NATIONAL BUREAU OF STANDARDS REPORT

8950

PROGRESS REPORT

April 1 through June 30, 1965

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

NBS

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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SUMMARY

Two measurement approaches were used to detect the amount of fluorescent soil remaining on a specimen after a "standard" cleaning treatment. In the first, the test area of the specimen was soiled with anthracene, cleaned and then irradiated with an ultraviolet light source. The amount of residual soil was then determined by the intensity of the emitted fluorescent (visible) radiation. The instrument used for these measurements was a modified, Hunter Multipurpose Reflectometer. Poor results were obtained mostly because of the unavailability of suitable filters at a reasonable cost.

The second approach involved dissolving the residual soil from a fixed area of the specimen in a known amount of benzene. The fluorescence of the resulting solution was then evaluated. A Turner fluorometer was used to measure the fluorescence. Initial results with this approach were promising. Benzene was found to have a combination of properties which would recommend its use as a solvent for removing anthracene from porcelain enamelled surfaces.

Work directed toward a test method to evaluate the continuity of porcelain enamel coatings was continued. Some indications have been

obtained that a simple electrical discharge test may serve to indicate the acceptability of porcelain enamel coatings for various types of service.

I. CLEANABILITY

INTRODUCTION

Previous progress reports in this series have outlined the needs for a test method to evaluate the cleanability of porcelain enamels and perhaps other competitive finishes. Two possible approaches have been considered: (1) finding a suitable method for evaluating either the ease of removal or the soil remaining after a standardized cleaning treatment when using individual soiling agents or a composite soil, and (2) using a fluorescent solid to simulate the common soils and then evaluating the fluorescent solid remaining after a standardized cleaning treatment by measuring the intensity of the emitted radiation on exposure to an ultraviolet source.

Use of the first approach is complicated by the need for several soiling agents that will be both strongly adherent and easy to standardize. It is also difficult to determine when soil removal is complete by reflectance measurements especially when non-white specimens are evaluated. However, since a fluorescence approach should work equally well with white or colored specimens and since it is potentially capable of evaluating small differences in "cleanability", major attention during this report period has been directed to the fluorescent method.

SURVEY OF METAL-CLEANING TESTS

A literature survey was made of test methods used in metal-cleaning.

The principal problem in establishing a cleanability method for porcelain enamels is in finding a way to quantitatively determine the amount of small residues on a surface. This is precisely the problem encountered in evaluating metal cleaners and cleaning techniques.

Morgan and Lankler [1/] in 1942 devised a method for photographically recording the intensity of the fluorescence of mineral oil remaining on metal surfaces which had been cleaned. The claim that this method could detect as little as 4 micrograms of oil per square centimeter was supported by gravimetric determinations of the oil extracted from similar soiled surfaces. The method was accurately described as "visually quantitative" because of the necessity of a visual comparison of the photographs.

Edeler [2/] suggested that small residues of oil of the order of one part in 20,000 of solvent could be determined by dropping the volatile solvent from the cleaned panel onto photographic quality ground glass and observing for a ring appearance due to any nonvolatile oil present.

Harris, et al [3/] mentioned the time-honored "water break" test for soil retention which is quite sensitive to oily or greasy films. They also state: "Another recognized method for estimation of the degree of cleanliness is either to weigh the metal piece being cleaned before and after the cleaning process, or to wash the cleaned piece with solvent and weigh the extract. This method suffers when the amount of soil remaining is less than the sensitivity of the balance in use."

This earlier work on metal-cleaning tests suggested a possible test procedure for porcelain enamels. This would involve measurement of the residual fluorescent soil on a surface by first extracting the soil with a suitable solvent and then evaluating the amount of residual soil that was present by measuring the fluorescent intensity of the resulting solution with a commercially available fluorometer.

RESULTS AND DISCUSSION

1. Tests with the Modified Hunter Multipurpose Reflectometer.

In a search for a suitable instrument with which to measure the intensity of fluorescence remaining on specimens that had been soiled and then cleaned, trials were made with a modified Hunter Multipurpose Reflectometer. Early trials with this instrument, made in the preceding report period, indicated that difficulties could be expected in separating that part of the signal due to specimen color or reflectance from the part due to the fluorescence of the residual soiling agent. The multipurpose instrument was specifically designed as a reflectometer for operation in the visible. In order to measure fluorescence it was necessary not only to replace the tungsten lamp with an ultraviolet source but also to introduce suitable filters so that the photocells would respond only to the fluorescent light emitted by the residual fluorescent soil on the specimen and not to radiation from the source that was reflected by the specimen onto the photocell.

This last requirement will be difficult to resolve completely since commercial filters with the necessary narrow band-pass are not available at a reasonable cost. Hence, it is necessary to use filters that are not 100% efficient. To determine whether filters of this type could be made to work in the modified instrument a number of tests were made.

In the first tests of this kind the instrument was first balanced to a null position on a specimen with no fluorescence, with the reflectance photocell near its front position (12 cm). Next, a small square of a fluorescent uranium glass, 0.22-in. by 0.22-in. by 0.039-in. was attached to the center of the specimen and a reading taken. The distance through which the travelling photocell needed to be moved to reestablish the null balance of the photocells was determined. If the filters were effective this distance should represent the apparent intensity of the visible radiation emitted by the fluorescent glass. When the same piece of glass was attached, in turn, to a series of specimens of various colors, it can be seen from Table I, however, that the photocell responses depended quite strongly on specimen color.

One might wonder why the instrument response should be 19.5 cm (31.5 - 12.0) when the fluorescent glass was attached to a black specimen, but only 2.6 cm when attached to a white specimen. Basically, it is due to poor filtering. The explanation follows: The net change in the response of the photocell which resulted from the attachment of the fluorescent glass consisted of two components which acted simultaneously: (1) radiation emitted by the fluorescent glass, a positive component, and (2) a reduction in the amount of reflected flux which resulted from shielding a part of the irradiated specimen face with the glass plate. The reduction (component 2) in the case of the black specimen was quite small compared to that of the white specimen because of the low reflectance of the dark colored specimen. Thus, the net result of the two components for the black specimen was larger than for the white one.

The value of the aforementioned experiment is in demonstrating the great need for suitable filters in the instrument. In fact, without such filters the modified instrument has little value for the intended application.

(a) Tests of New Filters. The following three filters were tested:

Filter	Transmission at 365 mμ percent	Type
7-60	55	Corning colored glass
7-37	21	Corning colored glass
365-Int	29	Interference, 2nd order

Measurements were made with these filters in the instrument. This was done by measuring the fluorescent intensity of a piece of uranium glass superimposed, in turn, on a black and a white specimen as previously described. The results are given in Table 2. In two of the three filter combinations, the indicated fluorescent intensity was greater from a black specimen than from a white one. This is in qualitative agreement with the results given in Table 1. In this comparison a 0.1 neutral density filter was used in conjunction with the 7-60 filter so as to partially equalize differences in their transmission properties. The smaller responses for both the black and the white specimens, given in Table 2, undoubtedly resulted from the resulting reduction of transmitted energy.

A comparison of the filters was also made by depositing known amounts of a saturated alcohol solution of anthracene on black and white specimens and, after drying, obtaining an instrumental indication of the fluorescent intensity. The weights of anthracene applied were based on its solubility in alcohol at 20°C (0.76 g in 100 ml) and the volume of a drop from a 1-ml Mohr pipette (0.19 ml). The results in Table 3 show that the galvanometer deflections were roughly proportional to the amount of anthracene, but the differences in deflection between black and white specimens were quite unsatisfactory with any filter combination that was tried.

(b) Conclusion. The results given in Tables 1 to 3 indicate that the modified multipurpose reflectometer is unsuited for measuring the intensity of the fluorescence of anthracene, "in situ", on a wide range of porcelain enamel colors. The disqualification of this instrument for fluorescence measurements rests squarely on the unavailability of narrow band-pass filters. As stated earlier, such filters are necessary to separate the influence of a specimen's reflectance from the property to be measured.

2. Tests With a Turner Fluorometer.

The experiments with the modified Hunter instrument were directed toward the measurement, in situ, of fluorescent soiling agents remaining on cleaned specimens. The second approach investigated was to extract the residual soil with a solvent and then to evaluate the amount of soil that remained on the specimen by measuring the fluorescence of the resulting solution. This type of measurement can be made with high precision with commercially available instruments. Because of the promise indicated by the extraction approach, a Turner Fluorometer was purchased by NBS and made available to the Research Associateship. The instrument operates on the double-beam principle. In effect, it measures the difference between fluorescent light emitted by the sample and the direct light from a reference beam. The same light source is used to irradiate the sample and to supply the reference light beam. Light source variations cannot affect the light balance since sample and reference beams are equally affected. Measurements are made on about 5 ml of solution and through the use of a calibration curve can be expressed in units of weight of fluorescent material per unit area of specimen surface. Accurate fluorescence measurements depend, of course, on careful extraction and dilution techniques as well as on the use of reagents of known purity, uniformity and stability.

A requisite of the extraction method was the selection of a suitable solvent for the extraction and dilution of anthracene. The degree of solubility of anthracene, the volatility of the solvent, and the intensity of its fluorescence were considered of importance. Table 4 gives these properties for five common organic solvents which might be considered. The study of these properties resulted in the selection of benzene which has the lowest volatility, a good solubility for anthracene and an acceptably low fluorescence.

The new instrument was received late in the report period which precluded any extensive trials of the extraction approach to cleanability. However it was possible to check the sensitivity capabilities of the instrument. These showed considerable promise. Anthracene concentrations in benzene of as low as 0.001 micrograms per milliliter (one part per billion) could be easily measured with the instrument.

3. Experiments with Domestic Soils.

Before the fluorescent soil approach could receive any wide degree of acceptance when incorporated into a cleanability test, it would first be necessary to show that the test results correlated with the ease with which some of the more common soils could be removed from various types of finishes. As a first step toward this goal, a preliminary study was made of soiling agents that might typify soils encountered in the home.

In studying the cleanability of porcelain enamels, one difficulty that has been encountered is that many soiling agents clean off too easily and do not allow one to discriminate between one porcelain enamel and another. The other extreme, of course, occurs when a soil (such as nail polish) is retained so tenaciously that special solvents or extreme abrasion must be resorted to.

(a) Tests with Kitchen Soils. The relative effort required to remove several domestic kitchen soils from a single enamel was investigated. The results are given in Table 5, which also includes a description of the soils and the hand-rubbing methods that were used. It is interesting to note that the two operators placed the soiling agents in the same order with respect to the effort required to remove them from the enamel surface.

An egg-mixture was used on several different enamels and on glass to determine if a more objective, mechanical cleaning method could measure the effort or time required for cleaning, and thus discriminate between the types of finishes studied. Mechanical dry-rubbing as outlined in Table 6 was used to show differences in cleaning time required for different surface finishes. Enamel Q and the glass specimens retained the baked egg-mixture so tenaciously that the dry-rubbing used failed to completely remove the deposit in a reasonable time. Two of the enamels, Y and A, required only two to six minutes for complete removal as judged by visual observation. The same soil on other specimens of the same enamels were cleaned by wet-rubbing in times too short to measure.

(b) Powdered Graphite as a Soiling Agent. When powdered graphite was used as a soiling agent on white enamels, reflectance measurements were used to determine how much soil remained after uniform amounts of a cleaning treatment. The results, given in Table 7, indicate that graphite is a soiling material which is quite difficult to remove and that there were marked differences between dry and wet mechanical rubbing. The variable character of the reflectance measurements, however, did not indicate any statistically significant difference between enamels A and Y after either dry or wet rubbing.

FUTURE PLANS

Work during the next report period will be concerned with: a) Further experiments with the Turner fluorometer to determine its applicability for the determination of the cleanability of porcelain enamels. b) The development of soiling and cleaning techniques with fluorescent soiling agents. c) Development of a cleanability test that will permit qualitative ratings of the ease of cleaning of specimens so that these ratings can be compared with measurements made by the fluorescent approach.

II. CONTINUITY OF COATING

INTRODUCTION

Protection of the base metal from corrosion is one of the prime reasons for using a porcelain enamel coating on a metal product. In a previous report, methods that have been used for measuring continuity of coating were discussed. Of these methods, the one that appeared most promising for a standard continuity of coating test was the high-voltage discharge test.

RESULTS AND DISCUSSION

Before progressing too far into the factors affecting the high-voltage discharge method, it seemed desirable that the research associates should visit several plants to ascertain how industry copes with the problem of discontinuities in porcelain enamel coatings. Trips were made to plants engaged in the manufacture of (a) frit, (b) hot water tanks, and (c) high-voltage test equipment.

Many aspects of continuity of coating were discussed during our visit to the frit company. A discussion of (a) the types of discontinuities and (b) the methods of test that have been used to determine discontinuities revealed one test in addition to those given in the previous report. This is the rust spot test. It consists of first forming a reservoir on the enameled surface with any good calking compound, and then filling the reservoir with an aqueous solution consisting of 1% by weight sodium chloride and 1/2% sodium carbonate. Next, a DC potential of 9 volts is applied for 15 minutes between the solution and the metal backing of the specimen. At the end of this time, the enameled surface is washed and the number of rust spots is counted. According to current practice, the acceptable number of rust spots permitted for an appliance enamel is five per twelve square inches. It was also stated that the products that are most susceptable to rust spots caused by non-continuous coatings are dishwashers, laundry baskets, and architectural panels. An interesting sidelight of this visit was observing the methods used in their laboratory for preparing polished cross-sections of porcelain enameled specimens and taking photomicrographs.

This particular frit manufacturer has agreed to prepare several specimens of one enamel both with and without defects. These specimens will permit us to compare acceptable and unacceptable enamels by a number of different test methods.

The visit to the hot water tank plant was also interesting. The need for a continuous coating is not so great for enameled hot water tanks since the magnesium anode inserted before shipment prevents rusting at any small discontinuities that may be present. It was the feeling of this manufacturer that a continuity of coating test would be used mostly as an acceptance test, since the checking of each tank for a continuous coating as it came off the production line would be a slow and costly operation. This company has prepared several water tank enamel specimens, both with and without defects, for use in our development of a continuity of coating test.

A visit to the manufacturer of high-voltage test equipment for glass-lined steel tanks for the chemical industry provided us with many interesting facts on their high-voltage test equipment. Although the tanks that they test are made with much thicker coatings than are applied to ordinary porcelain enameled products, they find that an AC voltage of 5 KV will locate areas that may give corrosion difficulties. The tanks are tested before they are installed and also after periodic periods of service. If punctures occur on any area at a voltage of 5 KV, repair of this area is indicated.

These three visits were interesting and informative but they left a few questions unanswered in the Research Associate's minds. In an effort to get a more thorough understanding of the opinions of the industry on the subject of continuity of coating, a questionnaire to the fabricator membership of PEI has been prepared.

Meanwhile, the types of defects located with the high-voltage tester have been studied in further detail. Specimens of architectural enamels that duplicate those which had rusted in service were tested with the high-voltage test equipment. The specimens were tested at increments of 0.2 KV from 0-5 KV. The defects located were marked, sectioned, and examined with a metallographic microscope. Photomicrographs of defects detected in one architectural enamel are shown in figure 1.

The microscopical examination revealed the types of defects that are detected with the high-voltage tester. Cracks, blisters, pinholes, subsurface pores, and contamination in the surface of the enamel were located at relatively low voltages. Copperheads in ground coat enamels were also located, but generally higher voltages were required. The majority of the detected defects consisted of pinholes, blisters, and subsurface pores. An examination of any one enamel indicated that the voltage required to puncture the coating at a subsurface bubble was a function of the thickness of the enamel over the bubble (see figure 2). However, slight differences in the enamel composition appear to affect the dielectric strength so this relationship becomes masked when all the enamels are considered. Therefore, if this method of test is to be used as a non-destructive test, preliminary testing of each enamel, sectioning and measuring the thickness of enamel over the defects might be necessary to determine the proper test voltage. In the architectural enamels studies, no corrosion seemed to occur in seven years at a severe seacoast site if the thickness of enamel over the bubble was greater than about 0.0005 in.

A somewhat more desirable goal in coating continuity might be to arrive at a test voltage that would separate enamels with acceptable and unacceptable coverage. Fairly clear-cut dividing lines seem to be forming for the enamels tested to date. Many of the enamels tested were duplicate specimens of architectural enamels which had been subjected to long-time weathering tests. The specimens were probed to located discontinuities as previously described. In this way the number and type of defects could be associated with the results on similar specimens from long-time exposure testing. Four of the five enamels that had failed at six years' service had defects on the storage specimens which were detected at 0.8 KV; 12 of the 15 enamels tested that failed after seven years' exposure had defects which were located under 2.5 KV; while three enamels tested which had not failed in seven years' exposure, had no defects detectable at less than 3 KV.

The hot-water-tank enamels need not be as free of coating discontinuities as other enamels since the magnesium anode offers protection for small localized failures. For this reason, these enamels might be tested at a preselected voltage, say 5 KV, and the good enamels separated from the bad by the difference in the number of defects detected. In the testing of "good" and "bad" hot-water-tank enamels it was observed that the "bad" enamel showed approximately five times as many punctures when tested at 5 KV as did the "good" enamel. Figure 3 illustrates the number of defects located in these two hot-water-tank enamels at the different voltages.

PLANS FOR NEXT REPORT PERIOD

It appears that the high-voltage test equipment could be adapted for an acceptance testing of porcelain enameled products. However, many more enamels need to be tested before voltage limits can be established. Requests for specimens with and without defects have been made to a number of fabricators. Additional tests will be conducted as soon as these specimens are received.

III. EXPOSURE TEST OF PORCELAIN ENAMEL ON ALUMINUM

INTRODUCTION

During the preceding quarter, the exposure test of porcelain enamels on aluminum, authorized by the Aluminum Council of the PEI, became a reality with the installation of triplicate specimens of 51 enamels at Kure Beach, North Carolina (80 feet from the ocean), Washington, D. C., and Montreal, Canada.

RESULTS AND DISCUSSION

During this quarter, exposure specimens were installed at New York City and Los Angeles. In addition, spall tests on triplicate specimens of each enamel were completed. Some spalling occurred on seven enamels (AA-C, AB-A, AB-C, AD-B, AD-C, AE-A, and AW-B) after 96 hours' exposure in ammonium chloride. However, since this spalling did not occur on all three of the specimens and since the spalled areas were all less than 1/8 inch in diameter, these seven enamels all passed the ASTM test for spall resistance.

PLANS FOR NEXT REPORT PERIOD

The specimens exposed at Washington, Montreal, and Kure Beach will be returned to the National Bureau of Standards and inspected after exposure for six months.

STANDARD REFERENCE MATERIALS

The following stock of standards was on hand July 1, 1965:

Corundum abrasive, March 1960 issue, for subsurface abrasion	293 lb., 73 jars
Standard Pennsylvania Glass Sand, July 1963 issue, for surface abrasion	285 lb., 97 jars
Distinctness of image gloss standards	20 sets
Calibrated glass plates for abrasion testing	27.5 doz.

Respectfully submitted,
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2. A. Edeler, Ind. and Engr. Chem., Anal. Ed., 15, 282 (1943).

3. J. C. Harris, R. E. Kamp, and W. H. Yanko, Detection of Soil Removal in Metal-Cleaning by the Radioactive Tracer Technique, J. Electrochem. Soc., 97, 430-32 (1950).

TABLE 1. The Effect of Superimposing a Small Uranium Glass Plate with Constant Fluorescence Intensity on a Series of Porcelaing Enamels Ranging From Black to White.

Specimen Color	Initial Null Balance on Bare Specimen[b]	Final balance with uranium glass superimposed at specimen center[a]
	cm.[b]	cm.[b]
Black	12.0	31.5
Black	12.0	29.8
Dk. Blue	12.0	21.1
Lt. Blue	12.0	15.8
Lt. Blue	12.0	15.0
Med. Blue	12.0	15.1
Lavender	12.0	15.7
Buff	12.0	15.7
White	12.0	15.1
White	12.0	14.6

[a] Measurements with a Hunter Multipurpose Reflectometer, modified with a mercury-arc source, a CS 7-60 primary filter, and a Wrattan No. 3 secondary filter.

[b] Distance of movable photocell from specimen.

TABLE 2. Measurements of the Intensity of Fluorescence of a Standard Uranium Glass Superimposed of Black and White Porcelain Enamels using Different Primary Filters.

	Black Specimen			White Specimen		
Filter	Initial Balance	Balance With U-Glass	Δd	Initial Balance	Balance With U-Glass	Δd
	cm.	cm.	cm.	cm.	cm.	cm.
7-60+0.1 ND	10.0	13.2	3.2	10.0	11.8	1.8
7-37	10.0	11.0	1.0	10.0	12.4	2.4
365-Int.	10.0	13.0	3.0	10.0	10.5	0.5

TABLE 3. Measurement of the Intensity of Fluorescence of Anthracene Deposited on Black and White Specimens of Porcelain Enamels Using Various Primary Filters in the Multipurpose Reflectometer.

Filter	Volume of Reagent	Weight of Anthracene	Galvanometer Deflection Black Specimen	Galvanometer Deflection White Specimen
	drops	μg	div	div
7-37	0	0.0	0.0	2.9
	1	14.4	10.5	>50.
	2	28.8	18.0	"
	3	43.2	21.0	"
	4	57.6	33.0	"
365-Int	0	0.0	2.0	>50.
	1	14.4	15.0	>50.
	2	28.8	27.2	"
	3	43.2	42.2	"
	4	57.6	48.8	"
7-60+0.1 ND	0	0.0	0.4	8.0
	1	14.4	14.5	>50.
	2	28.8	24.2	"
	3	43.2	41.0	"
	4	57.6	44.2	"

TABLE 4. Properties of Some Organic Solvents for Anthracene.

Solvent	Relative Fluorescence of Solvent[a]	Anthracene Solubility 15°C[b] g in 100 ml	Boiling Point °C
Carbon disulphide	1.0	1.5	46
Chloroform	1.5	1.7	61
Benzene	3.0	1.3	80
Ether	23.0	1.2	35
Ethyl Alcohol	80.0	0.08	78

[a] These measurements made with the Turner Fluorometer give the fluorescene of the solvents without the addition of any other material. They were "blank" determinations.

[b] Data from "The Dictionary of Organic Compounds," I. Heilbron, Oxford Univ. Press, New York 1934-38.

TABLE 5. Relative Effort Required to Remove Domestic Soils from Specimens Prepared from the Same Enamel

Soiling Agent [a]	Number of Strokes Required to Clean.			
	Operator A		Operator B	
	Dry Rubbing	Wet Rubbing	Dry Rubbing	Wet Rubbing
1	250	--	268	--
2	100[b]	3	100[b]	28
3	100[b]	70	100[b]	112
4	100[b]	115	200[b]	132

[a] (1) Soap flakes, water, and red food color.
(2) Instant coffee, evaporated milk, and sugar.
(3) Evaporated milk and food color.
(4) Black Magic Marker.

Note: All soils except No. 4 were thoroughly blended on magnetic stir plate. Equal, small amounts of the four soils were applied to a single specimen of Enamel Y for each operator, oven dried, and cooled to room temperature before cleaning. The cleaning treatment was by rubbing with a dry or moist cloth using a light pressure.

[b] No progress toward cleaning.

TABLE 6. Time Required for Soil Removal
From Various Materials

Specimen Material	Enamel Y	Enamel A	Enamel Q	Glass	Glass
Condition	New	New	New	Polished	Abraded
Specimen No.	Min.	Min.	Min.	Min.	Min.
1	2.6	[b]	36.+ [a]	39.+ [a]	36.+ [a]
2	6.5	[b]	36.+ [a]	[b]	[b]
3	2.2	2.0	36.+ [a]	[b]	[b]
4	1.7	6.2	36.+ [a]	[b]	[b]

[a] Not completely cleaned, a small amount of soil was tenaciously retained.

[b] Not determined.

Notes on Soil preparation, application and cleaning treatment.

The soiling agent consisted of:

Egg mixture (1 yolk, 1 white)	50 ml.
Water	50 ml.
Red food color to make a pink soil	

The mixture was homogenized for 5 minutes on a magnetic stir plate, strained thru 200 mesh. Five drops of the soil was applied at the center of a 4 x 4 inch specimen, dried on a hot plate and oven dried at 60 C., overnight. Cleaning was by dry rubbing with the mechanical lap. The specimen rotated face up at 78 RPM. A felt-covered brass disc-shaped head was caused to bear on the specimen and pass back and forth along a lap diameter at 22 passes per minute. The three-inch brass disc used in this experiment weighed 840 grams.

TABLE 7. Reflectances of White Porcelain Enamels That Were Soiled With Powdered Graphite and Then Cleaned.

Specimen No	Acid Resistance	Initial Reflectance[a]	Reflectance after dry rubbing[b]	Decrease in reflectance[d]	Reflectance after dry rubbing[c]	Decrease in reflectance[d]
		Rd	Rd	Rd	Rd	Rd
A-5	D	74.9	59.4	15.5	71.6	3.3
A-6		76.1	58.75	17.35	73.3	2.8
A-7		76.75	63.3	13.45	74.65	2.1
			Average	15.4 ± 4.8		2.7 ± 1.5
			Std. Dev	1.9		.60
Y-1	D	84.1	65.3	18.8	81.7	2.4
Y-2		83.1	60.1	23.0	79.15	3.95
Y-3		86.0	70.35	15.65	83.0	3.0
			Average	19.2 ± 9.2		3.1 ± 1.9
			Std. Dev	6.7		.78

[a] Soil application following initial Rd measurement was by mechanical lap, using 1-inch brass head covered with plastic pad material, for one minute.

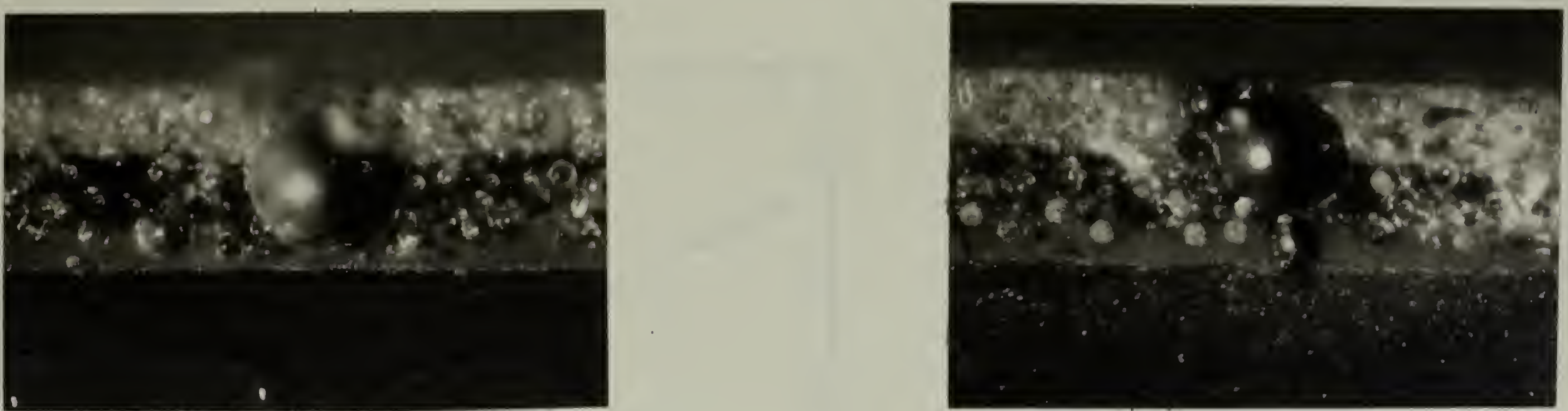
[b] Dry rubbing with a mechanical lap using a 3-inch brass head covered with black cotton flannel, for 1 minute.

[c] Wet rubbing with a mechanical lap using a 1-1/2 inch brass head covered with black cotton flannel, for 8 minutes.

[d] These values are related to retained soil.

(a) Defect located at 1.6 KV. There was no enamel over the bubble.

(b) Defect located at 3.2 KV. Thickness of enamel over the defect is 0.7 mils. Note the contamination on the top right of the bubble.



(c) Defect located at 4.4 KV. Thickness of enamel over the defect is 1.3 mils.

(d) Defect located at 4.4 KV. Combined thickness of enamel over both bubbles is 0.6 mils.

Figure 1. Photomicrographs of defects in architectural specimen R-4 that were located with the high-voltage tester. Total thickness of the enamel ranged from 8 to 10 mils. Magnification is approximately 100 times.

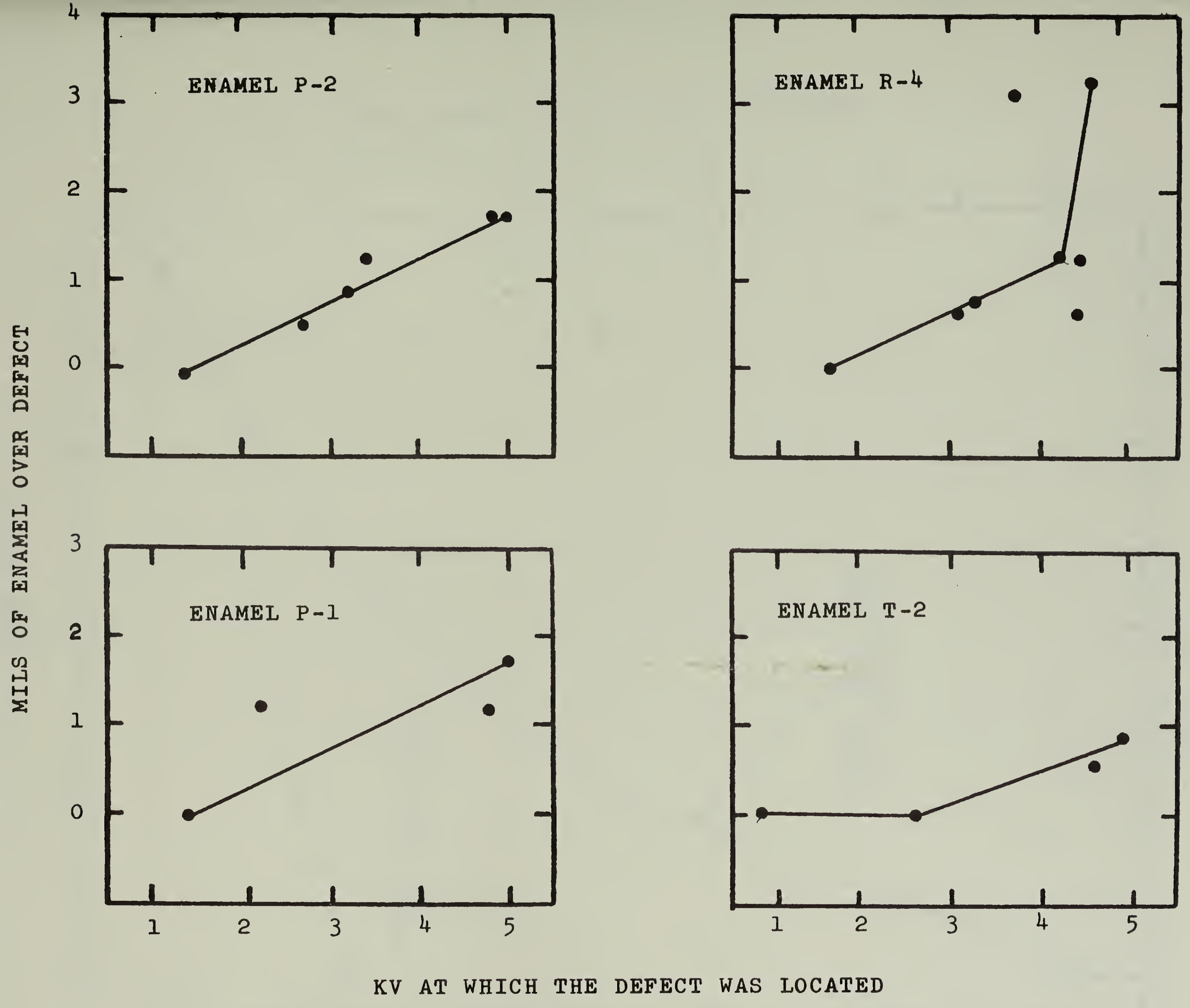


Figure 2. Correlation between breakdown voltage and thickness of enamel over a defect.

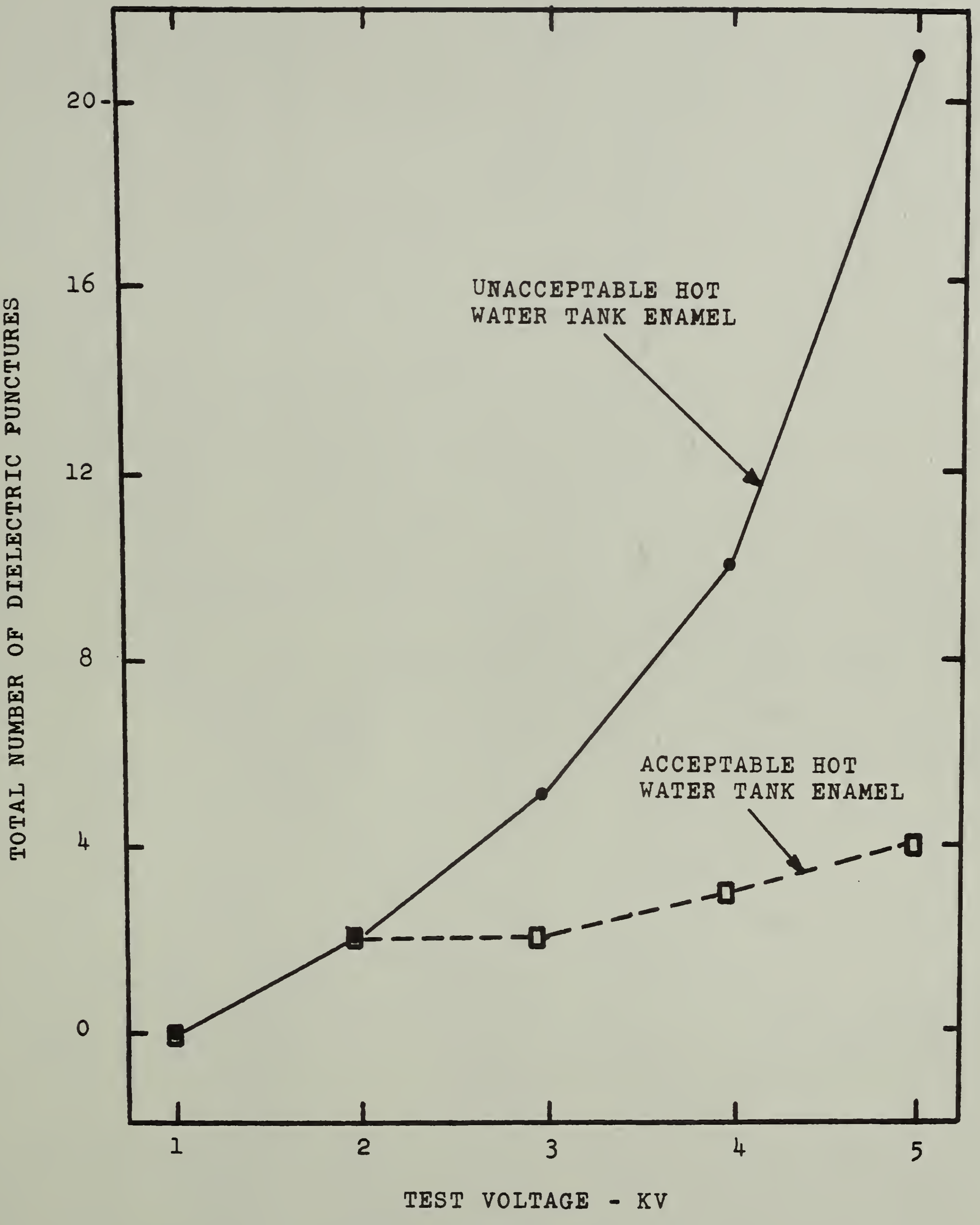


Figure 3. Total number of dielectric failures obtained on four-inch square specimens of "acceptable" and "unacceptable" hot water tank enamels.

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