NATIONAL BUREAU OF STANDARDS REPORT

9042

PROGRESS REPORT

October 1 through December 31, 1965

Development of Methods of Test
For Quality Control of Porcelain Enamels

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

NBS

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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SUMMARY

A tentative test procedure for cleanability of porcelain enamels has been developed. This procedure consists of mechanically soiling the specimen with a known amount of soil containing a fluorescent tracer, mechanically cleaning the specimen for a specified time and then determining the amount of retained soil by analytical procedures.

Many of the variables concerned with determining the reproducibility of the test have been studied and several different materials have been subjected to the test procedure. The test procedure has sufficient reproducibility to detect significant differences between 21 of the 29 glossy enamel surfaces tested.

The procelain enamels on aluminum exposed for six months at Kure Beach-80, Washington, New York City and Montreal have been inspected. The changes in gloss and color indicate that the Kure Beach site produces more severe changes in the enamel than the other three sides. The red enamels showed poor color stability at all sites. Poor color stability was indicated by all the red specimens failing the test for color stability currently in the architectural specification for porcelain enameled aluminum. There were no appreciable differences in color or gloss retention between the different gloss and thickness ranges after six months' exposure.

Storage specimens of the Nature-tone enamels were tested with the direct-current, high-voltage test equipment. The test results indicated that the best separation between the enamels that did and did not rust was obtained at 2 kV. However, the large percentage of good enamels that failed at this voltage led to an investigation of the relative corrosion rates of mild steel specimens exposed at Kure Beach-80 and other sites in the United States. This investigation revealed that specimens exposed one year at Kure Beach-80 had as much corrosion as would occur in 5-7 years at many industrial locations in the United States.

I. CLEANABILITY

INTRODUCTION

The use of performance criteria for building materials and domestic appliances is a logical way to compare products of different materials intended for the same service. The development of these criteria and of suitable evaluation procedures is receiving increased attention both among government procurement agencies and the industries supplying the needed materiel. The establishment of acceptable levels of performance must be preceeded by the selection of testing methods to measure the performance of products regardless of the material from which they are formed.

One of the current goals of the Porcelain Enamel Institute research effort is the selection and development of a testing procedure to evaluate the cleanability of porcelain enamels and other competitive building and appliance systems.

The procedure under development involves: (a) the application of a standard soiling agent to a specimen surface, (b) the partial removal by a standardized cleaning treatment and (c) the determination of the amount of retained soil which is used as an inverse index of the property of cleanability.

TENTATIVE TEST PROCEDURE

The results and discussion that follow, in later paragraphs, deal with variations of the individual parts of a tentative test procedure and the application of this technique to specimen surfaces of porcelain enamel and other materials. This section describes the sequence of test procedures used, in order to provide a frame of reference for the results and later discussion.

1. Tha Soiling Agent.

The standard soil used was described in a previous report and consisted of:

Ingredient	Amount in Percent by Weight
BBOT[a]	3.3
Powdered Graphite	32.8
Mineral Oil	63.9

a/ 2,5-bis-[5' - tert-butylbenzoxazolyl (2')]-thiophene.

2. The Cleanability Test Procedure.

a. Specimens were prepared for test by a cleaning sequence which involved scrubbing with a cellulose sponge moistened with a one percent solution of trisodium phosphate until a "water break" was not observed.

The specimens were then washed thoroughly with a household detergent and rinsed with running tap water, distilled water and absolute alcohol and allowed to dry in a near vertical position.

b. A cleaned specimen was attached, face up, to an 8-inch lapping wheel with tape across the corners as shown in Figure 1.

c. A weighed amount of the premixed graphite and BBOT was added to three drops of mineral oil on the specimen surface. The dry components and the oil were blended on the specimen with a spatula.

d. The soil was uniformly distributed over a 3-inch diameter central area of the specimen by the combined action of the rotation of the specimen with the lapping plate, and the back-and-forth motion of the padded brass head.

e. A mechanical cleaning action was provided through the use of a tissue-covered, 2 1/4-inch diameter brass disc which operated with the same action as described above. The tissues were changed at specified intervals.

f. A circular area, 1 1/4-inches in diameter, at the center of the cleaned specimen was covered with a teflon mask. All of the specimen surface except the covered area, was cleaned by hand-rubbing and solvent action, first with a tissue moistened with toluene, followed with a clean, dry tissue. This cleaning operation was repeated two more times, after which the mask was removed. At this stage, the soil retained on the specimen after the mechanical cleaning operation (e above) had been removed except for the masked spot.

g. The oil and BBOT from the "spot" on the specimen surface was extracted with toluene which is a good solvent for these reagents. The graphite of the original soil was inert to toluene and remained on the specimen. A 150-ml 2-inch diameter glass reagent bottle, from which the bottom had been removed, was clamped against a 1/16-inch thick teflon gasket and the specimen. A weighed portion of toluene was poured into the reagent bottle which was then closed with a standard-taper glass stopper. The toluene was repeatedly agitated during a two minute period by up-ending and swirling the extraction device and specimen.

h. A small portion of the toluene solution was poured into a clean beaker and transferred to a 5 ml cuvette so that the intensity of the fluorescent solution could be measured in the fluorometer. The concentration of extracted BBOT, in micrograms per ml, was obtained through the use of the appropriate calibration curve, Figure 2. The volume of the toluene used for the extraction was calculated from its weight and density at the solution temperature.

The weight of BBOT found (μg) = concentration (μg/ml) x volume of solvent (ml).

$$\text{Total soil retained, } \mu g/cm^2 = \frac{\text{BBOT, } \mu g \text{ found}}{\text{BBOT content x Extraction area}}$$

$$= \frac{\text{BBOT, } \mu g \text{ found}}{0.033 \times 7.917 \text{ cm}^2}$$

$$= \text{BBOT, } \mu g \text{ found} \times 3.828$$

3. A Modified Procedure Using Aluminum Alloy Specimens.

A series of experiments was made using uncoated specimens of aluminum alloy. This material was selected because it presented a uniform textured surface, and adjacent 4-inch specimens from the same sheet had a greater probability of being uniform, than porcelain enamel specimens from the same lot. In addition the material, in 0.064-inch thick sheets, was easily shearable into 1-inch square test pieces which would provide replicate coupons from a specimen soiled and cleaned in a single operation. The soil from a 1-inch coupon could be rapidly extracted by dropping the coupon into a known volume of toluene, thus minimizing the possible errors of the normal extraction procedure. Precise estimations of coupon area were readily obtained from the specimen weight, density and thickness.

The pattern for shearing four 1-inch coupons from a 4-inch specimen is illustrated in Figure 3. The aluminum alloy specimens were cleaned before testing in the manner outlined for porcelain enamel specimens except that a 30-second scrub with a nylon bristle hand brush in a mild etching cleaner was substituted for the trisodium phosphate scrub.

RESULTS AND DISCUSSION

Seven soiling and cleaning methods were explored in an attempt to find the most reproducible. These methods, which are outlined in Table 1, differ in the soiling implement, the grade of cleaning tissues used and the length of time used in the cleaning process. Methods one through four were evaluated using similar specimens of a buff colored porcelain enamel from a single lot. Eight specimens of the porcelain enamel were tested by each method and individual amounts of retained soil were recorded. The results obtained when using these four methods are given in the top part of Table 2. It can be seen that, as the time of the cleaning operation was increased from 0.75 to 3.5 minutes, the amount of retained soil steadily decreased. The results are also characterized by quite large specimen-to-specimen variability as indicated by the coefficients of variation. This measure of scatter is simply the standard deviation from the mean value expressed as a percentage of the mean value.

The results by which methods 2, 5, 6 and 7 were compared are given in Tables 2 and 3. As the cleaning operation was extended from 1.5 to 5.5 minutes in methods 5, 6 and 7, one can see a gradual reduction in the amount of retained soil, but what was more encouraging, the specimen-to-specimen variation also decreased materially.

Figure 4 shows the dependance of amount of retained soil on the cleaning time when methods 5, 6 and 7 were used on aluminum alloy specimens. In this figure, the average amount of retained soil is represented by a point on the graph at the appropriate cleaning time. The vertical bars through each point extend from one standard deviation above to one standard deviation below each average value of retained soil. Thus the position of the points and the length of the deviation bars show both the effectiveness of the cleaning treatment and its variability.

The principle variables involved in the measurement of the fluorescence extracted from replicate pieces were the simplified extraction procedure and the variability associated with the analytical method. The variation between specimen averages, on the other hand, must be associated with the combined errors in the soiling, the cleaning, the extraction and the analytical determination of fluorescence. The variation among replicate pieces of the same specimen, which might be referred to as the error of the "method", was small when compared with the variation between specimens. This suggested that the analytical method was precise enough to sort out real differences from specimen to specimen of the same composition.

Method 7, together with the method of fluorescence measurements, was shown to be a procedure capable of determining retained soil on a series of uniform specimens with a coefficient of variation of 10 percent. This method was the best of those tried and was selected for a series of tests on specimens of porcelain enamels and other materials. It was desired to show the range of values for retained soil that might be found for candidate surfaces that differed in gloss, acid resistance, color, material and texture. It was also desired to determine whether this testing procedure was sufficiently precise to provide significantly different cleanability values for these surfaces.

The results obtained on the surfaces tested are given in Table 4. In most cases six specimens of each candidate surface were evaluated and the average given together with its coefficient of variation.

It can be observed that the average value for the coefficient of variation was 24 percent when method 7 was applied to porcelain enamel and other materials. It will be recalled that this method was capable of yielding a 10 percent coefficient between aluminum alloy specimens. The somewhat greater variability found when this method was applied to other surfaces, indicates that the responsibility for the increased variability must be attributed either to the more complicated extraction procedure used in the latter case or to real differences in specimen cleanability within a group of similar surfaces (the same enamel composition).

The porcelain enamels in Table 4 have been arranged in the order of decreasing gloss. In general there appears to be some dependance of retained soil on gloss. It is probable that the acid resistance of enamels has little influence on cleanability. This is not surprising because acid resistance would be expected to depend, to a large extent, on the composition of the enamel layer. The cleanability, on the other hand, might be expected to depend more on surface texture than on enamel composition.

Eight porcelain enamels tested had values of 45° specular gloss between 55 and 63 units. It was of interest to determine whether the average amounts of retained soil found in these tests indicated statistically significant differences in cleanability among these porcelain enamels. The eight enamels were arranged in the order of their cleanability values as shown in Table 5. Comparisons were made between each enamel and all of the others, individually. The statistic used to test the significance of the observed differences was "t"[1/] which is defined in Table 5. It can be seen that no sighificance, at the 95 percent confidence level, could be attached to the small differences found when seven of the nearest neighbor (in this series) enamels were compared. In the other 21 comparisons, however, where the differences between average values were somewhat larger, the differences were found to be statistically significant at the 95 percent confidence level.

The results given in Table 4 suggest the following observations:

1. The specimen-to-specimen variability in cleanability values for materials tested to date was not unreasonable in view of the microgram quantities of retained soil determined.

2. A test for cleanability as outlined in this report should be based on the average of no less than six specimens.

3. The cleanability test used was sensitive enough to differentiate between many of the glossy porcelain enamels when average values of retained soil were less than one microgram per square centimeter.

PLANS FOR NEXT REPORT PERIOD

(a) Determinations using method 7 on other surfaces such as polished plate glass, glazed vitrified china, wall tile, and polyester gel-coats.

(b) The use of image gloss and profilometer traces to describe surface textures.

(c) Improvement of the extraction method.

(d) A program to show whether correlation can be found between cleanability estimates by the use of fluorescent soils and other estimates that more closely simulate domestic cleaning procedures.

(e) Determining the soiling and cleaning treatments necessary with new, less expensive lapping equipment to give results comparable with those obtained with the equipment illustrated in Figure 1.

II. EXPOSURE TEST OF PORCELAIN ENAMELED ALUMINUM

INTRODUCTION

The development of porcelain enamels for aluminum has opened a whole new field in the porcelain enameling industry. Early exposure test data[2/] on these enamels have indicated that accelerated exposure tests designed for porcelain enamels on steel were not completely reliable indicators of the weatherability of the lower firing enamels that are applied to aluminum. This is especially true when these enamels are compared with enamels that are applied to steel. Therefore, early in 1964, the Aluminum Council of the Porcelain Enamel Institute authorized an exposure test of enamels on aluminum to be conducted jointly by the Porcelain Enamel Institute and the National Bureau of Standards. These enamels have now been exposed for six months. The specimens exposed at all sites except Los Angeles have been returned to the Bureau of Standards for inspection. Those exposed at Los Angeles have not yet been received but they are expected early next quarter.

1. Test Specimens

Sixteen enamels are included in this test. These enamels vary in gloss, color and thickness as previously reported. If minor variations in milling and firing for the different fabricators, are taken into consideration, a total of 51 different enamels are included in this test.

In an effort to minimize specimen to specimen variations, each enamel was applied to a 3 x 5 foot sheet of 0.064-inch 6061 aluminum alloy. After the sheets had been fired, they were cut into 94 exposure specimens.

2. Exposure Sites

The enamels are exposed on the roofs of Federal Government buildings in New York City, New York; Los Angeles, California; and Washington, D.C.; as well as the roof of the Stores Department Building in Montreal, Canada, and a ground site at Kure Beach, North Carolina - 80 feet from the ocean. The specimens are exposed at 45° and face south at all sites except Kure Beach where they are exposed, courtesy of the International Nickel Company; on their exposure racks which are at 30° and face the ocean at East-Southeast.

RESULTS

1. Cleaning of Specimens

In previous exposure tests [2,3] the specimens exposed at one of the sites required scouring before the enamel surface could be examined. These scouring treatments tended to increase the gloss readings of the enamels so they were not comparable with enamels exposed at the other sites. Therefore, in this test, it was decided to scour the specimens both before and after exposure.

The specimens were cleaned by 1) scouring 30 strokes with a sponge dampened 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 finally 4) rinsing with alcohol. This method of cleaning was satisfactory for the specimens exposed at all sites except New York City. The specimens exposed for six months at New York City were covered with a film, approximately 0.03 mils thick, that was very difficult to remove. The cleaning procedure was altered slightly to scouring with calcium carbonate on cheesecloth until the specimens were clean. They were then rinsed as described above.

2. Gloss and Color

The 45° specular gloss of the enamels was measured at four orientations near the center of the specimen, both before and after exposure. The gloss is reported as the percentage gloss retained after exposure.

The color of the specimens was measured with a color difference meter. One of the reference panels was used as the standard in measuring the color difference. This was done to obtain efficiency with this type of instrument. The reference standard was, in turn, measured against calibrated NBS color standards to determine whether the enamels change color during storage. The color change is reported as color retention which is 100 minus the color difference in NBS units[4/].

The average percentage gloss retained and color retention for the three specimens of each enamel exposed at each site as well as the reference enamels are given in Table 6.

3. Comparison of Exposure Sites

The average values for color retention and percentage gloss retained for all enamels exposed at each site are given in Table 7. A two-sided sign test[5/] performed on the data indicated a significant difference between Kure Beach and all other sites for both gloss and color. There was also a significant difference noted between Washington and both Montreal and New York for one of the two parameters but not both. Therefore, these differences were not considered significant at this time. It must be noted that six months is a relatively short exposure time and that the differences between sites will probably be more pronounced with increased exposure time.

4. Comparison of Enamel Colors

The average color retention and percentage gloss retained for each of the nine colors included in the test are presented in Table 8. It is obvious that the red enamels showed the poorest color retention at all sites. However, all the red enamels failed the 15-second nitric acid spot test included in the Specification for Porcelain Enamel on Aluminum for Weather Exposure; PEI:ALS-105. In addition, all the red enamels failed the cupric sulfate test for color retention which is included in the Specification for Architectural Porcelain Enamel on Steel for Exterior Use; PEI: S-100.

There was very little difference between the color stability of the remaining eight colors. The slight differences which did occur were not considered to be significant at this time. Again this may change with longer exposure time.

5. Comparison of Enamels in the Different Gloss Ranges

The enamels were divided into three gloss ranges; low, medium and high. The low gloss enamels had an initial 45° specular gloss reading of less than 35, the medium between 36 and 69, and the high over 70. Table 9 shows the average gloss and color data for these enamels. The color retention data are a better criteria for comparing these enamels because small changes in gloss result in increasingly larger percentage losses as the initial gloss of the enamel is lowered. When comparing were tested with the high-voltage tester. The enamels were arbitrarily divided into two classes, poor and good, depending on whether the exposed specimens did or did not rust in six months. The results of the high-voltage probes are presented in Figure 5. Here it can be seen that the best separation occurs at 2 kv. All of the enamels that rusted in service failed the discharge test at 2 kv. However, 40% of the enamels that did not rust also failed at this voltage. This high percentage could be caused by 1) the short exposure time which did not permit the potentially poor enamels to rust, 2) differences between the storage specimens and the exposed specimens and 3) lack of correlation between the test method and actual service data.

2. Relative Severity of Kure Beach-80

The high percentage of good enamels that failed the high-voltage discharge test at 2 kv led to an investigation of the relative severity of Kure Beach-80 and other sites. Perhaps specimens which rusted in six months at Kure Beach-80 wouldn't rust at all for 15-20 years at any other exposure site. A review of the literature disclosed an exposure test conducted by ASTM[6/] that may be applicable in the present situation. This work was done to compare the corrosion occurring on both mild steel and zinc exposed at many different sites. It was found that one-year exposures of steel were significant to get reproducible results at rural and industrial sites but specimens exposed at marine sites had corrosion occurring at increased rates for the first four years of exposure. This increased corrosion rate was thought to be caused by the accumulation of salt deposits on the underside of the specimens.

However, since the enamels in question had been exposed for only six months, the one-year data for steel specimens reported in reference 6 were evaluated. In this evaluation the relative severity of each site was determined by dividing the average weight loss of the specimens exposed at the different sites into the average weight loss for the specimens exposed at Kure Beach-80. This gave an indication of how much longer specimens would have to be exposed at other sites before corrosion comparable to that noted at Kure Beach-80 would occur. These data are presented in Table 12. The data indicate that specimens that rusted at Kure Beach-80 in one year would be apt to rust within 5-8 years at many marine or industrial sites. This is, indeed, a very short time for any architectural porcelain enamel installation to last. Thus the rusting of 25% of the nature-tone enamels, which have had excellent public acceptance, in six months exposure at Kure Beach-80 is a problem that cannot be neglected. It appears reasonable that losses encountered before installation by testing these enamels at 2 kv would be small when compared with the losses resulting from a bad public image when these enamels rust within five to eight years after installation.

3. High-Voltage Test Equipment

There are two basic types of high-voltage test equipment on the market: AC and DC. The test equipment used in this work has been one with a variable output of 100 to 5000 DC volts. AC equipment is used to test glass lined chemical tanks. However it must be noted that AC and DC volts are not the same. Miller[7/] has stated that a conversion factor of 1.7 for AC to DC is commonly agreed on. This means that

1700 volts DC are equal to 1000 volts AC. This is very important to remember if one is performing tests with AC instruments instead of DC. Miller also states that the output of DC equipment is not accurate below 10-20% of its maximum output.

PLANS FOR NEXT REPORT PEROID

During the next report period it is planned to test enamels of various thicknesses to determine the effect of thickness, on the high-voltage discharge testing. It is also planned to test some appliance enamels.

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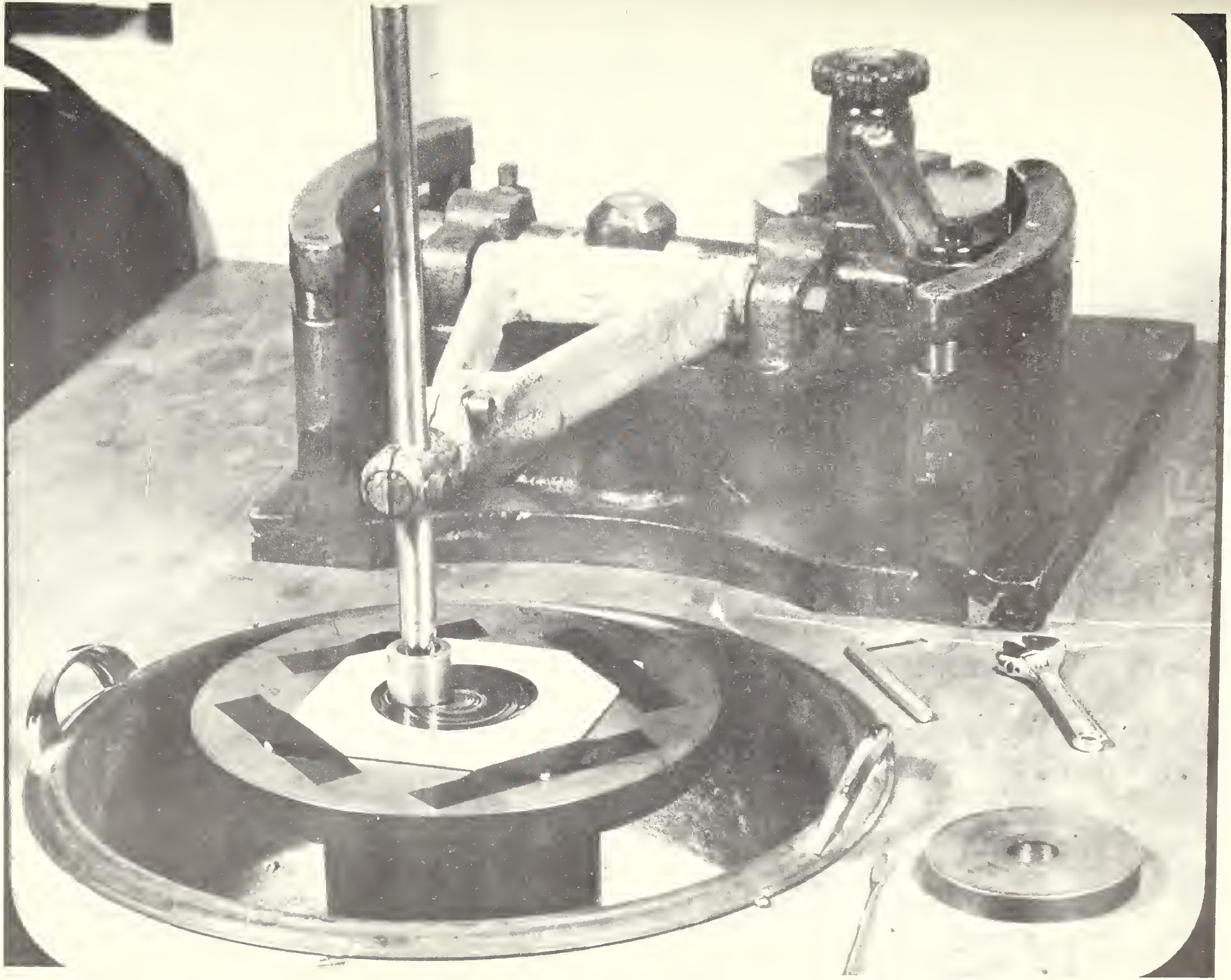

Figure 1. Lapping Equipment Used for Soiling and Cleaning Specimens.

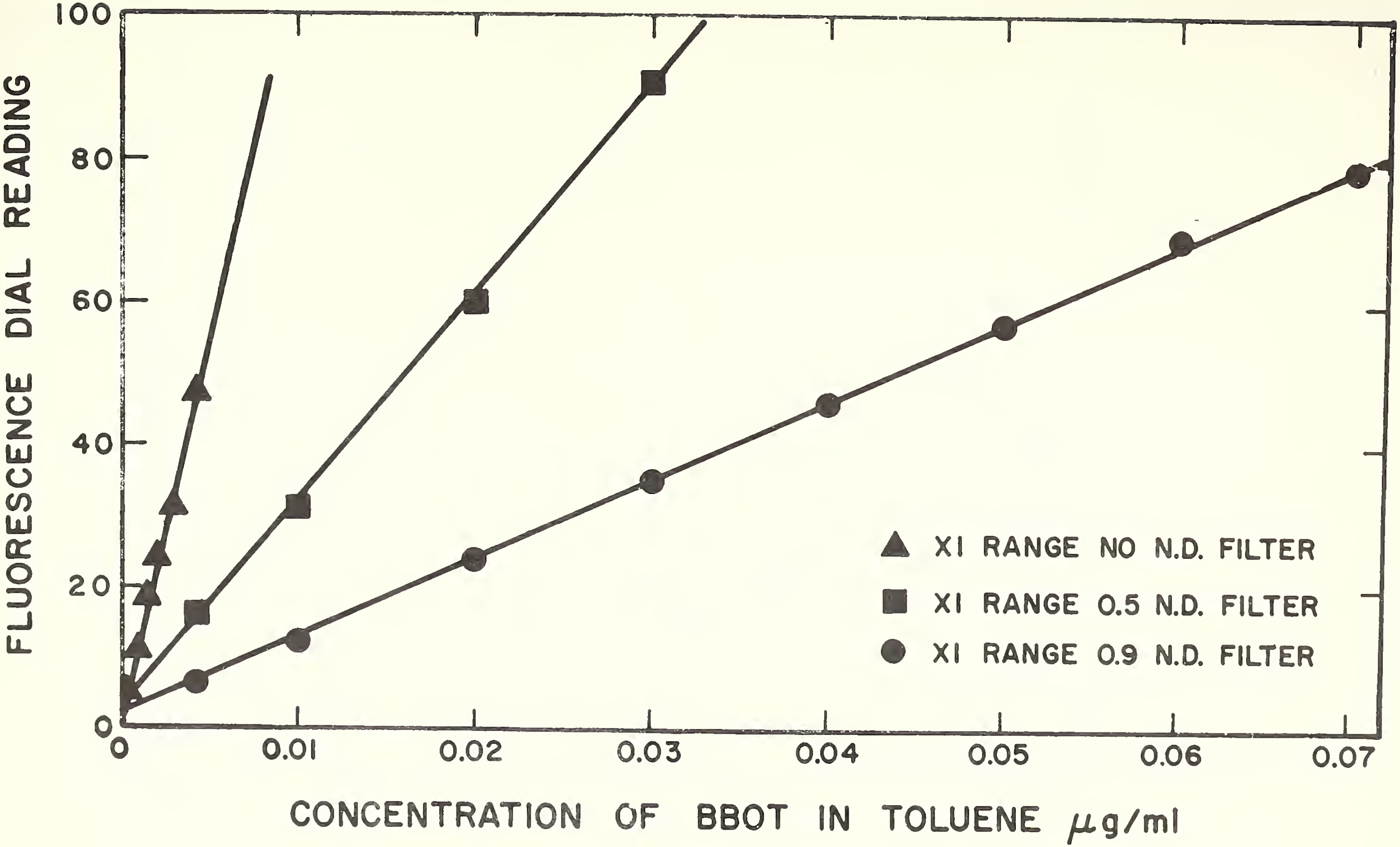

FIG. 2 CALIBRATION OF FLUOROMETER WITH BBOT IN TOLUENE.

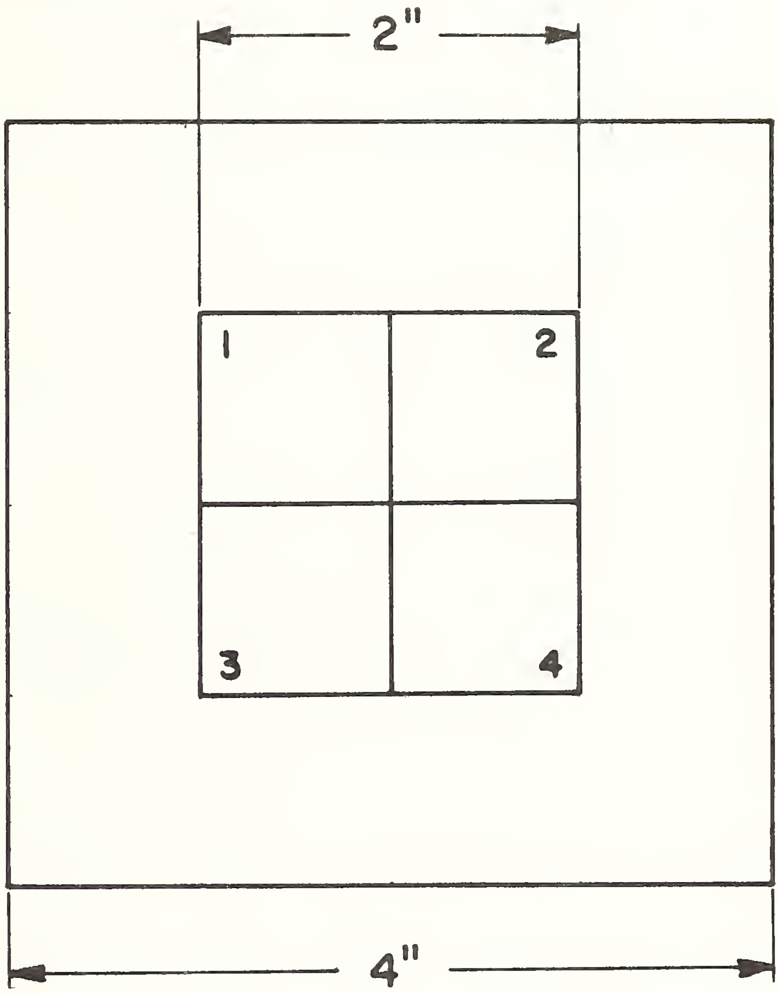

Figure 3. Showing the Location of Four Replicate Coupons Relative to an Aluminum Alloy Test Piece From Which They Were Sheared.

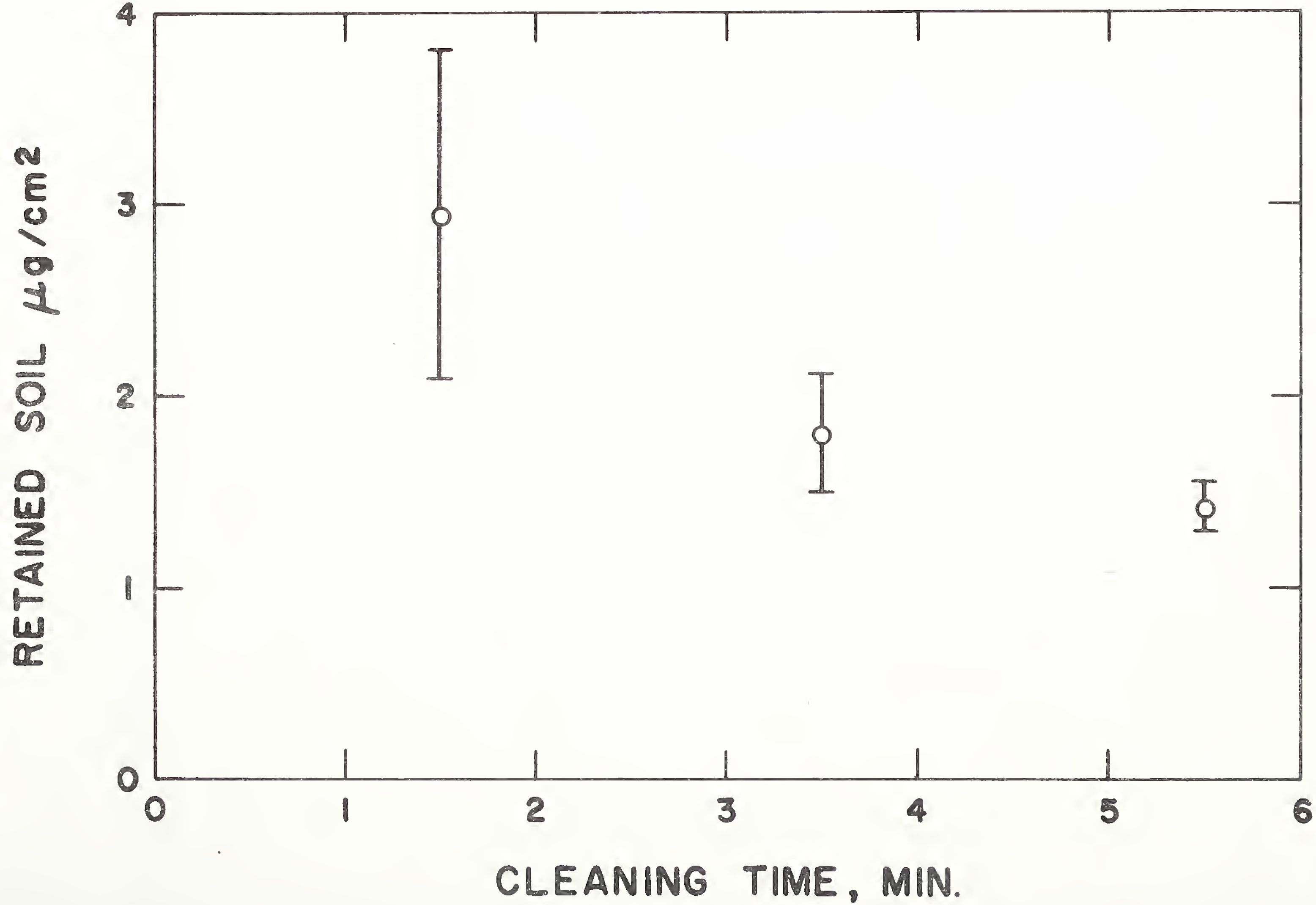

Figure 4. Relation of Residual Soil and Cleaning Time.

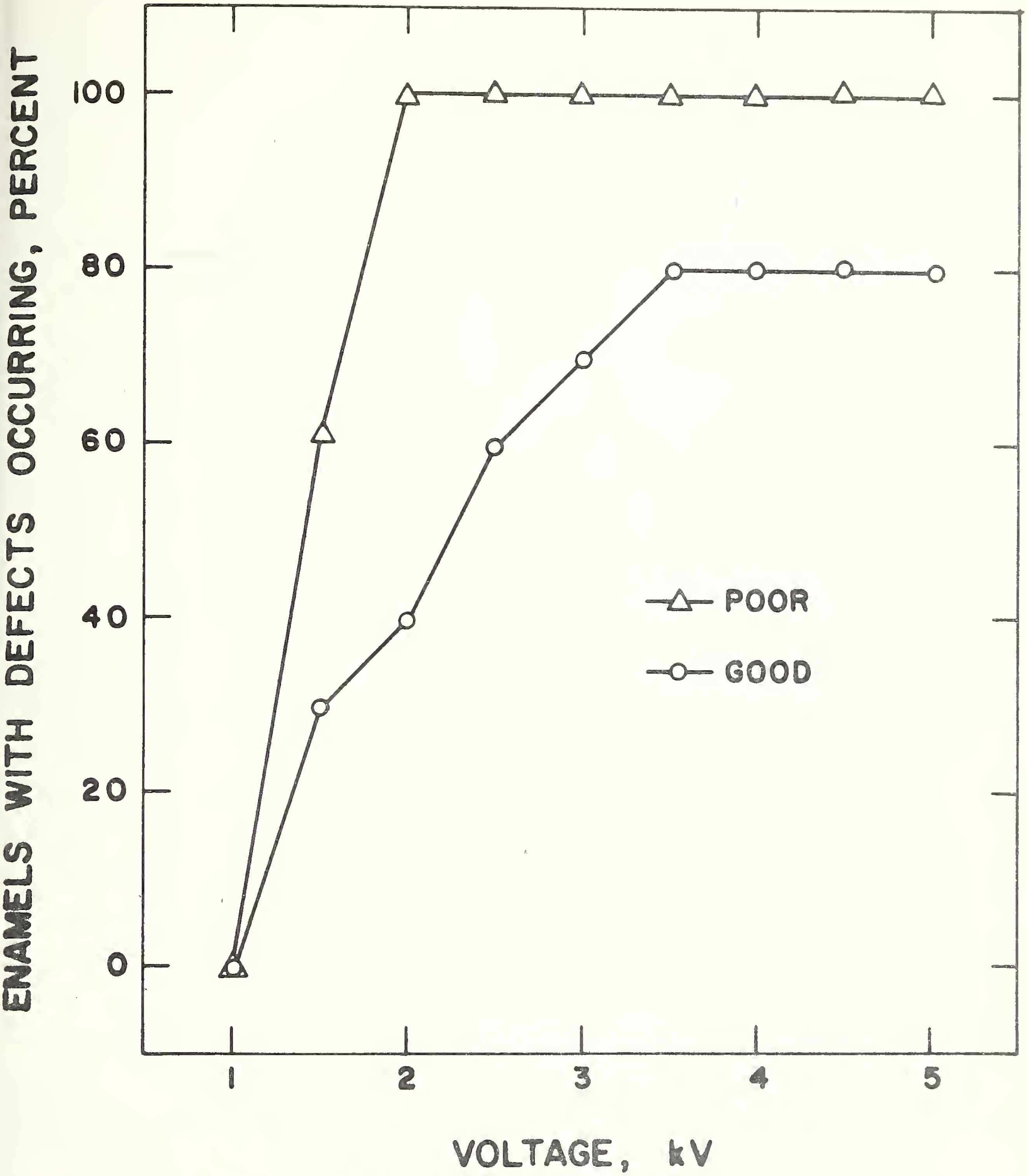

Figure 5. Comparison of High-Voltage Test Results for Good and Poor Nature-Tone Enamels.

Table 1. Description of Soiling and Cleaning Methods. a/, d/

Method No.	Soiling Application	Cleaning Times Before Tissue Changes					Total Cleaning Time
		1st	2nd	3rd	4th	5th	
		Seconds					Minutes
1	b/	15	15	15	--	--	0.75
2	b/	15	15	60	--	--	1.5
3	b/	15	15	60	60	--	2.5
4	b/	15	15	60	120	--	3.5
5	c/	15	15	60	--	--	1.5
6	c/	15	15	60	120	--	3.5
7	c/	15	15	60	120	120	5.5

a/ Soil composition (weight percent): BBOT 3.3; Graphite 32.8; Mineral oil 63.9. A total weight of 0.097 g of the soil was used for each specimen.

b/ The soil was mechanically applied with a 1-inch brass head covered with a plastic pad. The horizontal stroke was 1.5 inches and the application time was one minute.

c/ The soil was mechanically applied with a 1-inch brass head covered with two thicknesses of unbleached muslin. The horizontal stroke was three inches and the application time was one minute.

d/ The cleaning employed a 2-1/4-inch brass head covered with four thicknesses of cleaning tissue operated with a horizontal stroke of three inches. Methods 1 thru 4 employed a highly absorbant wiping tissue. Methods 5 thru 7 employed a less absorbant and harder lens tissue.

Table 2. Comparison of Soiling and Cleaning Methods by Fluorometric Analyses of Retained Soil.

Specimens of BUFF Porcelain Enamel
Acid Resistance "A" - Gloss 55 Units

	Method 1	Method 2	Method 3	Method 4
	$\mu g/cm^2$	$\mu g/cm^2$	$\mu g/cm^2$	$\mu g/cm^2$
	1.97	1.46	1.46	0.78
	3.09	1.63	6.83 [a/]	.54
	1.82	1.40	0.74	.62
	1.25	1.61	.62	.81
	3.69	1.31	1.65	.90
	2.80	1.72	1.64	.99
	2.37	1.65	1.84	1.00
	1.78	1.80	1.35	0.94
Average	2.35	1.57	1.33	0.82
Coef. of Variation	34%	11%	35%	20%

Specimens of 6061 Aluminum Alloy Mill Finish

Soiling and Cleaning Method 2

4" x 4" Specimen No.	Soil Retained on 1" x 1" Replicate Pieces of the Same Specimen					Coeficient of Variation (Between Replicates)
	$\mu g/cm^2$				Average	Percent
A	7.80	6.51	6.69	6.31	6.83	9.7
B	8.18	7.94	8.17	8.60	8.22	3.4
C	5.90	6.19	6.29	6.13	6.13	2.7
D	6.66	6.07	6.62	6.42	6.44	4.3
	Average				6.90	5.0
	Coeficient of Variation (Between Specimens)				13%	

a/ Omitted from average.

Table 3. Comparison of Soiling and Cleaning Methods of Specimens of 6061 Aluminum Alloy by Fluorometric Analyses of Retained Soil.

4" x 4" Specimen No.	Soil Retained on 1" x 1" Replicate Pieces of the Same Specimen				Coeficient of Variation (Between Replicates)
	$\mu g/cm^2$			Average	Percent
			Method 5		
1	3.72	3.05	3.24	3.33	10.1
4	4.26	4.14	4.26	4.22	1.6
9	2.17	2.18	2.24	2.20	1.7
7	2.01	1.88		1.94	4.8
8	2.68	2.61		2.64	1.9
10	3.40	3.27		3.24	2.8
		Average		2.94	3.8
		Coeficient of Variation (Between Specimens)		29%	
			Method 6		
5	2.04	1.75	2.04	1.94	8.6
6	1.83	1.53	1.51	1.62	11.0
2	2.12	2.24	2.76	2.37	14.3
11	1.72	1.65		1.69	2.9
12	1.81	1.74		1.78	2.9
13	1.52	1.42		1.47	5.7
		Average		1.81	7.5
		Coeficient of Variation (Between Specimens)		17%	
			Method 7		
14	1.40	1.23		1.32	9.1
15	1.44	1.45		1.44	0.1
16	1.29	1.17		1.23	6.9
17	1.43	1.47		1.45	2.0
18	1.63	1.64		1.64	0.4
19	1.45	1.37		1.41	4.0
		Average		1.42	3.8
		Coeficient of Variation (Between Specimens)		9.8%	

Table 4. The Estimation of the Cleanability of Porcelain Enamels and Other Materials.[a]

Material	Characteristic	45° Specular Gloss Value	Acid Rating	Total Soil Retained[b]	Coefficient of Variation
				μg/cm^2	Percent
Porcelain Enamel	White	63	A	0.18	24
"	1AA	62	AA	.33	24
"	FOR	61	B	.78	11
"	Brown	60	AA	.24	23
"	1RA	60	A	.41	17
"	OAA	58	AA	.53	24
"	Buff	55	A	.15[c]	15
"	CO	55	C	.30	26
" (matte)	4F	16	D	1.72	25
" "	2F	9	B	7.72[d]	19
" "	F1	8	A	8.76	30
" "	3F	6	C	1.24	41
Polyester Gel Coat	DF	56	--	1.82	14
Aluminum Alloy	6061	--	--	1.42	10

a/ These estimates of cleanability were made employing Method 7, outlined in Table 1. Low values of retained soil indicate good cleanability; larger values are associated with poorer cleanability.

b/ The value given is the average for six specimens unless otherwise noted.

c/ Average for 5 specimens.

d/ Average for 4 specimens.

Table 5. Results of Tests for Significance of the Differences in Cleanability Among the Glossy Porcelain Enamels on Steel.[a/]

		Buff 0.152	White 0.185	Brown 0.241	CO 0.295	IAA 0.329	IRA 0.412	OAA 0.533	FOR 0.780
FOR	0.780	s	s	s	s	s	s	s	--
OAA	.533	s	s	s	s	s	ns	--	
IRA	.412	s	s	s	s	ns	--		
IAA	.329	s	s	ns	ns	--			
CO	.295	s	s	ns	--				
Brown	.241	s	ns	--					
White	.185	ns	--						
Buff	.152	--							

An "s" in the body of the table indicates that the cleanability values for the enamels at the head of that row and column were found to differ significantly at the 95% confidence level.

An "ns" in the table indicates that no significance was found by a "t" test for that pair of enamels at the 95% level of confidence.

a/ The statistic used to test the significance of differences between averages was:

$$t = \frac{\bar{x} - \bar{y}}{Sp} \sqrt{\frac{nm}{n + m}}$$

where:

$\bar{x}$ = mean value for n determinations in one set.

$\bar{y}$ = mean value for m determinations in the other set.

Sp = standard deviation pooled from both sets.

TABLE 6 SUMMARY OF SIX MONTHS EXPOSURE DATA FOR PORCELAIN ENAMELS ON ALUMINUM

Enamel	KURE BEACH		WASHINGTON		MONTREAL		NEW YORK		STORAGE		VISUAL	ACID SOLUBILITY
	Gloss	Color	Gloss	Color	Gloss	Color	Gloss	Color	Gloss	Color	Color	mg/in^2
AA-A	85.5	99.4	93.2	99.5	93.8	99.5	98.3	99.4	98.8	99.9	White	5.5
AA-B	94.0	99.3	92.7	99.5	98.6	99.4	94.5	99.7	99.2	99.7	White	5.9
AA-C	90.7	99.0	90.7	98.8	92.0	98.9	92.3	99.2	99.1	99.9	White	5.0
AA-D	76.0	98.3	94.6	97.8	100.0	97.8	101.1	97.9	99.2	99.8	White	12.7
AB-A	81.2	98.8	82.8	98.8	83.9	98.7	95.9	98.1	99.6	99.9	White	7.2
AB-C	79.6	99.6	81.0	99.5	82.7	99.4	83.9	99.2	98.1	99.8	White	4.9
AB-D	75.3	98.5	93.3	98.9	80.0	98.9	100.5	98.3	99.2	99.9	White	7.9
AC-A	90.2	99.4	93.0	99.3	98.6	98.6	96.3	99.3	99.0	99.4	White	6.4
AC-B	85.8	98.7	92.8	99.1	101.3	99.0	103.4	99.0	99.3	99.8	White	11.3
AC-C	90.6	98.3	93.7	98.6	98.3	98.9	99.0	98.7	99.8	99.7	White	9.9
AD-A	87.6	98.9	91.7	99.4	90.3	99.5	100.9	99.2	99.6	99.7	White	6.2
AD-B	89.0	99.4	89.8	99.6	90.5	99.5	97.4	99.1	99.6	99.8	White	6.7
AD-C	82.8	98.1	90.9	99.0	88.6	99.1	105.3	98.1	98.8	99.7	White	7.1
AD-D	87.5	98.1	98.0	96.9	87.7	98.8	104.7	98.1	99.6	99.7	White	12.4
AE-A	76.4	99.1	81.3	98.6	82.1	99.8	82.3	99.8	97.8	99.6	Black	6.5
AE-B	65.1	98.6	86.5	99.8	88.8	99.5	84.6	99.6	98.8	99.8	Black	10.1
AE-C	72.6	98.9	89.4	99.6	91.9	99.5	86.7	99.6	98.4	100.0	Black	12.1
AE-D	71.1	98.6	82.2	98.0	87.4	99.7	83.3	98.9	98.6	99.5	Black	15.5
AF-A	65.6	98.4	69.5	96.0	90.4	99.3	82.1	98.5	99.0	99.7	Black	14.2
AF-B	69.7	99.1	115.0	97.9	95.6	99.4	88.3	99.4	98.5	99.8	Black	9.0
AF-C	72.2	98.4	84.5	98.8	88.2	99.8	84.4	99.3	98.8	99.6	Black	10.1
AG-B	82.0	97.6	100.5	98.6	81.3	98.9	76.2	98.4	98.6	99.7	Black	12.5
AG-B	46.9	98.2	105.7	99.4	31.8	99.5	35.9	98.3	96.2	99.4	Black	7.5
AH-A	90.8	97.5	95.8	98.1	97.8	97.5	118.3	97.6	100.3	99.3	Red	8.1
AH-B	64.3	93.0	72.3	94.6	75.4	95.2	81.7	96.6	100.1	99.7	Red	8.8
AH-C	73.9	90.1	70.8	91.9	77.3	92.8	75.5	91.5	100.1	99.4	Red	6.5
AH-D	59.7	83.6	74.7	88.9	82.8	89.7	79.0	95.2	99.6	99.6	Red	10.5
AO-A	76.6	95.4	82.1	99.1	83.8	99.3	80.2	99.7	99.5	99.7	Dk.Green	19.9
AO-B	72.5	99.5	84.0	99.5	83.4	99.7	83.0	99.7	99.2	99.7	Dk.Green	10.1
AO-D	74.1	97.8	83.8	98.5	87.8	99.4	81.0	99.4	98.9	99.7	Dk.Green	17.0
AP-A	82.2	98.7	95.5	99.4	92.1	99.5	102.3	99.4	99.2	99.8	Lt.Green	12.3
AP-B	75.5	99.4	82.9	99.4	78.6	99.6	86.3	99.6	98.7	99.8	Lt.Green	6.4
AP-C	73.9	99.5	85.7	99.0	76.4	99.5	85.8	99.6	98.2	99.8	Lt.Green	5.2
AP-D	87.5	99.1	93.9	99.0	91.7	99.3	95.4	99.5	98.1	99.8	Lt.Green	10.0
AR-A	47.0	99.6	111.8	99.5	62.4	99.6	54.2	99.3	94.5	99.7	Lt.Green	4.4
AR-B	0.0	99.4	82.5	99.6	4.4	99.7	0.0	98.8	100.0	99.8	Lt.Green	5.5
AR-C	0.0	99.4	85.7	99.6	0.0	99.7	0.0	98.8	100.5	99.7	Lt.Green	8.1
AS-A	78.2	98.7	90.2	99.4	91.2	99.5	91.7	99.4	98.7	99.9	Gray	13.4
AS-B	83.7	98.9	83.0	99.3	83.0	99.4	85.0	99.2	99.1	99.6	Gray	7.4
AS-C	92.5	99.8	91.8	99.6	91.7	99.8	90.4	99.6	99.0	99.7	Gray	5.4
AT-A	75.2	99.0	83.8	98.9	68.3	99.1	80.4	98.9	98.8	99.8	Blue	6.2
AT-B	79.8	98.6	93.8	98.9	91.0	99.3	91.5	98.6	99.4	99.9	Blue	7.0
AT-C	81.5	98.7	78.8	97.1	80.9	99.3	83.3	99.2	98.8	99.8	Blue	6.1
AU-A	89.1	99.3	84.3	99.7	81.2	99.8	88.3	99.7	99.1	99.6	Brown	5.3
AU-B	75.7	99.2	92.4	99.6	79.9	99.8	98.0	99.5	98.2	99.8	Brown	7.5
AU-C	87.4	99.8	94.5	99.5	91.5	99.8	95.1	99.6	98.6	99.8	Brown	7.6
AW-A	81.4	99.2	82.7	99.4	85.7	99.6	86.2	99.5	98.8	99.9	Yellow	7.8
AW-B	78.8	99.3	93.3	99.2	94.2	99.2	95.6	99.3	98.5	99.8	Yellow	8.7
AW-C	72.1	98.9	84.6	99.4	90.3	99.4	91.4	99.4	99.7	99.9	Yellow	18.6
AZ-A	100.9	97.7	93.5	99.3	102.4	99.1	103.4	99.2	100.7	99.9	White	9.5
AZ-B	94.2	99.1	90.6	99.0	93.9	99.3	90.9	99.2	100.0	99.7	White	5.2
Average	75.8	98.2	87.3	98.5	81.7	98.9	85.7	98.8	99.0	99.7		

Table 7. Average Gloss and Color Retention of Porcelain Enameled Aluminum at the Different Exposure Sites

Exposure Site	Color Retention	Gloss Retained (Percent)
Kure Beach-80	98.2	75.8
Washington	98.5	87.3
Montreal	98.9	81.7
New York	98.8	85.7
Storage	99.7	99.0

Table 8. Average Gloss and Color Values for the Different Colors of Porcelain Enameled Aluminum Exposed for Six Months

Enamel	Color					Gloss				
Color	K.B.	Wash.	Mont.	N.Y.	Stor.	K.B.	Wash.	Mont.	N.Y.	Stor.
Red	91.1	93.4	93.8	95.2	99.5	72.2	78.4	83.3	88.6	100.0
Blue	98.8	98.3	99.2	98.9	99.8	78.8	85.5	80.0	85.1	99.0
White	98.8	98.9	99.0	98.9	99.8	86.9	92.6	92.7	98.0	99.4
Black	98.5	98.5	99.5	99.1	99.7	69.1	90.5	81.9	78.2	98.3
Dark Green	97.6	99.0	99.5	99.6	99.7	74.4	83.3	85.0	81.4	99.7
Yellow	99.1	99.3	99.4	99.4	99.9	77.4	86.9	90.1	91.1	99.0
Gray	99.1	99.4	99.6	99.4	99.7	84.8	88.3	88.6	89.0	98.9
Light Green	99.3	99.4	99.6	99.3	99.8	52.3	91.1	57.9	60.6	98.4
Brown	99.4	99.6	99.8	99.6	99.7	84.1	90.4	84.2	93.8	98.6

Table 9. Average Color Retention and Percentage Gloss Retained for Different Gloss Ranges of Porcelain Enameled Aluminum Exposed for Six Months

Color Retention

Gloss Range	Kure Beach	Washington	Montreal	New York	Storage
Low	98.8	99.2	99.4	98.7	99.7
Medium*	99.0	99.0	99.5	99.2	99.8
High*	98.6	98.9	99.2	99.2	99.8

Percent Gloss Retained

Gloss Range	Kure Beach	Washington	Montreal	New York	Storage
Low	46.6	94.7	46.9	49.6	98.3
Medium*	82.1	90.1	87.1	92.9	98.9
High*	78.4	85.4	90.4	88.8	99.6

*The averages for the medium and high gloss enamels were calculated omitting the red enamels since they showed such great color changes.

Table 10. Average Color Retention and Percentage Gloss Retained for One and Two Coat Systems of Porcelain Enameled Aluminum Exposed for Six Months

Color Retention

Number of Coats	Kure Beach	Washington	Montreal	New York	Storage
One*	98.5	98.7	99.3	99.1	99.7
Two	99.1	99.2	99.4	99.2	99.8

Percentage Gloss Retained

Number of Coats	Kure Beach	Washington	Montreal	New York	Storage
One*	76.8	90.3	86.7	87.1	98.9
Two	75.7	88.7	80.8	84.3	98.9

* The red enamels were omitted when the average values for the one coat systems were calculated because they showed such great color changes.

Table 11. Comparison of Porcelain Enamels on Aluminum with Other Porcelain Enamels Exposed for Six Months at Kure Beach-80

Exposure Test	Gloss	Color	Number
Present Aluminum Test	75.8	98.2	51
Aluminum Enamels in 1956 Test	80.5	98.5	10
AR Enamels on Steel, 1956 Test	77.8	98.4	25

Table 12. Comparison of the Corrosion of Mild Steel Exposed at Eleven Sites for One Year

Exposure Site	Grams Weight Lost[a/]	Severity Ratio (KB-80/Exp. Site)
	Marine Sites	
Kure Beach-80, North Carolina	90.2	1.0
Daytona, Florida	48.5	1.9
Pt. Reyes, California	12.2	7.8
Kure Beach-800 North Carolina	12.0	7.5
	Industrial Sites	
New York City, New York - Fall Installation	40.5	2.2
Kearny, New Jersey	22.2	4.1
New York City, New York - Spring Installation	21.1	4.3
Middletown, Ohio	8.4	10.7
	Rural Sites	
South Bend, Pennsylvania	10.5	8.6
State College, Pennsylvania	6.8	13.3
Perrine, Florida	5.8	15.6

a/ See reference 6.

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