guide for the proposed revision of Commercial Standard CS144-47 on Formed Metal Porcelain Enamel Sanitary Ware. In addition, data on hot-water testing of similar specimens made by four industrial laboratories were assembled and analyzed.

Reduction and analysis of data from the 7 yr inspection of the PEI-NBS weathering test was completed. Some of the more significant findings at 7 yrs were: (a) the boiling citric acid test provided a somewhat better correlation with color stability than did the citric acid spot test, (b) glossy steel enamels produced since World War II showed comparable gloss retentions to the glossy enamel types produced prior to World War II, and (c) a correlation existed between the average relative humidity at a site and the site severity.

Tests with the alkali resistance equipment showed that the ratio of the volume of test solution to the exposed area of the specimens can have an appreciable effect on the measured weight loss. This information was needed before preparing a write-up of the proposed test for the alkali resistance of porcelain enamels. The write-up is now virtually completed.

A few preliminary measurements were made on specimens submitted for the new exposure test of aluminum enamels. Eight of the ten fabricators who agreed to participate in the test completed their coating assignments during the quarter and returned the coated panels to NBS.

II. REVISION OF COMMERCIAL STANDARD CS 144-47

Introduction

A proposed revision of Commercial Standard CS 144-47 on Formed Metal Porcelain Enameled Sanitary Ware, dated October 8, 1963, was recently reviewed by the Standards Committee of the Porcelain Enamel Institute. The committee agreed that the requirements for porcelain enameled coatings should be changed so as to better define acceptable quality and performance requirements. On the basis of present experience and practices, it was the feeling that requirements covering resistance to abrasion, hot water and alkalies could be added to the standard. In addition it was agreed that a section on cleanability would be advantageous if an adequate testing method could be developed. A decision made by the committee was that several of the committee members would perform the hot-water tests and that the Research Associates would make the necessary abrasion and alkali tests and also explore possible cleanability tests.

Results and Discussion

The tests were performed on specimens representative of several typical production-quality plumbing fixture materials. In addition, several non-acid resistant porcelain enamels were included in order to broaden the range of property values.

The surface and sub-surface abrasion tests were performed in accordance with ASTM Standard Method C 448 while the alkali test was made using the recently recommended test equipment and procedures described in Section IV. The resistance of porcelain enamels to hot water was determined by the use of equipment similar to that used for the alkali tests but distilled water was substituted for the alkaline solution and a series of six-hour cycles was used.

The measured values obtained by these various test procedures are given in Table 1 and 2.

Development of a Cleanability Test

The goal in this part of the program was to develop a practical and workable test procedure for determining the cleanability of porcelain enamels. Preliminary work was done employing approximately twenty-five household items including acid containing foods, lipstick, greases, household dyes, and detergents. There were all found to be easily removable including the acid-containing foods; however, the latter did etch the porcelain enameled surface slightly. Thus, it was obvious that a stronger staining material was needed. Further testing indicated that a solution of methylene-blue would serve this purpose. However, it was found, when using this stain, that cleanability as indicated by the ease of stain removal correlated directly with the acid resistance of the enamel.

On the basis of this work the following proposed test method for cleanability was submitted for possible inclusion in the revised commercial standard:

"The specimen passes the cleanability test if stains formed by (1) a dye solution and (2) a burning cigarette can be completely removed by rubbing with a wet cloth. The dye solution shall be prepared by dissolving 0.5 gram of water-soluble methylene blue in 100 ml of distilled water to which eight drops of Aerosol OT has been added.[1/] Place several drops of the dye solution on the specimen to form a pool, and immediately cover with a one-inch watch glass. The quantity of solution shall be sufficient to approximately fill the covering glass. After five minutes, flush the dye and watch glass from the enameled surface with cold, running tap-water. Vigorously rub the specimen in running tap-water and dry by rubbing with a clean towel. Lay a freshly lighted cigarette on a flat untested area of the specimen, so that the lighted end is in contact with the porcelain enamel surface. After five minutes, remove the cigarette and vigorously rub the remaining stain with a wet cotton cloth for five seconds. Rinse and dry the specimen as before. Examine the specimen visually. If no residual stain can be detected from either treatment, the specimen passes the test; otherwise it fails."

It should be pointed out that the test method specified above was developed in a very short time with a minimum of laboratory work. This was necessary because of a deadline set for revising the commercial standard. A much more thorough study of cleanability is indicated. Hence, the above test, if it is used at all, should be considered as an interim type of test procedure that gives, at best, only a very rough indication of enamel cleanability.

1/ Both reagents available from Fisher Scientific Co., 7722 Fenton St., Silver Spring, Maryland.

Plans for Next Report Period

The divided reaction of the PEI Standards Committee concerning the adequacy of the proposed test for cleanability suggests that further work should be undertaken to develop a more universally acceptable testing procedure. Specimens are now in hand to permit a start on this program during the next report period.

II. NEW WEATHERING TEST OF PORCELAIN ENAMELS ON ALUMINUM

Introduction

Early in 1964, the Aluminum Council of the Porcelain Enamel Institute, authorized a new exposure test of porcelain enamels on aluminum. The enamels to be included in the weathering test were given in the preceding report. Both the information forms and aluminum sheet had been sent to the fabricators in late June. It was expected that all of the sheets would be coated and returned to the Research Associates at the Bureau by early September. Apparently, however, summer vacations at some of the plants delayed production schedules and by Oct. 1, two of the ten fabricators had still not returned the coated sheets. This of course has caused a delay in starting the exposure testing.

Plans for the Next Report Period

Arrangements have been made to cut the enameled sheets received thus far into 4 - 5/16 inch-square test specimens. Once these are cut, the acid solubility, acid spot tests, gloss, color and thickness will be measured. The new target date for installation of the specimens is late in November of this year.

III. PEI - NBS WEATHERING TEST

Introduction

The PEI-NBS exposure test is now in its eighth year. At the end of seven years all the specimens were returned to Washington and their gloss and color were measured. These data have been reduced and analyzed. The boiling acid solubility was determined on duplicate specimens for all enamels in the test. Results of the seven year inspection are given in this report.

Results and Discussion

1. Ease of Cleaning of the Exposed Specimens

The ease with which the specimens could be cleaned varied with exposure location. The specimens exposed at Dallas, New Orleans, Washington, and the two Kure Beach locations were cleaned easily with a one percent solution of trisodium phosphate. The specimens exposed at Los Angeles were covered with a gum-like film which could be removed easily with benzene. Following the benzene cleaning, the specimens were again washed with trisodium phosphate. Some of the specimens exposed at Pittsburgh had tar and cement spattered on them, apparently during a reroofing of the post office building. The tar was easily removed with benzene and the cement was removed by heating at 200 degrees C for 24 hours. A tightly adherent deposit which appeared to consist mostly of soot and fly ash still remained on the enamel surface after the tar and cement had been removed. This was removed by scouring with Bon Ami. The enamels were again washed with trisodium phosphate following this treatment.

2. Corrosion Protection

None of the enamels exposed at Los Angeles, Washington, Pittsburgh, and Dallas showed signs of corrosion of the base metal. However, one enamel exposed at New Orleans, ten at Kure Beach-800 and twenty-nine at Kure Beach-80 showed some rust on the surface. The rust on all these panels occurred around pinhole-type defects in the enamel.

3. Comparison of Exposure Sites

The average gloss and color retention for the enamels at the different exposure sites is listed in Table 3. These data were treated statistically to determine whether there were significant differences at the 95% confidence level between the exposure sites. It was found that all sites except New Orleans and Pittsburgh were significantly different from each other. After the 3-year inspection the New Orleans site was classified as "mild", and it differed significantly in severity from the Pittsburgh site, which was classified "moderate." At the end of seven years, however, the apparent order of severity of the two sites was reversed with Pittsburgh the less severe of the two as shown in the following tabulation:

Site	Gloss retained at end of:	
	3 years	7 years
New Orleans	79.9	70.5
Pittsburgh	70.1	74.2
Difference	9.8	3.7

It is believed that the apparent increase in average gloss of the specimens exposed at Pittsburgh at 7 years as compared to 3 years can be attributed to the polishing action of the vigorous scouring treatment that was essential for cleaning the Pittsburgh specimens after they had been exposed for 7 years. As stated earlier, the New Orleans specimens cleaned easily with trisodium phosphate and no scouring treatment was required.

4. Effect of Atmospheric Conditions on Site Severity

It was known from earlier test results that porcelain enamels exposed at various sites do not weather at the same rates. Obviously these differences in rates must be influenced by differences in atmospheric conditions at the exposure sites. Some atmospheric parameters that might have an effect on the weathering of enamels are given in Table 4. It was found that of these parameters only relative humidity and pH had large, independent effects on changes in gloss and color. This is illustrated in Figures 1 and 2, respectively. It can be seen from these two figures that the mildest conditions with respect to loss-of-gloss of the enamels are the dry climates (Los Angeles and Dallas) where the air pollutants are of nearly neutral pH, while the most severe conditions exist at the two Kure Beach sites where the humidity is high and the pH of the suspended ~~porcelain~~ particulates is low.

Although the pH of particulates and relative humidity were the only atmospheric parameters that gave individual correlations with gloss and color change, there was good evidence from a data correlation analysis,

which was made with the aid of the computer, that other parameters such as temperature and weight of particulates have second order effects. Empirical equations have already resulted from this work that will permit calculation of both the gloss and color change of one enamel (L-4) in seven years at any site for which weather and air pollution data are available. This type of work will be extended, as time permits, with the ultimate objective of being able to obtain a quantitative prediction of the weathering behavior of any given enamel at any selected site.

5. Effect of Exposure Time

The effect of exposure time on the gloss and color of the enamels exposed seven years at all sites is shown in figures 3 and 4 respectively. It can be seen in figure 3 that major changes in gloss occur during the first three years' exposure. After this time only slight changes in gloss occur at the five milder sites. However, the gloss of specimens at the two Kure Beach sites continues to decrease during the entire seven-year exposure period.

The color changes most rapidly during the first year's exposure as seen in Figure 4. After this period the color changes at constant, but different, rates at all sites.

6. Correlation of Weather Resistance with Acid Resistance

The weather resistance has previously [1,2] been shown to correlate with the acid spot test ratings (see figure 5). It must be noted that this correlation exists only when averages are considered and there are many deviations within any one acid rating. This scatter in the data is illustrated in figure 6.

The boiling acid solubility [3] was determined on duplicate specimens of all the enamels in the test. Figure 7 shows a slightly better correlation between color stability and this measure of acid resistance than with the acid spot test ratings. The acid solubility is also as effective for the mat enamels as for the glossy ones as can be seen in figure 7 where the mat enamels on steel are on the same figure as the glossy enamels on steel. The two straight lines in this figure are fitted through the glossy and mat values respectively. The architects increased interest in mat finishes, together with the recognized difficulty of performing spot tests on mat enamels, makes the use of the acid solubility test worthy of further study.

7. Weather Resistance of Various Enamel Types

The glossy acid resistant enamels on steel and the 1300°F enamels on steel had the best weather resistance of any of the enamel types included in the test (See Table 5). This is in agreement with the three-year results. The acid solubility data indicate that the mat enamels on steel would weather as well as the glossy acid-resistant enamels on steel if they could be produced with better acid resistance than the ones included in this test. The enamels on aluminum weather fairly well at all but the Kure Beach locations. The mat enamels on aluminum seemed to be slightly superior to the glossy ones, the color stability of the mat enamels on aluminum being not significantly different from the glossy acid-resistant enamels on steel at three of the exposure locations.

8. The Use of Kure Beach 80 as an Accelerated Weathering Test

It has long been desired to develop an accelerated weathering test which would correlate with actual exposure testing. To date the acid spot test has been used as an indicator of an enamel's weather resistance. However, this has not been too effective for individual enamels or on the new low temperature enamels. The severity of attack of the enamels exposed at Kure Beach 80 has suggested this location for a possible natural "accelerated" exposure test. To determine whether this might be done, a preliminary correlation analysis was performed. This has shown promise but more work is required before a positive conclusion can be reached regarding the value of the accelerated test site approach.

9. Comparison of Titania Opacified with Antimony and Zirconia Opacified Enamels

One of the objectives of this test was to determine how the weather resistance of the enamels produced after World War II, many of which are opacified with titania, would compare with the enamels produced prior to World War II which were opacified, for the most part, with either Zirconium or Antimony oxide. Table 6 shows that the average gloss retained by the newer porcelain enamels, does not differ significantly at the 95 percent confidence level from the average gloss retained by the older porcelain enamels. This comparison is based on 7-year results at the Washington, D. C. exposure site since this was the only site common to both tests.

10. Presentation of the Seven Year Weathering Test Data

An oral report on this weathering program was presented at the Fall Meeting of the Ceramic-Metal Systems Division of the American Ceramic Society.

Plans for the Next Report Period

A paper will be prepared for publication as an NBS Monograph. This will include a complete listing of all data.

Oral descriptions of the program and tentative interpretations of the seven year results will be given at the PEI Forum in October and before the Eastern Enamellers Club at Philadelphia in November.

No further inspections of test specimens are planned until 1971.

IV. STANDARD ALKALI TEST

Introduction

The need for a standardized test for determining the resistance of porcelain enamels to alkali solutions has been emphasized in recent quarterly progress reports. Various equipment modifications have been made and previous experimental work has been described to support these changes.

One of the modifications to the older PEI Alkali Tester was to increase the testing capacity from three to six specimens. This change in specimen capacity resulted in decreasing the ratio of the volume of solution to specimen area exposed from 193 to 97 ml/in^2. The effect of this decreased ratio on the weight loss of specimens tested must be known since this variable needs to be considered in the proposed testing procedure.

Results and Discussion

In order to evaluate the effect of varying the ratio of solution volume to specimen area, a series of alkali determinations was made using specimens of a single porcelain enamel. In those tests involving the simultaneous testing of less than six specimens, the normal volume of solution was used and the exposure openings not occupied by specimens were sealed with stainless steel plates of the appropriate size. The results obtained in this series of tests are given in Table 7 and Figure 8. The average weight-losses observed were 7.2 and 6.0 mg/in.^{2} when three and six specimens respectively were tested simultaneously. The difference in weight-loss, 1.2 mg/in.^{2}, is statistically significant at the 95 percent confidence level. This result suggests that a standardized test method for alkali resistance of porcelain enamelled specimens must limit the ratio of solution volume to specimen area to a single value.

A proposed standardized test for the resistance of porcelain enamel to a sodium pyrophosphate solution has been prepared. The proposed procedure and equipment gives consideration to the control of variable conditions previously explored and tested thoroughly by round-robin testing, a number of years ago. In addition it reflects more recent research and modification of both equipment and technique. Finally, it is believed to provide the industry with a reproducible procedure for alkali testing.

Plans for Next Report Period

The proposed alkali test will be submitted to the PEI standards committee for their consideration. If the test is approved, no further work will be done.

V. STANDARD REFERENCE MATERIALS

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

Corundum abrasive, March 1960 issue,
for subsurface abrasion . . . . . 308 lbs., 77 jars

Standard Pennsylvania Glass Sand,
for surface abrasion, July 1963 issue . . . . . 333 lbs., 111 jars

Distinctness of image gloss standards . . . . . 20 sets

Calibrated glass plates for abrasion testing. . . 35 dozen

Respectfully submitted,

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

REFERENCES

1. D. G. Moore and Alan Potter, "Effect of Exposure Site on Weather Resistance of Porcelain Enamels Exposed for Three Years," NBS Monograph 44 (1962) U.S. Government Printing Office, Washington, D. C. 20234.
2. D. G. Moore and W. N. Harrison, "Fifteen-Year Exposure Test of Porcelain Enamels," National Bureau of Standards Building Materials and Structures Report 148, June 1957, U. S. Govt. Printing Office, Washington, D. C., 20234.
3. Standard Method of Test for Resistance of Porcelain Enameled Utensils to Boiling Acid, ASTM Designation, C283-54, p 244, Book of ASTM Standards, Part 13, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103.

Table 1. The Alkali, Abrasion and Hot Water Resistance of Several Plumbing Fixture Materials

Acid Rating	Alkali Resistance		Abrasion Resistance		Hot Water Resistance Weight Loss, mg/in.^{2}				
	Weight Loss mg/in.^{2}	Gloss Retained %	Surface % Retained Gloss	Subsurface mg/min.	6 hr	12 hr	18 hr	24 hr	30 hr
Sheet Steel Sanitary Ware Porcelain Enamels									
AA	8.3 ± 0.3	8.1 ± 0.5	60.0 ± 1.5	4.0 ± 0.1	0.3	0.6	1.0	1.5	-
A	5.3 ± 0.9	6.8 ± 0.2	59.5 ± 0.5	4.3 ± 0.0	0.3	0.4	1.1	1.1	1.3
A	7.2 ± 0.4	10.4 ± 1.2	59.4 ± 0.6	3.9 ± 0.1	-	-	-	0.7[a]	-
B	6.9 ± 0.9	7.5 ± 0.3	59.9 ± 4.2	4.2 ± 0.1	0.0	0.2	0.4	0.6	0.7
C	27.6 ± 1.6	5.3 ± 0.2	58.5 ± 0.9	4.9 ± 0.4	0.9[b]	-	-	-	-
C	12.0 ± 1.6	6.4 ± 0.0	58.6 ± 0.5	4.1 ± 0.2	0.3	0.7	0.7	1.2	-
Dry Process Cast Iron Porcelain Enamels									
A	30.0 ± 3.7	20.3 ± 0.9	47.1 ± 2.6	6.7 ± 0.4	-	-	-	-0.8[c]	-
Non AR	104.9 ± 8.6	6.7 ± 0.4	36.7 ± 1.2	7.8 ± 0.5	-	-	-	-66.8[c]	-
Plastic Gel Coat									
-	-11.5[c] ± 7.2	87.6 ± 4.6	8.9 ± 0.3	3.2 ± 0.3					

Footnotes: a 28 hours
b 1.5 hours
c A negative weight loss indicates a weight gain

Table 2. Changes in Gloss Retained by Several Plumbing Finishes After Exposure to Hot Water at 96°C

Sanitary Ware Material	Acid Resistance	45 Degree Specular Gloss Retained After Indicated Exposure Time in Hours							
		1.5	6	12	18	24	28	30	36
Sheet Steel	AA	-	107	111	111	113	-	-	-
Sheet Steel	A	-	-	-	-	-	101	-	-
Sheet Steel	Good	-	-	-	-	-	-	-	93
Dry Process Cast Iron	A	-	-	-	-	77	-	-	-
Sheet Steel	A	-	73	69	65	62	-	60	-
Sheet Steel	B	-	69	66	64	61	-	58	-
Sheet Steel	C	-	65	67	61	59	-	-	-
Sheet Steel	C	47	-	-	-	-	-	-	-
Sheet Steel	Poor	-	-	-	-	-	-	-	47
Dry Process Cast Iron	Non-AR	-	-	-	-	38	-	-	-

Table 3. Comparison of Severity of Weathering at the Different Exposure Sites.

Exposure Site	Ave. Gloss Retention For All Enamels	Ave. Color Stabiltity Index For All Non-White Enamels Except Screening Pastes
Kure Beach, 80 ft.	36.5	91.4
Kure Beach, 800 ft.	53.2	92.9
Washington	62.4	94.5
Pittsburgh	74.2	95.8
New Orleans	70.5	94.5
Dallas	82.0	97.1
Los Angeles	86.4	97.1

Table 4. Weather and Air Quality Data[a/]

Exposure	Ave. Ann. Relative Humidity	Ave. Ann. Temperature	Tot. Ann Sunshine	Tot. Ann. Precipitation	Total Suspended Particulate Matter	Benzene Soluble Organic Matter	Nitrates	Sulphates	pH[b/]
	(%)	(Deg.F)	(hours)	(inches)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	
Kure Beach[c/]	77	60	2669	58	31	1.5	1.4	7.3	4.9
Washington	67	57	2576	39	108	11.6	2.9	11.6	6.9
Pittsburgh	68	50	2202	34	160	10.5	2.3	15.0	6.7
New Orleans	74	70	2744	63	89	9.4	1.9	8.9	7.2
Dallas	63	66	2911	40	95	7.6	1.9	6.4	7.3
LosAngeles	62	66	3284	11	169	19.2	6.5	12.7	6.4

a/ Values are averages of measurements taken at approximately biweekly intervals.

b/ Measured for solutions prepared by refluxing an 8 percent aliquot of particulates with 50 ml of distilled water and diluting to 80 ml.

c/ Values for Kure Beach are from Cape Hatteras, North Carolina.

Table 5. Comparison of the Enamel Types Included in the Test.

Enamel Type	Average Gloss Retention For All Sites	Average Color Stability Index for all Sites
	%	
Regular Glossy Enamels on Steel - Acid Resisting	76.1	97.2
Mat Enamels on Aluminum	63.9	94.6
1300°F Enamels on Steel	80.9	97.4
Mat Enamels on Steel	61.7	95.8
Regular Glossy Enamels on Steel, Non-Acid Resisting	58.5	93.2
Glossy Enamels on Aluminum	58.8	91.7
1000°F Enamels on Steel	72.8	84.2
Screening Paste Enamels on Steel	83.9	-

Table 6. Comparison of Regular Steel Enamels after Seven Years' Exposure at Washington

Acid Spot Test Rating	1939 Enamels		1956 Enamels	
	Gloss Retention %	Number of Enamels	Gloss Retention %	Number of Enamels
AA	73.7	29	77.5	8
A	69.7	15	76.3	13
B	70.7	3	65.0	11
C	54.9	24	56.1	17
D	44.4	16	52.0	9
Average for all enamels	62.5	87	64.6	58

Note: Fishers "t" test shows no significant difference at the 95% confidence level.

Table 7. Effect of Ratio of Solution Volume to Specimen Area on the Weight Loss of Specimens Exposed for Six Hours to a 5 Percent Solution of Sodium Pyrophosphate at 96°C

Specimen No.	Ratio ml/in.^{2}	Weight Loss mg/in.^{2}	Specimen No.	Ratio ml/in.^{2}	Weight Loss mg/in.^{2}	Specimen No.	Ratio ml/in.^{2}	Weight Loss mg/in.^{2}	Specimen No.	Ratio ml/in.^{2}	Weight Loss mg/in.^{2}
D-75	580[a/]	8.2	D-86	290[b/]	7.6	D-68	193[c/]	7.7	D-69	97[d/]	6.0
76	"	8.6	87	"	8.0	81	"	7.6	70	"	6.1
77	"	7.3	88	"	6.9	82	"	7.3	71	"	5.7
78	"	7.4	89	"	6.7	83	"	7.0	72	"	6.0
79	"	8.0	90	"	7.5	84	"	6.6	73	"	6.1
80	"	8.2	91	"	7.5	85	"	7.1	74	"	5.9
		8.0			7.4			7.2			6.0

a/ Ratio obtained by testing 1 specimen in 5000 ml solution

b/ " " " " 2 " " " " " "

c/ " " " " 3 " " " " " "

d/ " " " " 6 " " " " " "

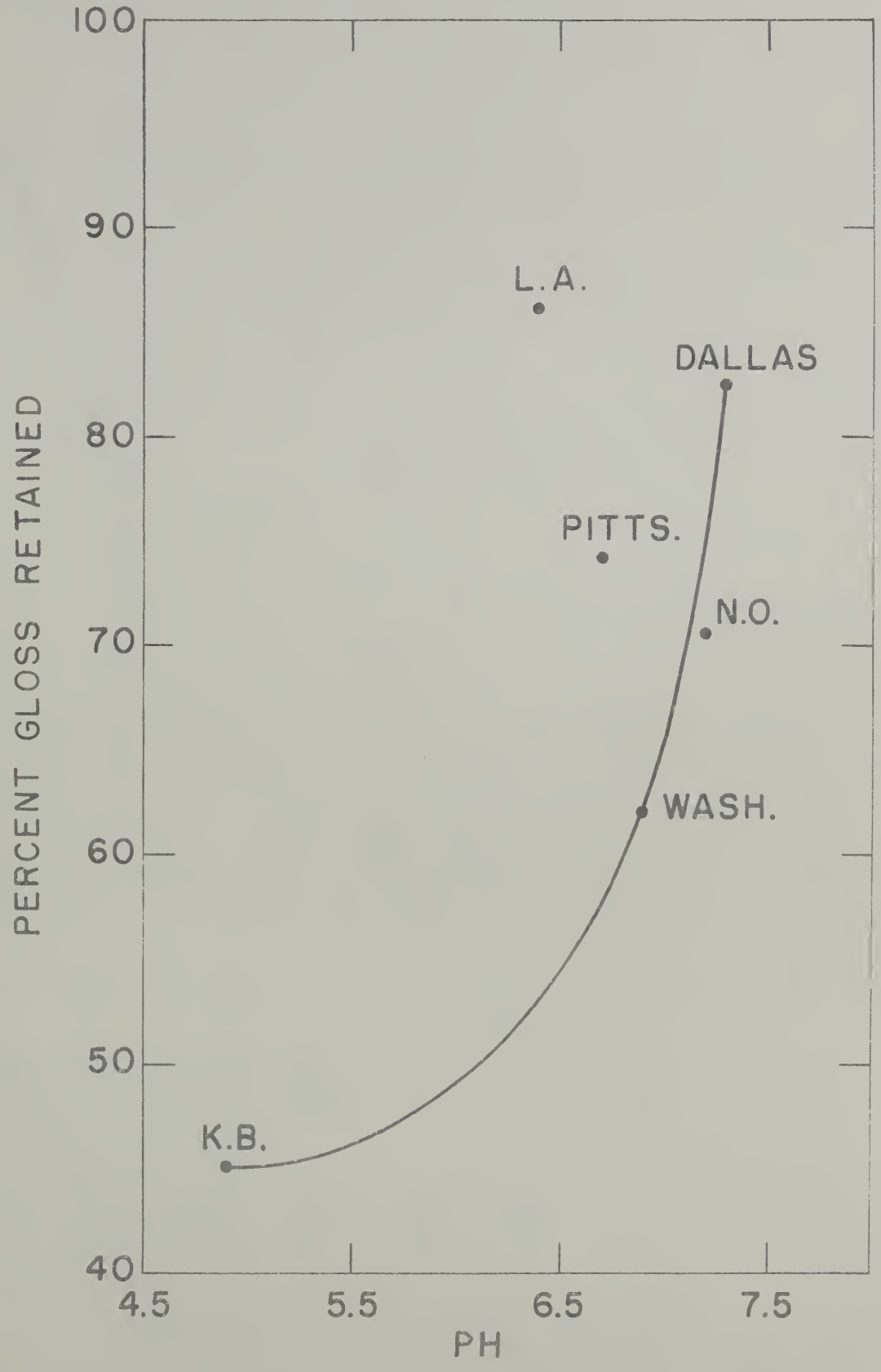

Fig. 1. The effect of pH on the Gloss Retention of All the Enamels Included in the Test.

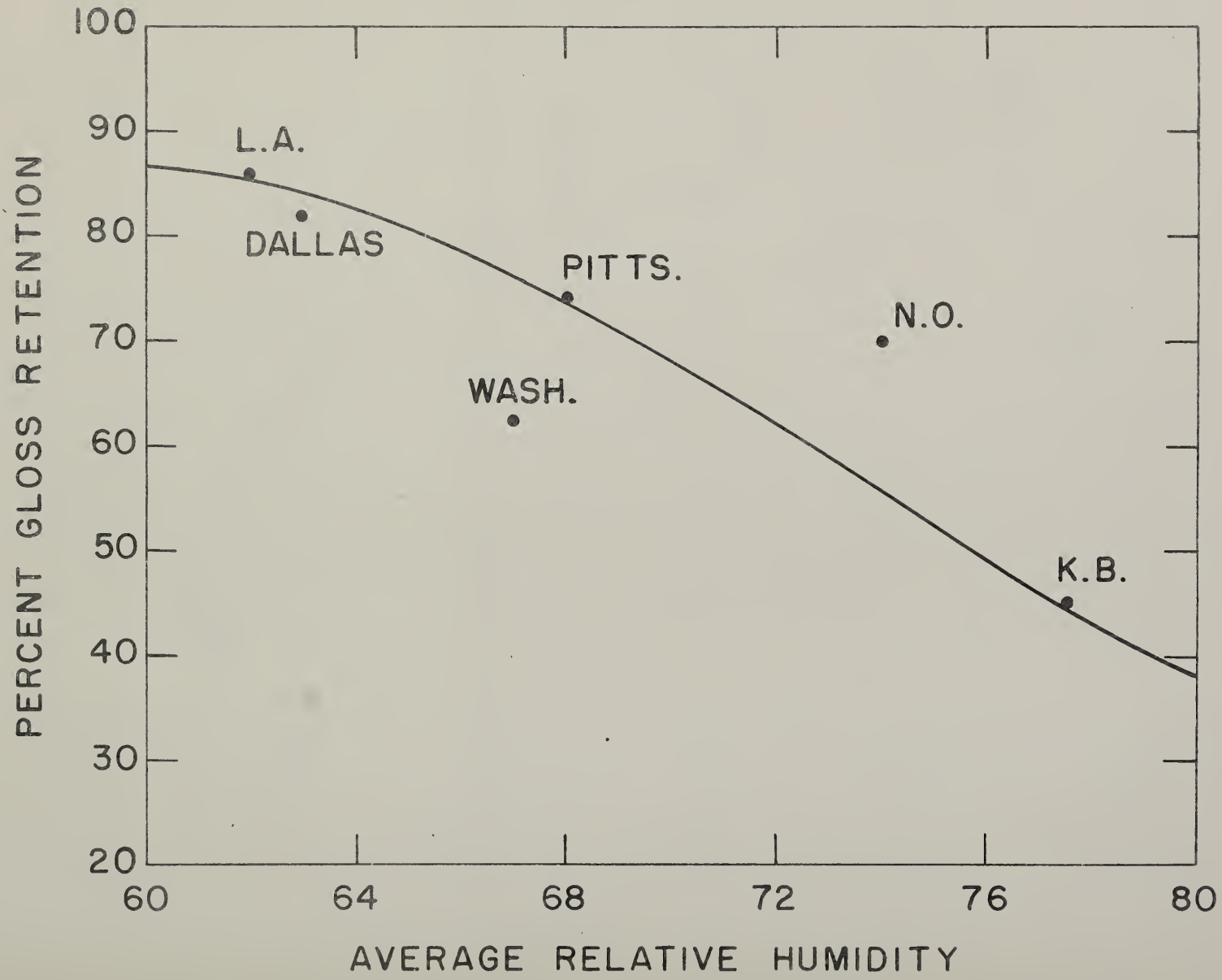

Fig. 2. The Effect of Relative Humidity on the Gloss Retention of All Enamels Included in the Test.

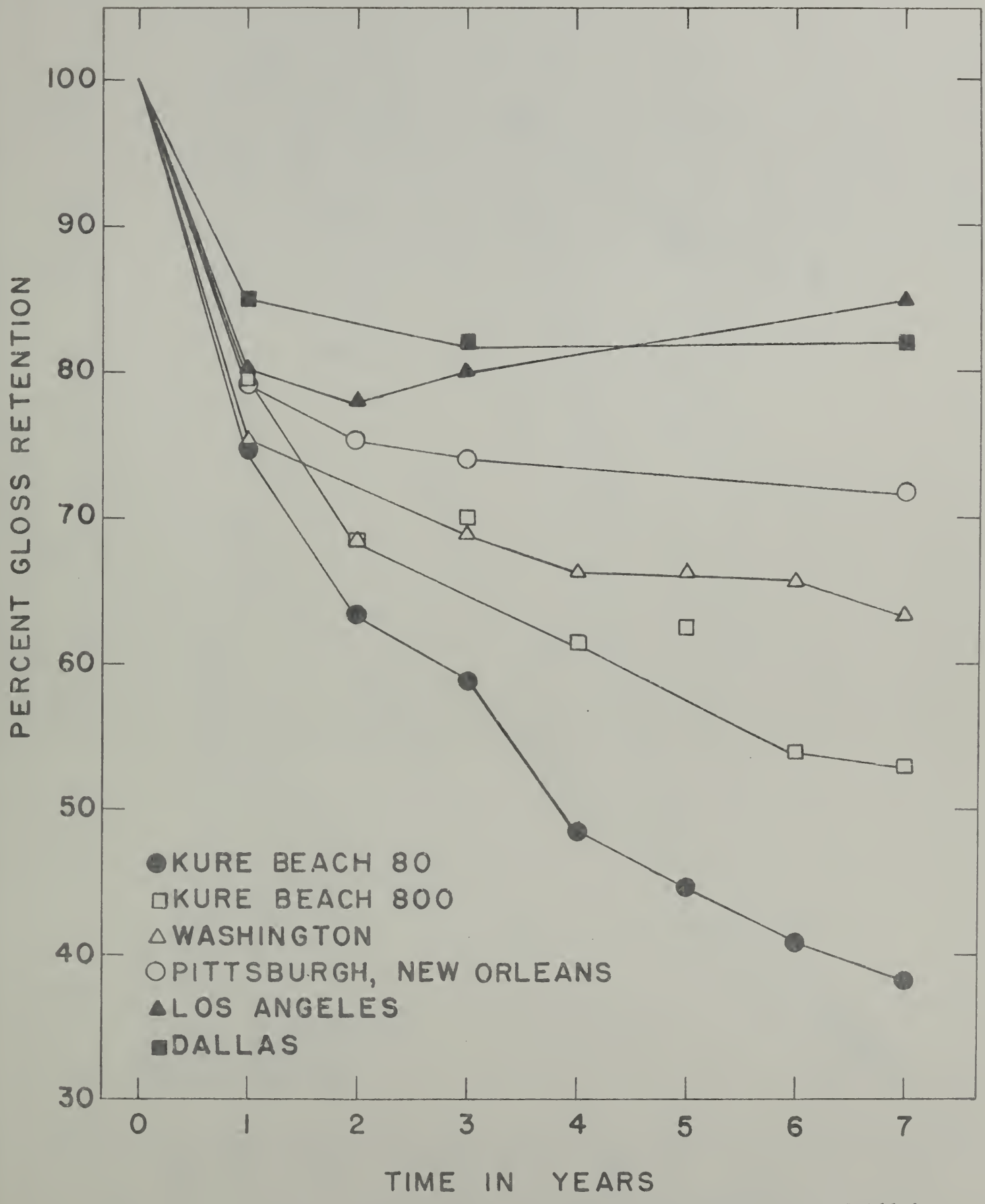

Fig. 3. The Effect of Exposure Time on the Gloss Retention of All but the Screening Paste Enamels.

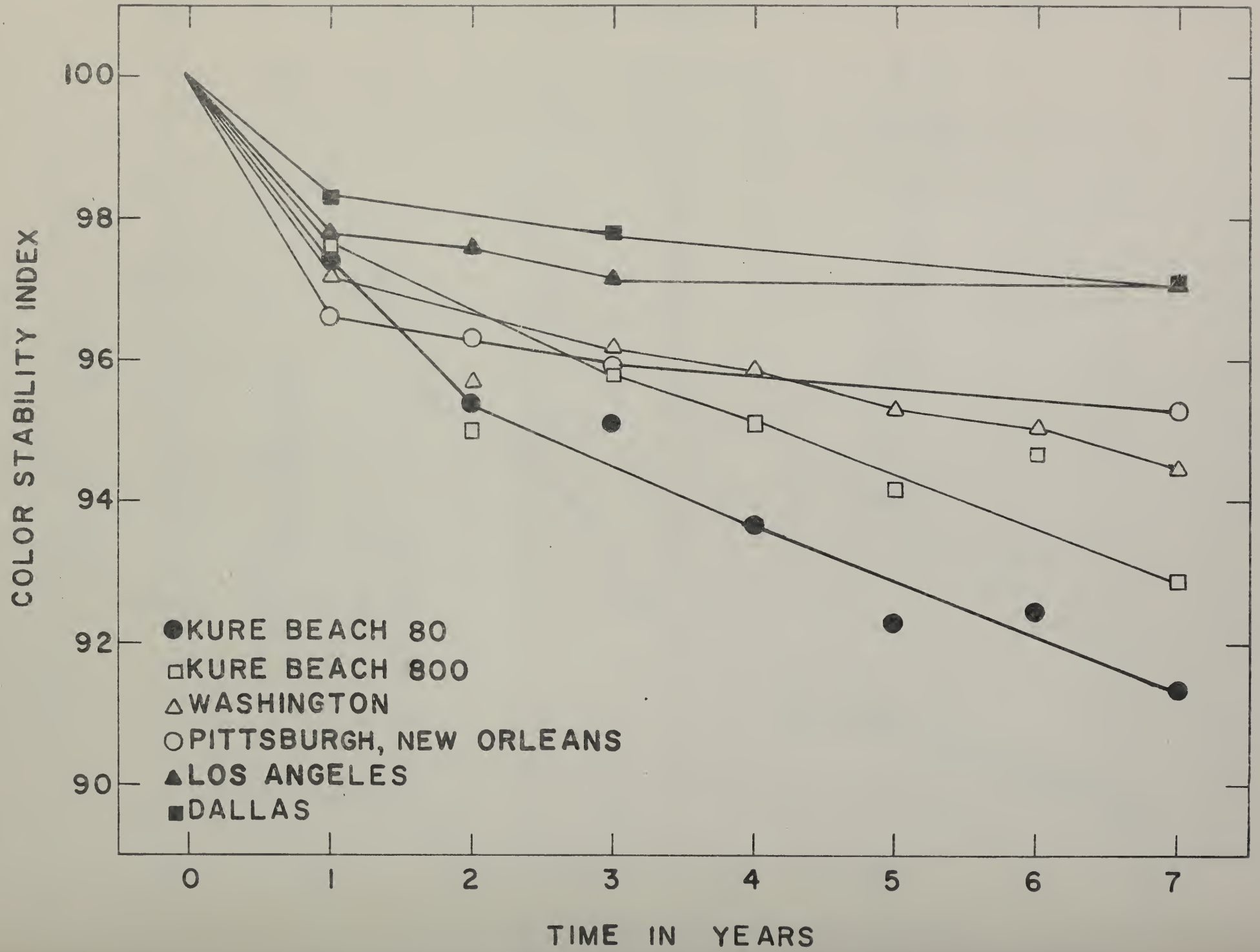

Fig. 4. The Effect of Exposure Time on the Color Stability of All Non-White Enamels Except Screening Pastes.

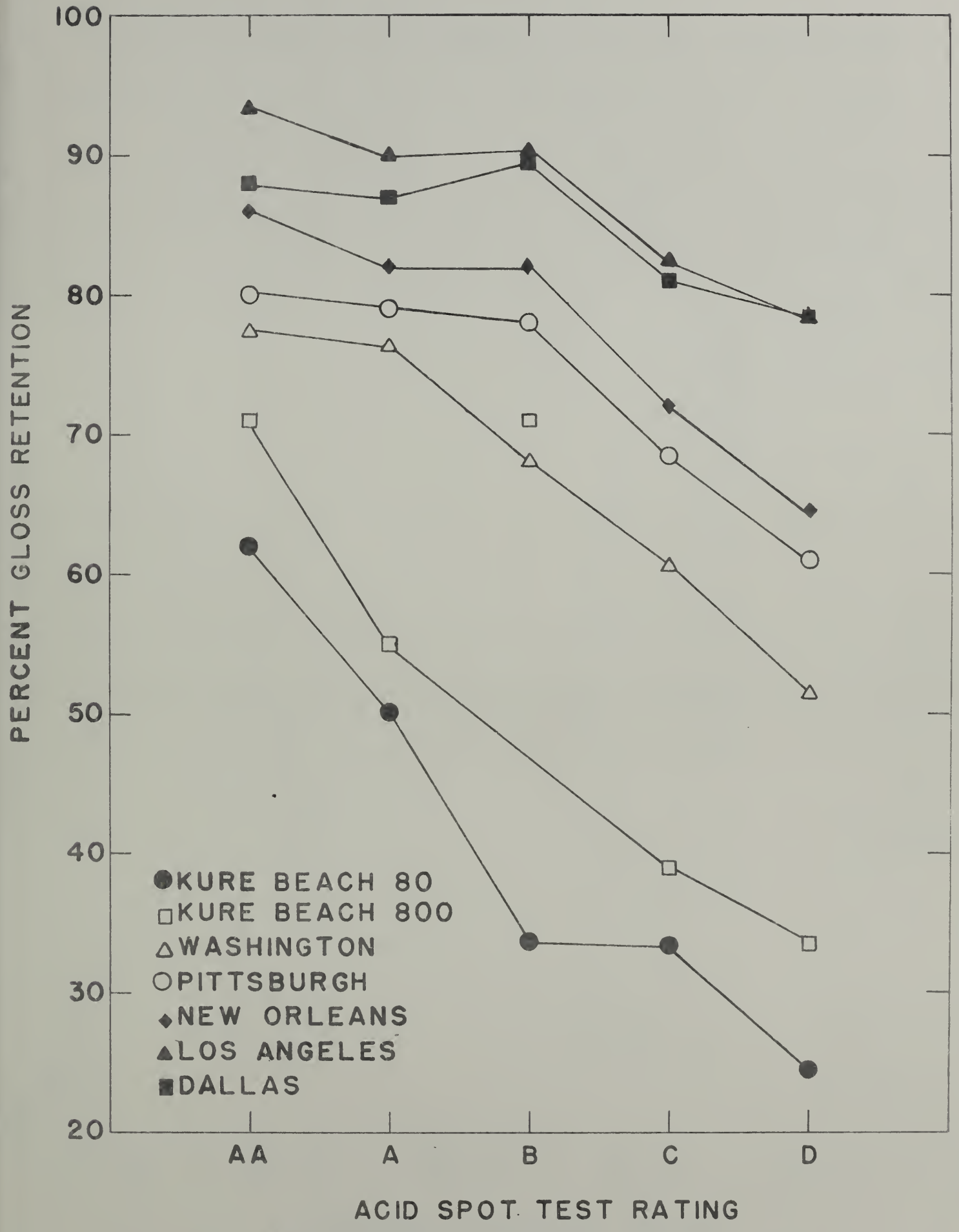

Fig. 5. The Effect of Acid Spot Resistance on the Gloss Retention of the Glossy Enamels on Steel after Seven Years' Exposure.

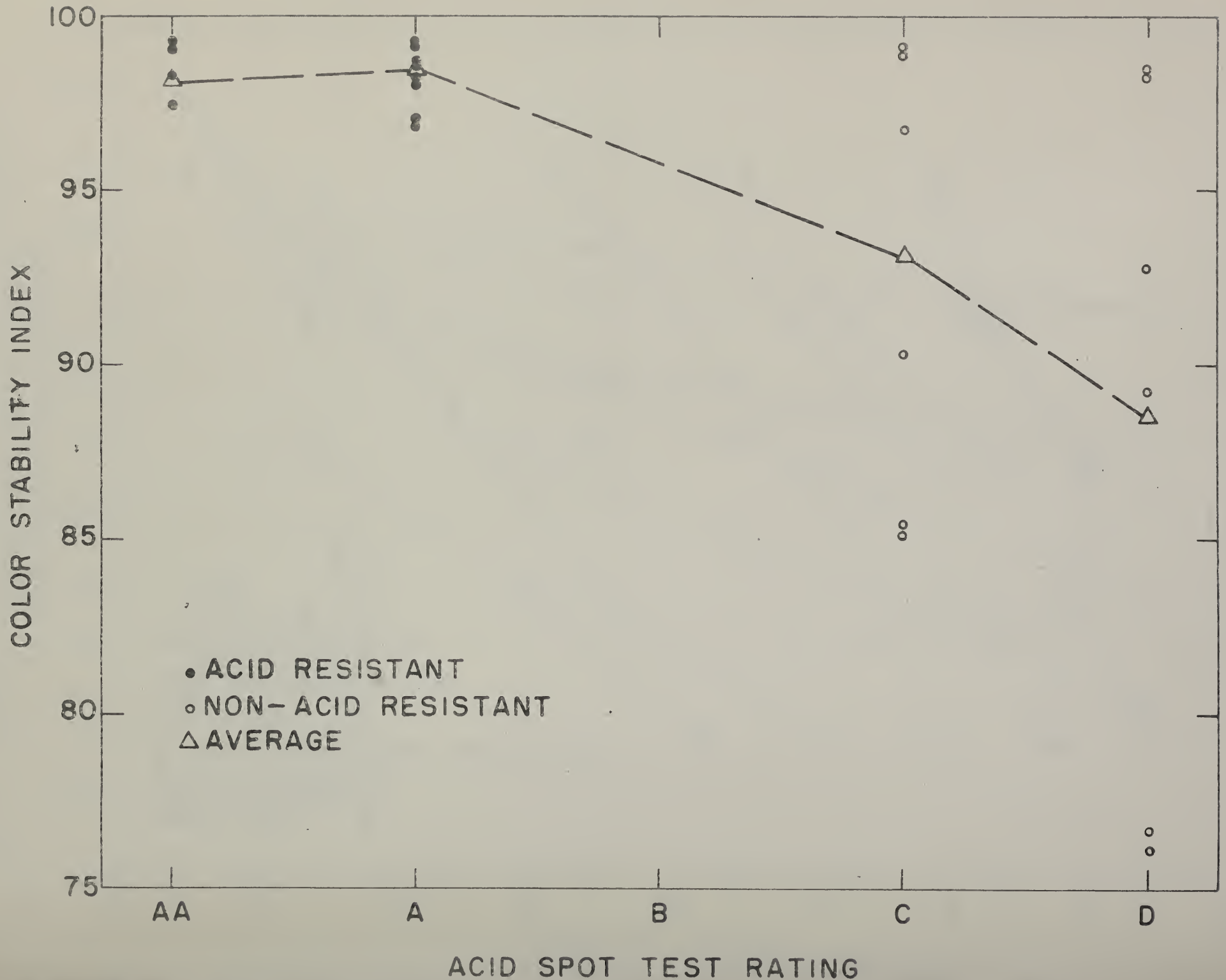

Fig. 6. Effect of Acid Spot Resistance on Color Stability of Gloss Enamels on Steel

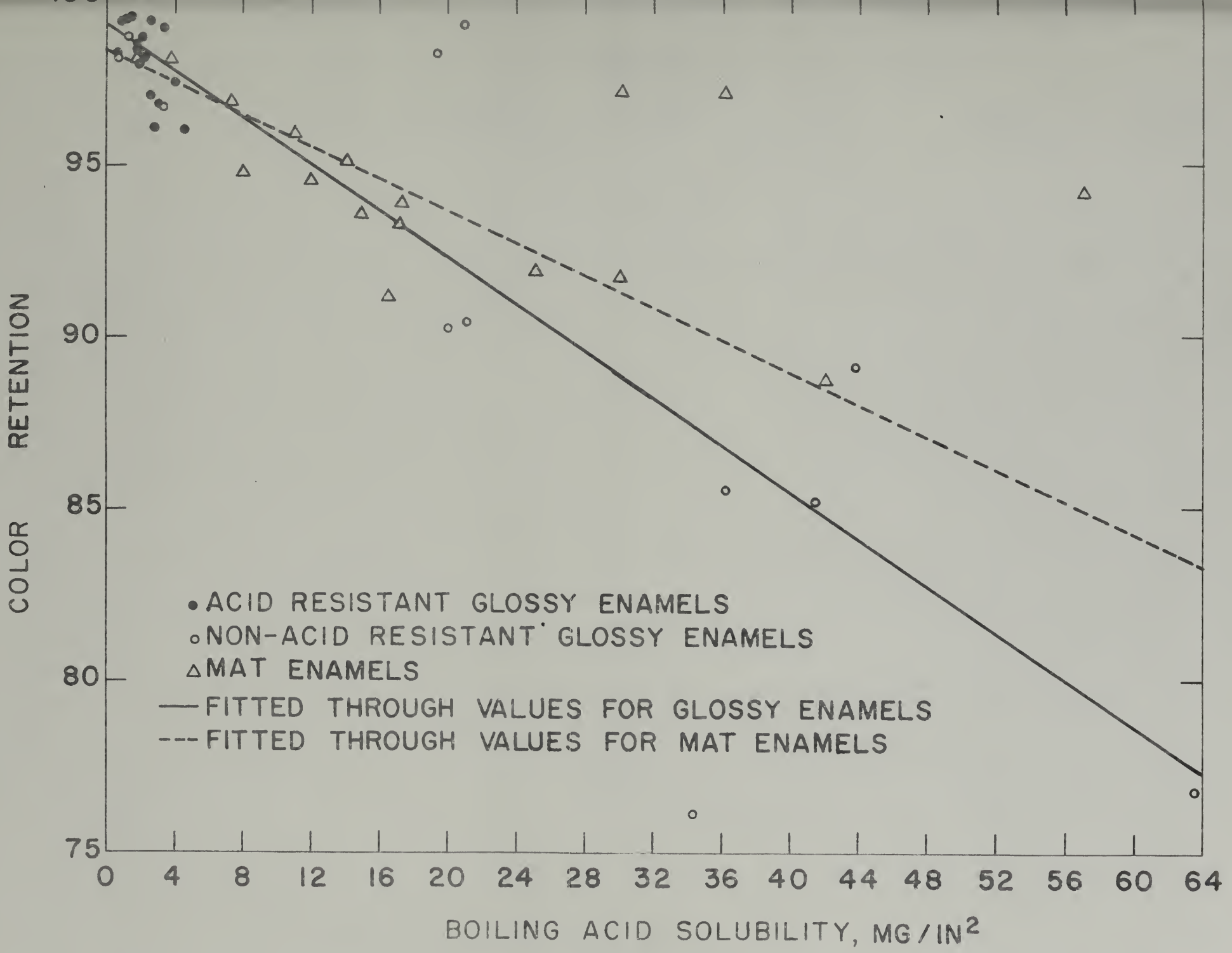

Fig. 7. Effect of Acid Solubility on the Color Stability of The Regular Enamels on Steel Exposed Seven Years at Washington.

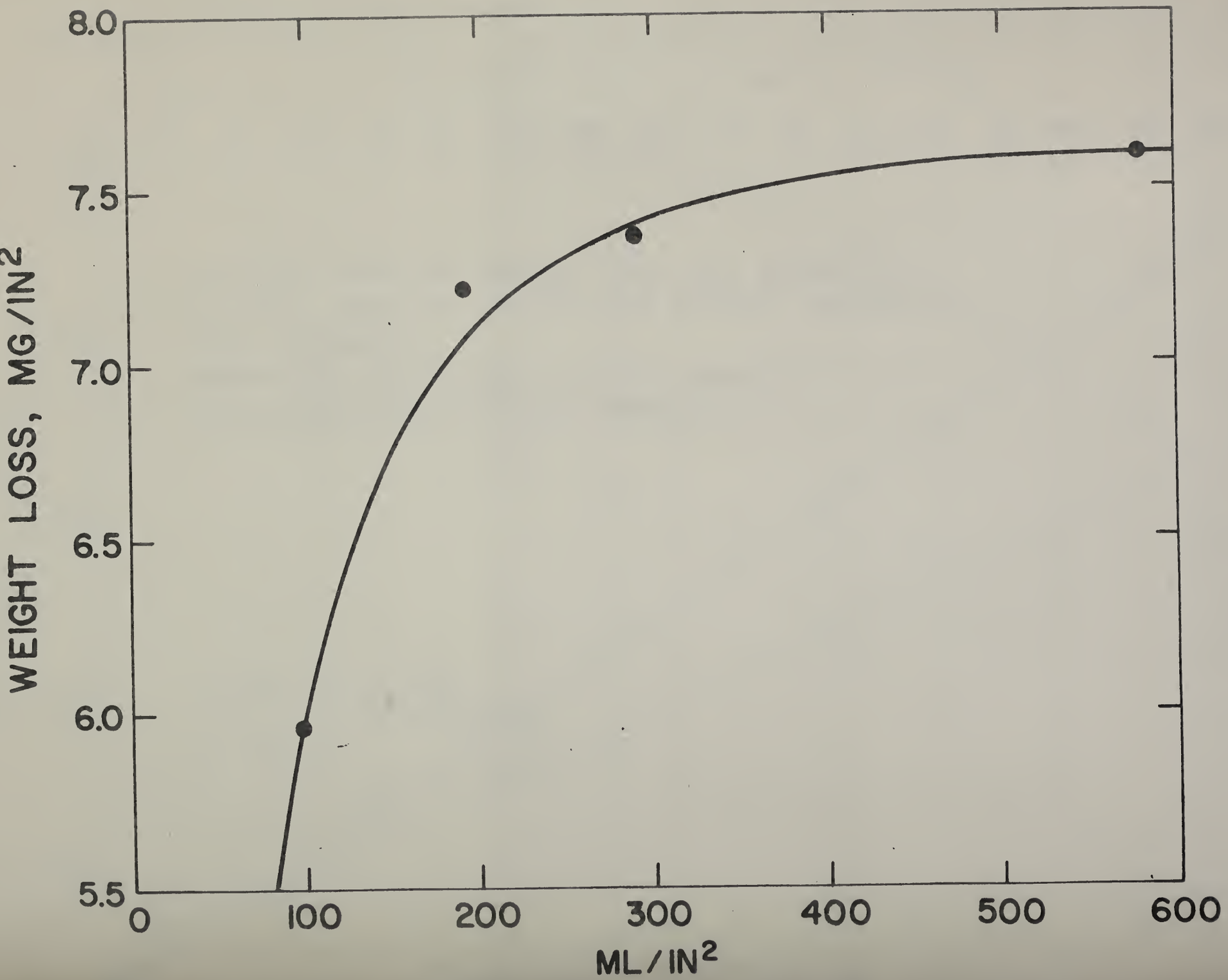

Fig. 8. The Dependance of the Alkali Resistance of Porcelain Enamels on the Ratio of Solution Volume to Specimen Area.


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