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Graffiti-Resistant Coatings: Methods of Test and Preliminary Selection Criteria

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U.S. DEPARTMENT OF COMMERCE, Rogers C.B. Morton, *Secretary*
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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

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ABSTRACT

The performance of graffiti-resistant coatings was evaluated and criteria were developed to aid in the selection of these materials.

From preliminary test of 47 commercially-available coatings, 19 were selected for more detailed study. The 19 coatings were evaluated for ability to release common markings and to resist ultraviolet radiation, high humidity, condensing moisture, abrasion and resistance to graffiti removers. The flexibility and water vapor permeance of the coatings were also determined. The substrates used were clay brick and a matte tile. Coatings highly resistant to defacement by spray paint, and highly resistant to felt-tip pen, crayon and lipstick markings were identified.

Key words: Color retention; ease of removal; graffiti; graffiti-resistant coatings; performance.

SI CONVERSION UNITS

In view of the present accepted practice in this country for building technology, common U.S. units of measurement have been used throughout this publication. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measures, which gave official status to the metric SI system of units in 1960, appropriate conversion factors have been provided in the table below. The reader interested in making further use of the coherent system of SI units is referred to:

NBS SP330, 1972 Edition, "The International System of Units"

E380-72 ASTM Metric Practice Guide (American National Standard Z210.1)

Table of Conversion Factors to Metric (S.I.) Units

Physical Quantity	To convert from	to	multiply by
Length	inch	meter	$2.54^* \times 10^{-2}$
	foot	m	$3.048^* \times 10^{-1}$
Area	$inch^2$	m^2	$6.4516^* \times 10^{-4}$
	$foot^2$	m^2	9.290×10^{-2}
Volume	$inch^3$	m^3	1.639×10^{-5}
	$foot^3$	m^3	2.832×10^{-2}
Temperature	Fahrenheit	Celsius	$t_c = (^tF-32)/1.8$
Temperature difference	Fahrenheit	Kelvin	$K = (^tF)/1.8$
Pressure	inch Hg (60F)	$newton/m^2$	3.377×10^3
Mass	lbm	kg	4.536×10^{-1}
Mass/unit area	lbm/ft^2	kg/m^2	4.882
Moisture content rate	lbm/ft^2 week	kg/m^2s	8.073×10^{-6}
Density	lbm/ft^3	kg/m^3	1.602×10^1
Thermal conductivity	Btu/hr ft^2 (F/inch)	$\frac{W}{mk}$	1.442×10^{-1}
U-value	Btu/hr ft^2 F	$\frac{W}{m^2k}$	5.678
Thermal resistance	F/(Btu/hr ft^2)	$K/(W/m^2)$	1.761×10^{-1}
Heat flow	Btu/hr ft^2	W/m^2	3.155

*Exact value; others are rounded to fourth place.

1. INTRODUCTION

The "graffiti problem," removal of common markings from building materials, has been estimated by Gossett [1]* to cost 600 million dollars annually. The problem exists in public, private, commercial and industrial buildings. Substantial savings could be made by the Department of Housing and Urban Development (HUD) if the exposed surfaces in public housing resisted defacement by graffiti. Therefore, HUD initiated a program to identify and evaluate coatings which resist defacement by marking devices.

It was learned from observing single and multi-family public housing units in Baltimore, Washington, Philadelphia, Chicago and Los Angeles that the exposed building materials of public housing were not easily cleaned of graffiti. Surfaces most frequently used by the graffiti artist were hallways, stairwells, vestibules, laundry rooms and lower exterior walls. These surfaces were generally finished with porous materials such as brick, concrete block and cast concrete. The markings are absorbed by these materials, thereby making removal difficult. There is, therefore, a need for coating materials which would resist the absorption of markings into these porous surfaces and be easily cleaned. Coatings of this kind would not only simplify removal but substantially reduce the cost of building maintenance.

The study of graffiti-resistant coatings described here is Part II of a study which included evaluation of graffiti removers. The evaluation of graffiti removers has already been reported to the sponsor [2].

1.1 Approach

The project was conducted in the following phases:

1. Phase 1 consisted of the identification of materials accessible to defacement in public housing, and identification of potential coatings to protect these materials from defacement. A literature survey of methods used for the removal of markings from building materials was also included.

2. Phase II was a laboratory evaluation of the effectiveness of commercially available graffiti removers.

3. Phase III was an evaluation of the performance and durability of proposed graffiti resistant coatings.

4. Phase IV was the development of interim criteria for the performance of graffiti removers and graffiti-resistant coatings.

1.2 Objectives

The objectives of the work described in this report were:

1. To identify commercially available coatings for commonly exposed building materials such as brick, concrete block, cast concrete and wood that would serve as release agents for removal of graffiti.

2. To select tests for evaluating the protective, and the functional characteristics of these graffiti-resistant coatings.

3. To evaluate commercially-available graffiti-resistant coatings and recommend interim performance criteria for their selection.

This report presents the information on graffiti-resistant coatings of Phases III and IV including methods of test. The purpose of the selected tests is to detect changes in the protective and functional properties of the materials.

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*Numbers in brackets represent references given in this report.

1.3 Identification and Evaluation of Graffiti-Resistant Coatings

Graffiti resistant coatings must provide for the effective removal of common markings in addition to protecting building materials. A coating must serve as a release agent to a variety of markings in order to be effective. Marking materials most frequently used to deface surfaces are spray paint, felt-tip pen, crayon and lipstick.

Potential graffiti-resistant coatings were identified by a review of the literature, contact with persons in the coatings industry, public housing engineers, and through visits to commercial sources. Among the 47 coatings obtained were products claimed to be suitable for application to steel, brick, tile, wood, concrete, concrete block and stone. Each coating is identified by a code number in this report so as to avoid the use of product names.

Table 1 indicates that more acrylics were available for use as graffiti-resistant coatings than any other generic type. The generic identification of the various coatings was determined by infrared analysis. The 47 coatings included 15 acrylics, 7 modified acrylics, 4 methacrylates, 6 urethanes, 4 modified urethanes, 3 epoxies, 2 silicones, 4 polyesters, 1 polyvinyl acetate and 1 polyvinyl butyral.

A screening test (Section 2.1) was employed to eliminate from further study those coatings that showed poor resistance to defacement, and/or lack of film integrity. The most promising coatings were then quantitatively evaluated for their ability to serve as release agents and to protect building materials.

1.4 Description of Marking Materials and Building Substrates

The marking materials and devices selected for the study included aerosol paints, crayons, felt-tip markers and lipstick. The selection of marking materials to be used in the program was based on those general types frequently used by the graffiti artist, and their availability in local stores. The resin type, color and sample number of each spray paint are listed in Table 2. In addition to the spray paints listed in Table 2, the following materials were used:

> <u>Felt-Tip Pens</u> - The colors selected were orange, black, red and black and manufactured* by Carter Ink, Skilcraft, Zip Mark and Flair Mfg. Co., respectively.
>
> <u>Crayons</u> - The crayon colors used were orange, pink, gold, dark green, black and light green and were manufactured by the Crayola Company.
>
> <u>Lipstick</u> - The lipstick colors were pink, gold frost and burnt sugar and were manufactured by Avon, Max Factor, and Elizabeth Arden Company, respectively.

Characteristics of the brick, tested in accordance with ASTM C-67-66 [3], are listed in Table 3. This brick was used as a substrate, as was matte tile conforming to U.S. Department of Commerce Specification USAS A1371-1967. These materials were chosen for their similarity to building materials used most frequently in public housing.

1.5 Measurement of Removal Effectiveness

As a basis for establishing limits of performance for graffiti-resistant coatings, it is necessary to be able to evaluate the degree to which the uniform appearance of the substrate can be restored following defacement by graffiti. To do this, a Hunter Color-Difference Meter [4] was used to measure the change in appearance. Measurements were made on each specimen before application of the graffiti and after the cleaning process. "Clean" implies a generally uniform appearance with no discoloration other than that due to weathering. Any departure from being clean can be considered unsatisfactory.

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*Identification of commercial products is included only to adequately specify the procedure. Identification does not imply recommendation or endorsement by the National Bureau of Standards.

Table 1. Effectiveness of Removal of Felt-Tip Pen, Crayon and Lipstick Markings from Coatings on Tile

Coating Type	Coating No.	Film Integrity	Markings (Aged 21 days @ 23 2°C, 50 5% rh)												
			Felt-Tip Pen*				Crayon*						Lipstick*		
			1	2	3	4	1	2	3	4	5	6	1	2	3
Acrylic															
Acrylic	1	Poor**	Unacceptable - peeled, flaked												
Acrylic	7	Good	4	5	5	4	6	3	4	4	5	6	6	6	6
Acrylic	15	Good	3	6	2	3	6	6	6	6	6	6	6	6	6
Acrylic	29	Good	6	6	6	5	5	5	4	6	6	6	6	6	6
Acrylic	30	Fair	4	2	6	4	6	5	6	6	6	6	6	6	6
Acrylic	31	Fair	2	2	6	6	6	6	6	6	6	6	6	6	6
Acrylic	32	Good	5	5	6	4	6	6	6	6	6	6	6	6	6
Acrylic	38	Good	6	5	6	6	6	6	6	6	6	6	6	6	6
Acrylic	39	Good	6	6	6	6	6	6	6	6	6	6	6	6	6
Acrylic	40	Poor	Unacceptable - peeled, flaked												
Acrylic	41	Fair	4	4	5	4	5	6	6	5	4	6	6	6	5

*Identified in Section 1.4.

**Good - No flaking, peeling or blistering.
Fair - Not more than 25% of coating peeled, flaked, blistered or eroded.
Poor - More than 75% of coating peeled, flaked, blistered or eroded.

6 - complete removal
5 - trace of mar - marking intermittent
4 - marking continuous and slightly visible
3 - marking continuous and apparent
2 - marking only slightly changed
1 - unaffected

Table 1. Continued

			Markings (Aged 21 days @ 23 ± 2°C, 50 ± 5% rh)												
			Felt-Tip Pen*				Crayon*						Lipstick*		
Coating Type	Coating No.	Film Integrity	1	2	3	4	1	2	3	4	5	6	1	2	3
Acrylic (continued)															
Acrylic	43	Good	5	6	6	4	6	6	6	6	6	6	6	6	6
Acrylic	44	Good	6	6	6	4	6	6	6	6	6	6	6	6	6
Acrylic	47	Fair	5	5	4	6	6	6	6	6	6	6	6	6	6
Acrylic	48	Good	6	6	5	5	6	6	6	6	6	6	6	6	6
Methacrylate	12	Good	4	5	4	4	5	6	6	6	6	6	6	6	6
Methacrylate	17	Good	6	5	5	5	6	6	6	6	6	6	6	6	6
Methacrylate	18	Good	6	5	4	6	6	6	6	6	6	6	6	6	6
Methacrylate	33	Good	6	4	6	5	6	6	6	6	6	6	6	6	6
Modified Urethane															
Fluorinated polyester urethane	11	Fair	3	2	6	4	6	5	6	6	6	6	6	6	6
Polyester urethane	13	Good	1	1	6	4	6	4	6	6	6	6	6	6	6
Polyester urethane	14	Good	4	1	6	4	6	4	6	6	6	6	6	6	6
Fluorinated polyester urethane	42	Good	6	6	6	6	6	6	6	6	6	6	6	6	6
Epoxy															
Epoxy	16	Good	3	3	5	6	6	4	6	6	6	6	6	6	6
Epoxy	20	Good	3	6	6	3	6	6	6	6	6	6	6	6	5
Epoxy	24	Good	4	4	5	6	6	5	6	6	5	6	6	6	6
Silicone															
Dimethyl silicone	22	Good	6	6	6	3	6	6	6	5	6	6	6	6	6
Dimethyl silicone	23	Good	6	6	6	6	6	6	6	6	6	6	6	6	6

Table 1. Continued

Coating Type	Coating	Film Integrity	Markings (Aged 21 days @ 23 ± 2°C, 50 ± 5% rh) Felt-Tip Pen* 1				Crayon* 1						Lipstick* 1		
			1	2	3	4	1	2	3	4	5	6	1	2	3
Polyester															
Polyester	26	Good	6	1	3	6	6	6	6	6	6	6	6	6	6
Polyester	34	Good	3	3	6	4	6	6	6	6	6	6	6	6	6
Polyester	35	Good	1	1	6	3	6	6	6	6	6	6	6	6	6
Polyester	46	Fair	5	6	3	6	6	6	6	6	6	6	6	6	6
Polyvinyl Acetate															
Vinyl chloride-acetate alcohol terpolymer	8	Good	1	1	6	3	6	6	6	6	6	6	6	6	6
Modified Acrylic															
Styrene acrylate	2	Poor	Unacceptable - peeled, flaked												
Vinyl-toluene acrylate	4	Good	4	6	6	5	6	6	6	6	6	6	6	6	6
Styrene acrylate	10	Good	6	5	2	5	6	6	6	6	6	5	6	6	6
Styrene acrylonitrile terpolymer	21	Good	6	5	2	4	6	6	6	5	4	6	6	5	6
Acrylic, polyethylene and epoxy resin	25	Poor	1	2	2	2	5	1	6	6	6	6	6	4	4
Styrene acrylate	27	Poor	6	1	6	1	6	6	6	6	6	6	6	6	6
Acrylic, polyethylene and epxoy resin	36	Fair	5	2	5	2	6	1	6	6	6	6	2	2	6

Table 1. Continued

Coating Type	Coating No.	Film Integrity	Markings (Aged 21 days @ 23 ± 2°C, 50 ± 5% rh)												
			Felt-Tip Pen				Crayon*						Lipstick*		
			1	2	3	4	1	2	3	4	5	6	1	2	3
Urethanes															
Urethane	3	Good	2	2	4	4	6	6	6	6	6	6	6	6	6
Urethane	5	Good	6	5	6	5	6	6	6	6	6	6	6	6	6
Urethane	6	Good	1	1	6	1	6	6	6	6	6	6	6	6	6
Urethane	9	Good	3	6	3	2	6	6	6	6	6	6	6	6	6
Urethane	28	Good	5	6	5	4	6	6	6	6	6	6	6	6	6
Urethane	37	Fair	6	3	4	5	6	6	6	6	6	6	6	6	6
Polyvinyl Butyral															
Polyvinyl butyral	45	Good	5	4	3	5	6	6	6	6	6	6	6	6	6

Table 2. Spray Paints Used to Determine the "Ease of Removal" of Paint from Coated Brick

Resin Type	Color	Sample Number
(a) Alkyd		
Vinyl toluene soya alkyd resin	Orange	6
Vinyl toluene soya alkyd, ester gum	Red	6B
Acrylic castor-tall oil alkyd	Red	16
Linseed alkyd, styrene copolymer soya alkyd, tall oil alkyd, ester gum and phenolic resin	Red, Red	26, 14, 24
(b) Acrylic-Alkyd		
Acrylic-vinyl toluene safflower alkyd	Blue	22
(c) Alkyd-Epoxy		
Epoxy ester soya alkyd	Black	2
(d) Alkyd-Cellulose		
Cellulose nitrate and oil modified alkyd	Black, Red	4B, 45
Cellulose nitrate and coconut-oil modified alkyd	Green	51
(e) Acrylic		
Silicone acrylic ester resin	Red	49

Table 2. Continued

Resin Type	Color	Sample Number
(f) Epoxy		
Epoxy ester resin	Gold	27
Dehydrated castor oil and modified epoxy resin	Black	48
(g) Linseed Oil		
Linseed styrene resin	Red, Blue	18, 5
Linseed styrene, coumarone resin	Green	1
(h) Coumarone-Indene Resin		
Coumarone-Indene resin and soya oil dicyclopentadiene	Aluminum	25

The color change, ΔE, in NBS units [5] was computed from these measurements and expressed in terms of color retention, C.R., which was defined as [6]:

$$C.R. = 100 - \Delta E^*$$

An NBS unit is equivalent to the (ΔE) as determined in Method 6123 of Federal Test Method Standard 141 [5].

2. METHODS OF TEST FOR GRAFFITI-RESISTANT COATINGS

Measurements of physical properties of coatings are used in assessing their performance attributes. These laboratory measurements have been used to predict the probable performance of coatings, since long term performance evaluation of the coatings is difficult and time consuming. For example, to determine the colorfastness of a coating under in-use conditions, monitoring over a period of years is required; however, when exposed to Weather-O-Meters testing, this property of the coating is accelerated and may be characterized within a few months.

The following tests were chosen to measure those physical properties which are directly related to the performance of graffiti-resistant coatings. The data obtained is presented below and the tests are referenced in the interim performance criteria of Section 4.

2.1 Preliminary Screening

The purpose of this test was to evaluate the cleanability of the coatings and to eliminate the poor performers from further study.

The coatings were applied by brush, in duplicate, to the matte tile substrate (Section 1.4), in accordance with the supplier's directions, and cured for 7 days at 23 ± 2°C and 50 ± 5% rh. Measurement of film thickness indicated a thickness range from 0.0375 to 0.0825 mm.

The coated tiles were then marked by drawing 6 lines of crayon, 4 lines of felttip markings and 3 lines of lipstick (brand or manufacture and color of each line are identified in Section 1.4), and aged 21 days at 23 ± 2°C and 50 ± 5% rh.

For testing, each tile was centered on a lapping wheel (figure 1) and held in place by means of double-sided adhesive tape. A cellulose sponge was then charged by applying 50 cm^3 of distilled water and rubbed with cake grit soap (conforming to PS-571, Type A) 25 times back and forth across the sponge. The charged sponge was placed in the center of the tile and the spindle attached to the polishing unit. The lapping wheel and polishing unit were then operated for one minute as described in "A Test for the Cleanability of Surface Finishes" [10].

Results of the screening tests are shown in Table 1. It can be seen that markings applied by felt-tip pens were, in general, more difficult to remove than crayon or lipstick. Only four coatings permitted the removal of the markings produced by all four pens, whereas most of the coatings were easily cleaned of crayon and lipstick. As indicated in Table 1, acrylics were easily cleaned of felt-tip pen markings; however, failures due to peeling, flaking and film erosion were most common among this group. Film integrity ratings of "good", "fair", or "poor" are used as indicators of film failures. The coatings retained for further study were: Nos. 4, 5, 14, 17, 18, 22, 23, 29, 32, 33, 37, 38, 39, 42, 43, 44, 46, 47, and 48.

---

*The color difference parameter, Rd (the 45°, 0° luminous daylight reflectance), a red-green) and b (yellow-blue) were measured with a color difference meter. The color change in NBS units was calculated by the following formula:

$$\text{Color change } (\Delta E) = \sqrt{(10\sqrt{Rd})^2 + a^2 + b^2}.$$

2.2 Removal Tests of Spray Paints from Coated Brick

The coatings selected from the preliminary screening tests were next tested for the protection of bricks, since brick is a common public housing material which is more difficult to clean than matte tile. The purpose of this test was to determine the ease with which markings could be removed from coatings applied on porous or absorptive materials.

In this test, 18 spray paints (Table 2) chosen because of their difficulty of removal from unprotected brick [2] were applied to cured (7 days at 23 ± 2°C and 50 ± 5% rh) coatings on brick. Two sets of specimens (each comprising 18 paints) were prepared for each coating. After curing of the paint (7 days at 23 ± 2°C and 50 ± 5% rh), attempts were made to remove the paint films from the coated brick. Remover 86 (mildly alkaline) was used for one set and remover 98 (highly alkaline) for the other. Application was in accordance with the supplier's directions, except that the contact time prior to washing was extended to 30 minutes to obtain maximum removal effectiveness. Then, the paints were washed from the coated brick with 5 gal/min of high pressure (1600 psi) water to remove the paint film. After drying, photometric measurements of the appearance were made by a color difference meter [4] and used with the results of measurements made before application of the paint to determine the color retention.

It is shown (Table 4) that the average color retention value for each coating is approximately 93. This represents a significant increase in effectiveness when compared to the average value of 88 obtained in removing graffiti from unpainted brick [2], since the higher color retention value was obtained for paints which were known to be particularly difficult to remove [2]. The removal process was shortened and a second application of remover was often unnecessary. The most effective coatings were: Nos. 5, 42, 44, 32, 22, 23, 37 and 14.

2.3 Natural Weathering of Graffiti-Resistant Coatings

Coatings used on exterior surfaces must resist the effects of the outdoor environment. The purpose of this test was to determine the ability of the coatings to resist discoloration when exposed to natural weathering.

Duplicate specimens were prepared by applying each coating to the face of brick. The supplier's directions for spreading rates were used. The coatings were cured for 7 days at 23 ± 2°C and 50 ± 5% rh. The specimens were then exposed at an angle of 45° south at the NBS Exposure Site for 10 months (May 5, 1974 - March 14, 1975). Measurements of surface color before and after exposure were used to calculate yellowness index difference [9] as specified in Method 6031 of Fed. Test Method Std. 141a. The yellowness index is a measure of the distance away from white toward yellow in the color coordinate system. The yellowness index difference is the difference between the yellowness index after exposure and the yellowness index before exposure [7].

Results of exposure of the 19 coatings at the NBS Gaithersburg site are shown in Table 5. The table gives the average yellowness index differences [7] for duplicate samples exposed for a period of ten months.

Coating numbers 38, 39, 42, 43, 47, and 48 showed the least tendency to yellow when exposed to the outdoor environment. Resistance to yellowing is essential for coatings suitable for application to exterior surfaces, but would not be a consideration for determining suitability for interior use.

2.4 Removal Tests of Felt-Tip Pen, Crayon, and Lipstick Markings

Since coatings must retain their functional properties for long periods of time under exposed conditions, the ease of removal of graffiti from 19 weathered coatings was determined.

Table 3. Dimensions and Physical Properties of Brick[a]

Saturation Coefficient	0.76	Width (mm)	90.4
Absorption (%) 24-hr cold	7.1	Length (mm)	193.5
Absorption (%) 5-hr boil	9.1	Height (mm)	57.2
Net Solid Area (%)	79.1	Gross Solid Area (mm)	1750.4

a/ Brick was tested in accordance with ASTM C-67-66 [3], except that results were expressed in SI units. Each value in the table represents the average of the results for five specimens.

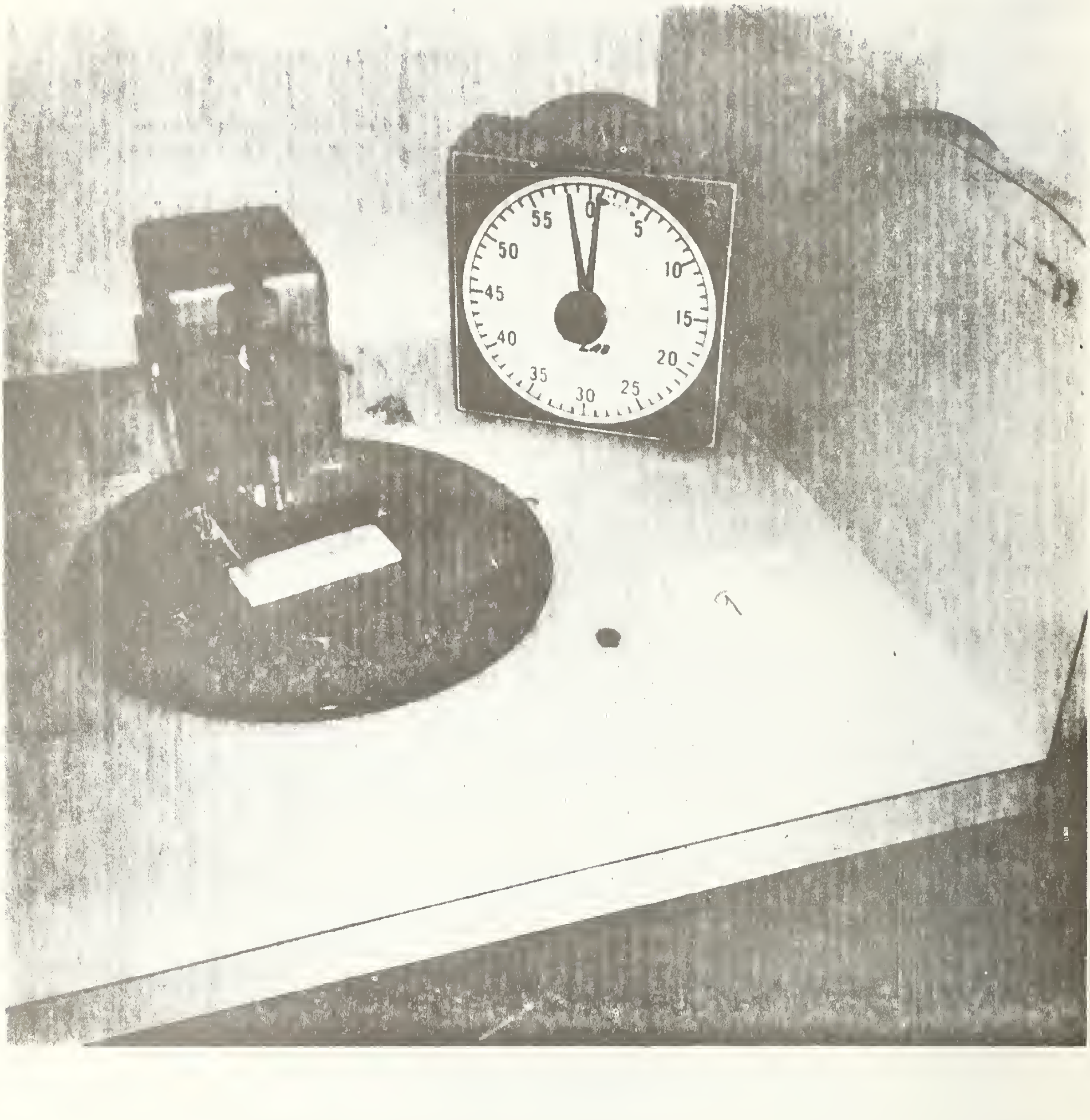


Figure 1. Lapping Wheel and Polishing Unit Showing Specimen in Attached and Unattached Positions

Table 4. Average Color Retention of 19 Coatings on Brick After Removal of 18 Spray Paints** by 2 Removers

Coating No.	Generic Type	Average Color Retention* Remover No. 86	Remover No. 98
5	Urethane	96	98
42	Fluorinated Polyester Urethane	94	97
44	Acrylic	95	97
32	Acrylic	95	96
22	Dimethyl Silicone	94	95
23	Dimethyl Silicone	95	95
37	Urethane	95	95
14	Polyester	95	95
29	Acrylic	94	94
4	Vinyl-toluene Acrylate	92	94
17	Methacrylate	93	92
33	Methacrylate	90	91
38	Acrylic	89	91
39	Acrylic	89	91
43	Acrylic	89	90
18	Methacrylate	90	89
46	Polyester	88	89
47	Acrylic	87	87
48	Acrylic	80	86
		Av. 92	Av. 93

*Duplicate panels for each remover C. R. = 100 - ΔE.

**Table 3.

Table 5. Extent of Yellowing of Coatings Due to Natural Weathering at the NBS Site

Coating No.	Generic Type	Average Yellowness Index Difference*
5	Urethane	0.06
14	Polyester	Peeled, flaked
18	Methacrylate	0.05
22	Dimethyl silicone	0.04
23	Dimethyl silicone	0.04
29	Acrylic	0.05
17	Methacrylate	0.05
4	Vinyl-toluene acrylate	0.07
32	Acrylic	0.06
33	Methacrylate	0.05
37	Urethane	0.07
38	Acrylic	0.01
39	Acrylic	0.03
42	Fluorinated polyester urethane	0.01
43	Acrylic	0.03
44	Acrylic	0.02
46	Polyester	0.05
47	Acrylic	0.02
48	Acrylic	0.03

*Average of duplicate specimens.

Duplicate specimens were prepared by applying each coating to the face of bricks in the manner recommended by the supplier. Specimens were cured for 7 days at 23 ± 2°C and 50 ± 5% rh. The duplicate specimens were exposed at an angle of 45° south for 10 months (May 5, 1974 - March 14, 1975) at the NBS Gaithersburg Exposure Site.

Samples were removed, rinsed with approximately 50 cm^3 of water and stored at 23 ± 2°C and 50 ± 5% rh for 48 hours. Then the color of the exposed coating was determined with a color difference meter [5]. The specimens were next marked with parallel lines, two inches long, using 4 felt-tip pens, 3 lipsticks and 6 crayons (brand or manufacturer and color of each line are identified in Section 1.4). The marked samples were then cured an additional 7 days at 23 ± 2°C and 50 ± 5% rh.

The removal process consisted of applying 10 cm^3 of remover No. 86 over the marked area and scrubbing by hand with a cellulose sponge for 35 strokes. The samples were then rinsed with water 100 cm^3 and scrubbed an additional 35 strokes by hand with a sponge charged with cake grit soap conforming to PS-571, Type A. The sponge was charged by applying 50 cm^3 of water and rubbing the soap by hand across its surface for a total of 25 strokes. The samples were rinsed with water (500 cm^3) and allowed to stand 24 hours before evaluating. Again, the color of the marked area was determined by measuring with a color difference meter and the change in color was computed [5].

Table 6 presents a ranking, by color retention (Section 1.5), of the coatings according to the effectiveness with which felt-tip pen, crayon and lipstick markings were removed. The six most effective coatings, in descending order, were numbers 42, 48, 38, 5, 43, and 22. These results indicate that all generic types of coatings may retain high resistance to defacement, even in outdoor exposures.

2.5 Resistance to Ultraviolet Radiation

Coatings for use on the exterior of buildings must resist U.V. radiation from the sun. The purpose of this test was to determine the effect of U.V. radiation on the appearance and integrity of the coatings. Duplicate brick specimens were prepared by applying each coating to the face of the bricks in accordance with recommendations of the coating supplier. After curing 7 days at 23 ± 2°C and 50 ± 5% rh, the color of the specimens was determined with a color difference meter prior to exposure in the twin-arc weathering machine. The apparatus was operated in accordance with Federal Test Method Standard No. 141a, Method 6152. The instrument was operated for 22 hours per day, 5 days a week and, in each 2 hour cycle, specimens were exposed to 102 minutes of light, then 18 minutes of light with water spray. The temperature was maintained at 60 ± 2°C. After each interval of 100 hours, the specimens were removed and stored at 23 ± 2°C and 50 ± 5% rh for 24 hours. The yellowness index difference was then calculated as specified in Method 6131 of Federal Test Method Standard 141a [7]. Specimens were exposed for a total of 300 hours.

The color changes resulting from 100, 200 and 300 hours of exposure in a Weather-O-Meter are presented in Figure 2. The data indicate that the initial rate of color change varies widely among the coatings. Generally, based on color changes at 300 hours, the coatings could be divided into two categories: (1) those showing a color change at 300 hours of less than 3 NBS units, and (2) those having a change greater than 3 NBS units.

2.6 Resistance to Condensing Moisture

Like U.V. radiation, the condensation of water on the surface of organic coatings is a major cause of deterioration. The purpose of this test was to determine the ability of coatings to resist change in appearance during prolonged exposures to condensing moisture.

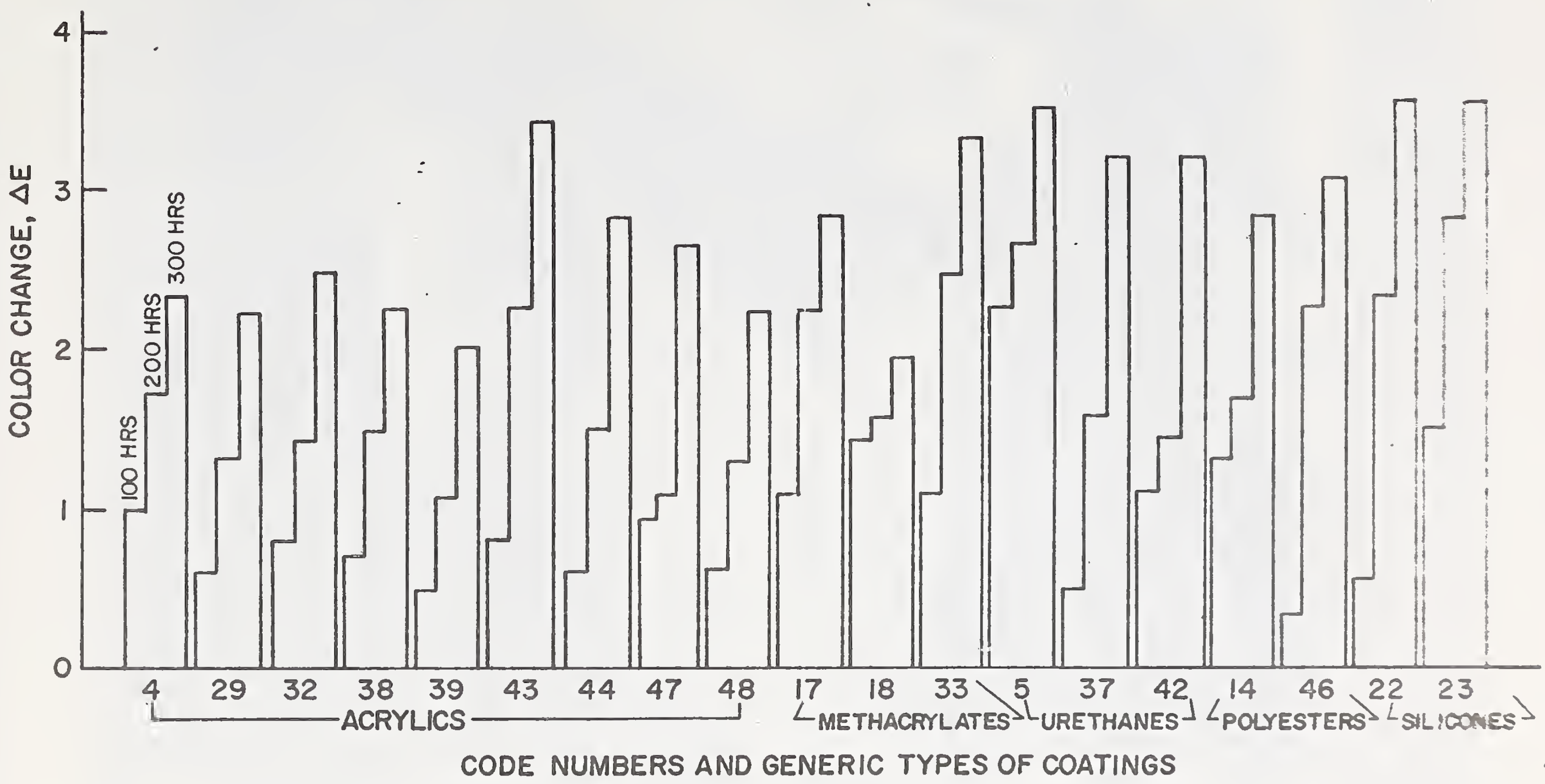
Duplicate brick specimens were coated (Table 1) in accordance with the supplier's recommendations. After curing (7 days at 23 ± 2°C and 50 ± 5% rh), the color of the coating was determined by measuring with a color difference meter [5]. The moisture condensation test, described in ASTM D2246-64T Tentative Method for Testing Coated Metal

Table 6. Ranking of Weathered Coatings on Brick According to Effectiveness of Removal of Felt-Tip Pen, Crayon and Lipstick Markings

Coating No.	Generic Type	Color Retention of Substrate*
42	Fluorinated polyester urethane	96
48	Acrylic	95
38	Acrylic	95
5	Urethane	94
43	Acrylic	94
22	Dimethyl silicone	94
29	Acrylic	93
37	Urethane	93
23	Dimethyl silicone	92
32	Acrylic	92
14	Polyester	92
44	Acrylic	92
39	Acrylic	91
46	Polyester	90
33	Methacrylate	90
4	Vinyl-toluene acrylate	88
47	Acrylic	87
18	Methacrylate	85
17	Methacrylate	80

*Color Retention, C.R. = 100 - ΔE (duplicate specimens).

Figure 2. Color Change of Graffiti-Resistant Coatings When Exposed to 100, 200 and 300 Hours of U.V. Radiation in a Weather-Ometer



Specimens at 100 Percent Relative Humidity [8], subjected specimens to condensation from heated water. Duplicate specimens were placed face down on an inclined rack over a pan of heated water at 44 ± 2°C for 14 days. The angle of the specimens permitted the moisture condensing on the specimens to run back into the reservoir. The surface color was measured after exposure and the color retention (see Section 1.5) was calculated as described in Method 6123 of Federal Test Method Standard 141a [5].

Significant changes occurred in all the coatings within 14 days. The average color retention values for duplicate specimens of each coating, in Table 7, show the effects of condensing water. Coating numbers 42, 29, 22, 48, 18, 14, 5, 38, 46 and 47, in descending order, were the ten most resistant coatings to condensing water.

The effects of condensing water and U.V. radiation (by Weather-O-Meter) on the appearance of coated brick are shown in Table 8. Because of the color changes caused by condensing water, graffiti-resistant coatings must be selected judiciously where the condensation of water is likely to occur.

2.7 Abrasion Resistance

Coatings that permit the removal of marking materials must retain their integrity during abrasion which might occur while in service and in the removal process. The purpose of this test was to determine the abrasion resistance of the coatings.

The test method was as described in Method 6192 [11] of Federal Test Method Standard 141a. Duplicate specimens were prepared by applying the coating by brush to 100 x 100 mm solvent cleaned No. 21 gage cold rolled steel according to the manufacturer's recommended spreading rate for smooth surfaces. The specimens were cured for 7 days at 23 ± 2°C and 50 ± 5% rh. Then a 6.25 mm diameter hole was drilled in the center of each steel square to permit mounting onto the abrasion tester (figure 4).

The initial weight of each square specimen was determined to the nearest milligram and mounted as directed in Method 6192 [11]. Using CS-17 calibrase wheels with a load of 500 grams on each wheel, the specimen was abraded for 500 cycles, and its weight loss determined.

The results of the abrasion tests are given in Table 9. It is seen that the urethane showed the greatest resistance to abrasion, while the acrylics, showed a wide range of abrasion resistance. Coating number 37 showed the lowest weight loss (1.5 mg), and coating number 22 showed the highest weight loss (39.6 mg). Resistance to abrasion is an essential property of coatings to be used in areas where direct contact with moving objects is likely, e.g. hallways, stairwells, doors and handrails.

2.8 Water Vapor Permeance

The application of coatings to building materials frequently causes problems by changing the pattern of moisture migration. The purpose of this test was to determine the suitability of graffiti-resistant coatings to aid in the control of water vapor. For example, to prevent the penetration of water vapor into walls and ceilings of bathrooms, kitchens and laundry rooms, these areas are frequently painted with highly impermeable coatings. Conversely, exterior areas, such as concrete walls, and wood sidings are frequently painted with permeable coatings to permit the transfer of water vapor within the walls to the exterior environment.

The basic test method used is described in ASTM E96 [12]. Duplicate specimens were prepared by application of the coatings to the highly permeable portion of penetration chart forms* at a wet film thickness of 0.125 mm. The specimens were then cured for 7 days at 23 ± 2°C and 50 ± 5% rh.

*Charts (Form HK) may be obtained from the Leneta Company, P.O. Box 576, Ho-Ho-Kus, New Jersey.

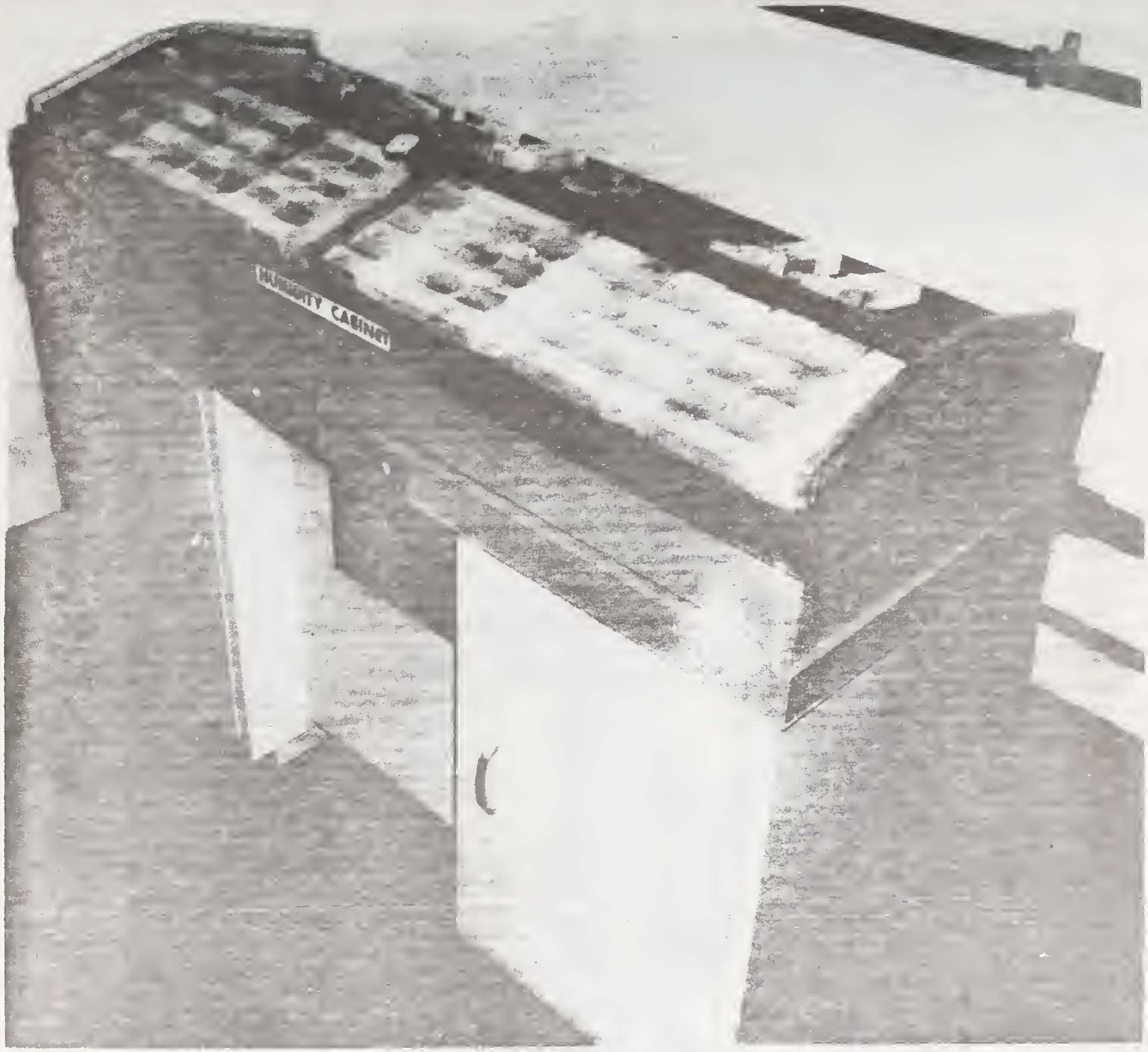


Figure 3. Condensed moisture aging test with test specimens installed face down on the surfaces of the humidity cabinet.

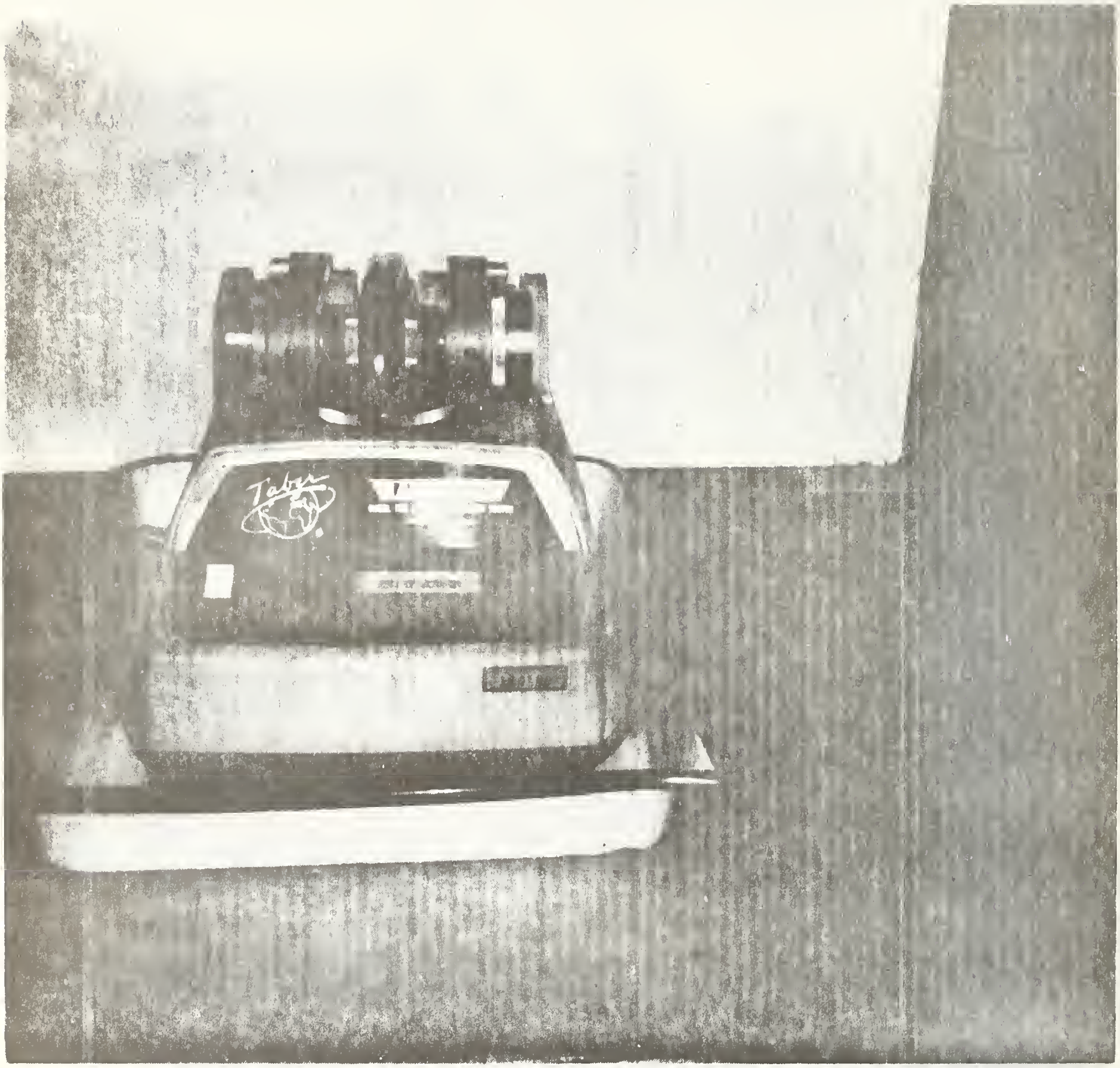


Figure 4. Abrasion test apparatus with abraser wheels being refaced on an abrasive disc.

Table 7. The Effect of Condensing Moisture on the Color Retention of Coatings on Brick

Coating No.	Generic Type	Average Color Retention*
42	Fluorinated polyester urethane	88
29	Acrylic	87
22	Dimethyl silicone	85
48	Acrylic	85
18	Methacrylate	84
14	Polyester	84
5	Urethane	84
38	Acrylic	84
46	Polyester	83
47	Acrylic	82
39	Acrylic	82
23	Dimethyl silicone	81
17	Methacrylate	81
4	Vinyl-toluene acrylate	81
44	Acrylic	81
32	Acrylic	80
33	Methacrylate	80
37	Urethane	80
43	Acrylic	76

*Color Retention, C.R. = 100 - ΔE (duplicate specimens)

Table 8. Visual Assessment of Effects of Accelerated Weathering on Coatings on Brick

Coating No.	Condensing Moisture (14 days) 44 ± 2°C	Weather-O-Meter, 60°C U.V., Water Spray (300 hours)
4	Slight darkening	No visible effect
5	No visible effect	No visible effect
14	Erosion of coating	Erosion
17	No visible effect	Slight darkening
18	No visible effect	Erosion
22	Erosion and whiting	Erosion
23	No visible effect	Erosion
29	Discoloration	Flaking
32	No visible effect	Erosion
33	Erosion of coating	Erosion
37	No visible effect	No visible effect
38	No visible effect	Erosion
39	No visible effect	Whitening and yellowing
42	No visible effect	No visible effect
43	No visible effect	No visible effect
44	No visible effect	No visible effect
46	No visible effect	No visible effect
47	No visible effect	Slight discoloration
48	Slight darkening	Slight yellowing

A disc (100 mm in diameter) cut from the chart with the cured film was sealed over the mouth of a permeability cup (figure 5) containing a desiccant and was placed in an atmosphere of 23 ± 2°C and 50 ± 5% rh. The assembly was weighed once every 24 hours, and the results for the period in which the gain in weight was linear with time were used to calculate the rate, in perms, of water vapor movement through the membrane.

The permeability of the coatings ranged from a low of 0.8 perms for number 5, to a high of 10.4 perms for number 42 (Table 9).

2.9 Flexibility

Organic coatings are formulated with varying degrees of ability to be deformed without cracking, checking or crazing. The purpose of the flexibility test was to determine the ability of coatings to resist deformation without damage.

Duplicate specimens of the coatings were applied to metal panels (Fed. Spec. QQ-S-698) at a wet film thickness of 0.125 mm by doctor blade** (a precision instrument designed for the application of uniform films of organic coatings). The coatings were cured for 7 days at 23 ± 2°C and 50 ± 5% relative humidity. The samples were removed and tested as outlined in Method 6221 of Fed. Test Method Std. 141 [9]. The specimens were subjected to both the 3.13 mm and the 6.250 mm mandrel tests (figure 6).

The results in Table 9 showed that many of the coatings were able to pass the flexibility test [9] on both mandrels. However, those that failed the 3.13 mm bend test, generally failed the 6.25 mm test also and would be considered poor.

2.10 Resistance to Graffiti Removers

If coatings are to provide lasting protection for building materials, they must resist removers used for cleaning markings from those materials. The purpose of this test was to evaluate the resistance of coatings to removers with which they are likely to come into contact during normal use.

Duplicate specimens were prepared by brush application of each coating to 100 x 100 x 6.25 mm matte tile, and allowed to cure for 7 days at 23 ± 2°C and 50 ± 5% rh. One cm^3 of the nineteen commercially available removers was placed in a 2.54 cm area on each coating and covered immediately with a watchglass. After one hour, the watchglass was removed, the solution washed away and the panel examined for wrinkling, blistering, lifting and discoloration of the coating.

The results are given in Table 10. Coating numbers 29, 32, 33, 38, 39 and 43 showed poor resistance to removers while coating numbers 5, 18, 22, 23, 37, 42, 44, 47 and 48 were highly resistant to removers. From this data, it was possible to identify compatible coating-remover combinations and thereby minimize the probability of damage to the coating. For example, Table 10 shows that remover numbers 8, 10, 17, 35, 59, 61, 62 and 78 would be appropriate for removal of markings from coating number 5; damage would be likely to occur if remover numbers 13, and 15 were used.

3. SUMMARY AND CONCLUSIONS

The results reported in Section 2 indicate that organic coatings can provide for the effective removal of markings. Nineteen coatings were evaluated and ranked according to the ease of removal of felt-tip pen, crayon, lipstick and spray paint markings. The performance of the coatings as protective membranes for building materials was also determined. Results of the laboratory tests reported in Section 2 show that organic coatings provide a wide variety of functions and perform at various levels of efficiency. For this reason, it is necessary to select coatings according to the function and level of performance required.

*Doctor blades may be obtained from the Gardner Laboratory, Inc., 5521 Landy Lane, Bethesda, Maryland.

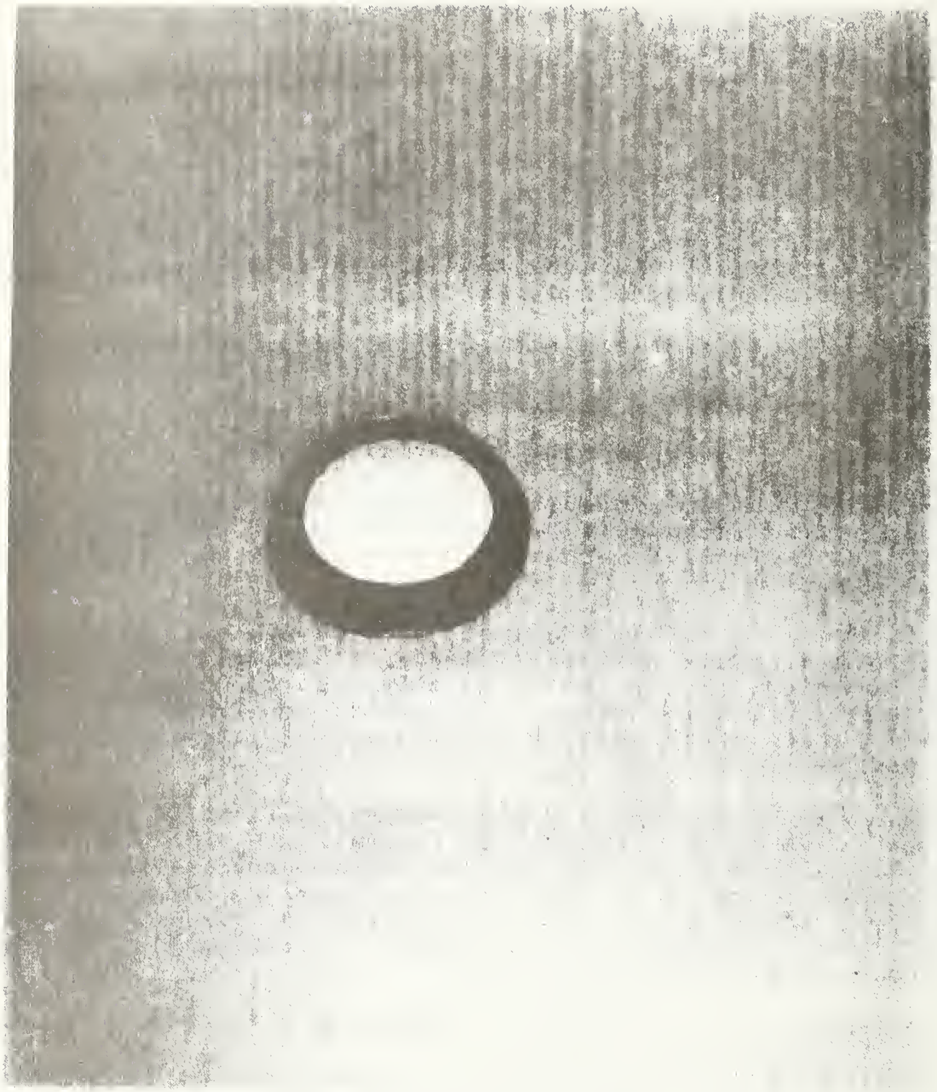


Figure 5. Water permeability test cup assembly.

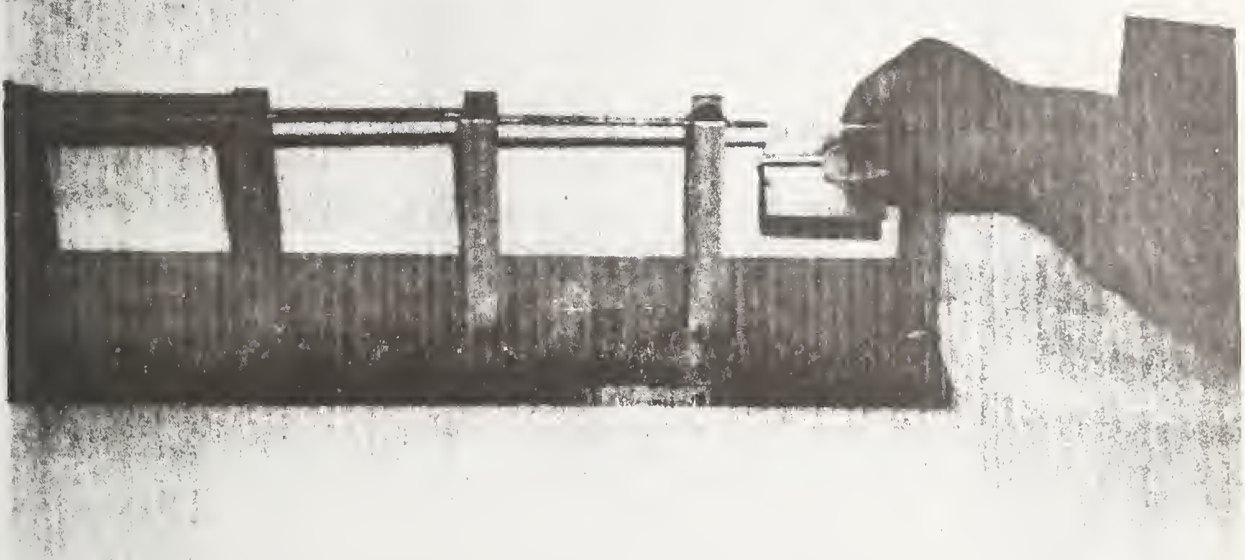


Figure 6. Series of mandrels showing test specimen being bent over 2.125mm mandrel.

Table 9. Physical Properties of Coatings

Coating No.	Generic Type	Water Vapor Permeance (Perms)*	Abrasion Resistance (Wt. loss in mg) 500 cycles	Flexibility (Mandrel Test) 3.125 mm	Flexibility (Mandrel Test) 6.250 mm
4	Vinyl-toluene acrylate	3.0	15.0	OK	OK
5	Urethane	0.8	4.0	OK	OK
14	Polyester	6.4	35.0	OK	OK
17	Methacrylate	4.8	25.0	OK	OK
18	Methacrylate	3.9	31.1	Fails	Fails
22	Dimethyl silicone	4.4	39.6	OK	OK
23	Dimethyl silicone	3.2	6.4	OK	OK
29	Acrylic	4.7	39.3	Fails	Fails
32	Acrylic	5.1	25.0	OK	OK
33	Methacrylate	7.0	27.0	Fails	Fails
37	Urethane	1.3	1.5	Fails	Fails
38	Acrylic	9.3	20.0	OK	OK
39	Acrylic	2.5	2.4	OK	OK
42	Fluorinated Urethane	10.4	22.4	OK	OK
43	Acrylic	6.5	18.8	Fails	OK
44	Acrylic	3.6	29.5	OK	OK
46	Polyester	5.0	28.6	Fails	Fails
47	Acrylic	6.1	38.4	OK	OK
48	Modified acrylic	6.4	35.0	OK	OK

*A perm is defined as a water vapor transmission rate of 0.0647 gm of water vapor per 0.0929 square meter per hour per 0.0254 meter of mercury difference in vapor pressure.

Table 10. The Effect of Graffiti Removers on Coatings on Brick

Coating No.	Generic Type	Remover No. 8	10	13	15	17	21	22	23	30	35	39	59	61	62	72	78
4	Vinyl-toluene acrylate	1	2	1	2	1	4	1	1	2	1	2	1	1	1	1	2
5	Urethane	1	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1
14	Polyester	1	1	1	1	1	4	1	4	4	1	4	1	1	1	4	1
17	Methacrylate	1	2	1	2	2	3	2	4	2	3	2	1	1	1	4	1
18	Methacrylate	1	2	1	4	1	1	1	1	1	1	1	1	1	1	1	1
22	Dimethyl silicone	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	Dimethyl silicone	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
29	Acrylic	2	2	4	4	1	4	3	4	4	1	4	1	1	1	4	1
32	Acrylic	1	1	4	4	1	4	2	4	4	1	4	1	1	2	1	1
33	Methacrylate	4	4	3	4	4	1	1	2	4	4	1	1	1	1	4	1
37	Urethane	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1
38	Acrylic	1	1	4	4	1	2	1	4	4	1	4	1	2	1	4	1
39	Acrylic	2	2	4	4	2	4	4	4	4	1	4	1	2	2	4	1
42	Urethane	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
43	Acrylic	1	2	2	1	2	2	1	1	1	1	2	1	1	1	2	1
44	Acrylic	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	1
46	Polyester	1	1	1	4	1	1	1	4	1	1	4	1	2	4	1	1
47	Acrylic	1	2	2	1	1	2	1	1	1	1	1	1	1	1	1	1
48	Modified acrylic	1	1	1	1	1	2	1	1	1	1	2	2	1	1	1	1

1 - No effect
3 - Partial removal
2 - Slight effect (dulls, whitens)
4 - Complete removal

Table 1 shows that more acrylics were available for use as graffiti-resistant coatings than any other generic type. The nineteen coatings selected for further evaluation were comprised of 8 acrylics, 3 methacrylates, 2 silicones, 1 modified acrylic, 2 urethanes, 1 modified urethane and 2 polyesters.

Studies of the effectiveness of removal indicated that spray paint and felt-tip pen markings, two of the most difficult to remove markings, can be effectively removed from coated brick. Eight coatings had a color retention value of 95 or more after the removal of spray paint; 12 coatings had a color retention value of 92 or above after the removal of felt-tip pen, crayon, and lipstick markings (Table 6).

Exposure of the coatings to conditions encountered in the outdoor environment showed that care must be exercised in their selection to ensure that they do not discolor, abrade or erode from the substrate. Eleven coatings had a color retention value of 95 or more (figure 2) after exposure for 300 hours in the twin-arc Weather-O-Meter; 11 coatings had a color retention value of 82 or more after exposure to continuous condensation for two weeks (14 days).

The abrasion resistance of the coatings (ability to resist mechanical wear) was also determined. Thirteen samples showed an average weight loss (duplicate specimens) of not more than 30 milligrams when abraded as outlined in Section 2.7.

The water vapor permeance results (Table 9) showed that the coatings are permeable and permit the transfer of water vapor. Only one coating, number 5, was highly resistant to the transfer of water vapor (e.g. permeance less than 0.9 perms).

Data in Table 9 showed that graffiti-resistant coatings were able to pass the flexibility test on both mandrels. Thirteen coatings passed the 3.13 mm bend test. These coatings were considered to be flexible and suitable for application to substrates where expansion and contraction would be likely to occur.

The resistance of coatings to graffiti removers is shown by data in Table 10. Coating numbers 29, 32, 33, 38 and 39 showed poor resistance to removers while coating numbers 5, 18, 22, 23, 37, 42, 44, 47, and 48 were highly resistant to removers.

The selection of graffiti-resistant coatings requires identifying specific functions and specifying levels of performance required. The tables given in Section 2 identify properties necessary for the evaluation of durability and show levels of performance for each.

From the experiments on the ease of removal of markings, and the performance of 19 graffiti-resistant coatings, the following conclusions were reached:

1. A quantitative rating of the resistance of a coating to defacement can be based on measurements with a color difference meter.

2. No one coating performed all functions well.

3. Criteria based upon the evaluation in this report will aid in the selection of organic coatings that resist defacement by marking devices.

4. Coatings highly resistant to defacement by crayon, felt-tip pen, and lipstick were: Nos. 42, 48, 38, 5, 43, and 22.

5. Coatings most resistant to spray paint were: Nos. 5, 42, 44, 32, 22, 23, and 37.

6. Generally, many of the coatings exhibited failures that frequently characterize unpigmented coatings, e.g., erosion, film cracking, discoloration and checking.

7. The coatings demonstrated the capability to provide many functional properties, e.g., high permeability, low permeability, high resistance to U.V. radiation and resistance to condensing water.

8. Most of the coatings were permeable and therefore, permitted the transfer of water vapor.

Taking into account the factors mentioned above, and based on the data reported in Section 2, tentative selection criteria for graffiti-resistant coatings, to be used for the protection of substrates from defacement, have been established. These tentative criteria are presented in Section 4.

4. RECOMMENDED INTERIM CRITERIA FOR GRAFFITI-RESISTANT COATINGS

Although there is no substitute for long-term in-service performance evaluation, the laboratory test results presented in Section 2 provide the basis for the following interim criteria for graffiti-resistant coatings. The criteria are preliminary and may need to be up-dated as additional information becomes available.

4.1 Ease of Graffiti Removal

Requirement

Graffiti-resistant coatings should make it easy to remove common marking materials from surfaces of architectural materials to which they are applied. The ease and effectiveness of removal should reflect the minimum performance levels satisfying the user's needs.

Criterion 1 - Ease of Removal (Spray Paint)

When tested as outlined below, the color retention shall not be less than 95 for the removal of spray paint.

Test

The eighteen spray paints (Table 2) are applied to cured (7 days at 23 ± 2°C and 50 ± 5% rh) coatings on brick. Two sets (each comprising 18 paints) are formed for each coating. After curing of the paints (7 days at 23 ± 2°C and 50 ± 5% rh), ease of removal of the paint from the coated brick is evaluated. Remover 86 (mildly alkaline) is used for one set and remover 98 (highly alkaline) for the other. Application is in accordance with the manufacturer's directions, except that the contact time prior to washing is extended to 30 minutes to obtain maximum removal effectiveness. After 30 minutes, the paint is washed from the coated brick with 5 gal/min of high pressure (1600-1900 psi) water to remove the paint film. After drying, photometric measurements of the appearance of each brick are made by a color difference meter [4] and used with the results of measurements made before application of the paint to determine the color retention.

Criteria 2 - Ease of Removal (Felt-Tip Pen, Lipstick and Crayon Markings)

When tested as outlined below, the color retention shall not be less than 92 for the removal of felt-tip pen, lipstick and crayon markings.

Test

Two bricks (Table 3) are prepared for each coating by applying the coating to the faces of bricks in the manner recommended by the supplier. The coated specimens are cured for 7 days at 23 ± 2°C and 50 ± 5% rh. The specimens are exposed at an angle of 45° south for 10 months (May 5 - March 14) at the NBS Gaithersburg Exposure Site.

Following removal from the site, the samples are rinsed with approximately 50 cm^3 of water and stored at 23 ± 2°C and 50 ± 5% rh for 48 hours. Then the colors of the coatings are determined with a color difference meter [5]. Next, the specimens are marked with parallel lines, two inches long, using 4 felt-tip pens, 3 lipsticks and 6 crayons (brand or manufacturer and colors to be used are identified in Section 1.4). The marked samples are then cured for an additional 7 days at 23 ± 2°C and 50 ± 5% rh.

The removal process consists of applying 10 cm^3 of remover No. 86 (mildly alkaline) over the marked area and scrubbing by hand with a cellulose sponge for 35 strokes. The samples are then rinsed with water (100 cm^3) and scrubbed an additional 35 strokes by hand with a sponge charged with cake grit soap conforming to PS-571, Type A. The sponge is charged by applying 50 cm^3 of water and rubbing the soap by hand adross its surface for a total of 25 strokes. The samples are rinsed with water (500 cm^3) and allowed to stand 24 hours before evaluating. Again, the color of the marked area is determined by measuring with a color difference meter and the color retention computed [5].

Commentary

Generally, porous materials such as brick, concrete block and cast concrete absorb common marking materials, thereby making removal difficult. These criteria were selected so as to recognize graffiti coatings which minimize the difficulties in removing spray paint, felt-tip pen, lipstick and other crayon markings. The limits specified in these criteria reflect results obtained in removing felt-tip pen, spray paint, crayon and lipstick markings from coated bricks by a common removal method. The criteria reflect our present best judgment. Although they are based on results for the coatings on brick, we believe they will also be a good guide to coating performance on other architectural materials.

Eight of the 19 coatings subjected to the tests met the requirement for the removal of spray paint; 12 of the coatings met the requirement for the removal of felt-tip pen, crayon and lipstick markings. The coatings meeting both requirements were: Nos. 5, 42, 44, 32, 22, 23, 37 and 14.

4.2 Resistance to Discoloration

Requirement

Graffiti-resistant coatings should maintain their original appearance even after prolonged exposure to the outdoor environment.

Criterion 1 - Effect of U.V. Radiation

When subjected to U.V. radiation as outlined below, the coating shall have a color retention value of not less than 97 (minimum performance level) after 300 hours of exposure.

Test

Duplicate specimens are prepared for each coating by applying it to the face of two bricks (Table 3) in accordance with recommendations of the coating supplier. Specimens are cured for 7 days at 23 ± 2°C and 50 ± 5% rh. The colors of the specimens are determined with a color difference meter prior to exposure in the twin-arc weathering machine. The apparatus is operated in accordance with Federal Test Method Standard No. 141a, Method 6152. The instrument is operated for 22 hours per day, 5 days a week and, in each 2 hour cycle, specimens are exposed to 102 minutes of light, then 18 minutes of light with water spray. The temperature is maintained at 60 ± 2°C. After each interval of 100 hours, the specimens are removed and stored at 23 ± 2°C and 50 ± 5% rh for 24 hours. The yellowness index difference is calculated as specified in Method 6131 of Federal Test Method Standard 141a [7]. Specimens are exposed for a total of 300 hours.

Criterion 2 - Effect of Condensing Moisture

When subjected to condensing moisture as outlined below, the coating shall have a color retention value of 82 (minimum performance level) after 14 days exposure.

Test

For each coating, the faces of duplicate brick specimens are coated (Table 1) in accordance with the supplier's recommendations. After curing (7 days at 23 ± 2°C and 50 ± 5% rh), the colors of the coatings are determined with a color difference meter [5]. The moisture condensation test, described in ASTM D2247-64T Tentative Method for Testing Coated Metal Specimens at 100 Percent Relative Humidity [8], subjects specimens to condensation from heated water. Duplicate specimens are placed face down on an inclined rack over the pan of heated water at 44 ± 2°C for 14 days. The angle of the specimens permits the moisture condensing on them to run back into the reservoir. The surface color of each specimen is measured after exposure and the color retention (see Section 1.5) is calculated.

Commentary

These criteria were selected to ensure retention of the original appearance accepted by users of the coatings. Coatings for use on exterior surfaces should meet both the U.V. radiation and the condensing moisture criteria. However, compliance with these criteria is not normally necessary for coatings for interior use, since the exposure conditions will not normally be so severe. The condensing moisture criterion should be applied when interior coatings are selected for application in areas such as bathrooms, kitchens and laundry rooms.

4.3 General Durability

Requirement

Graffiti-resistant coatings should have long-service life even under exposure to abrasion, water vapor, deformation of the substrate and graffiti removers.

Criterion 1 - Abrasion Resistance

When tested as outlined below, the average weight loss of duplicate specimens shall not exceed 30 milligrams.

Test

Duplicate specimens are prepared by applying the coating by brush to 100 x 100 mm solvent cleaned No. 21 gage cold rolled steel according to the manufacturer's recommended spreading rate for smooth surfaces. The specimens are cured for 7 days at 23 ± 2°C and 50 ± 5% rh. Then a 6.25 mm diameter hole is drilled in the center of each steel square to permit mounting in the abrasion tester.

The initial weight of each square specimen is determined to the nearest milligram and mounted as directed in Method 6192 [11]. Using CS-17 calibrase wheels with a load of 500 grams on each wheel, the specimen is abraded for 500 cycles, and its weight loss determined.

Commentary

Interior coatings usually experience their most severe abrasion from occupant traffic and routine maintenance (cleaning). Exterior coatings are usually abraded by the forces of wind-driven rain, sand and other particulate matter. In this criterion, no distinction is made between the requirements for interior and exterior coatings. However, it should be noted that in areas removed from occupant traffic (interior wall levels above 2 meters from the floor) a lower limit may prove satisfactory. This criterion represents our present best judgment based on the results of the test program reported herein.

The expression of abrasion resistance as milligrams of weight loss per number of cycles establishes a meaningful comparison by which coatings can be rated. Thirteen of the 19 samples tested met the criterion.

Criterion 2 - Water Vapor Permeance

Where water vapor transmission is to be restricted, coatings shall have a water vapor permeance not greater than 0.9 perms when tested as outlined below.

Test

Duplicate specimens are prepared by application of the coatings to the highly permeable portion of penetration chart forms* at a wet film thickness of 0.125 mm. The specimens are cured for 7 days at 23 ± 2°C and 50 ± 5% rh.

A disc (100 mm in diameter) cut from the chart with the cured film is sealed over the mouth of a permeability cup (figure 5) containing 30 gms of calcium chloride and placed in

*Charts (Form HK) may be obtained from the Leneta Co., P.O. Box 576, Ho-Ho-Kus, New Jersey.

an atmosphere of 23 ± 2°C and 50 ± 5% rh. The assembly is weighed once every 24 hours, and the results for the period in which the gain in weight is linear with time is used to calculate the rate, in perms, of water vapor movement through the membrane.

Criterion 3 - Water Vapor Permeance

Where water vapor transmission is desired, the coating shall have a water vapor permeance greater than 1.5 perms.

Test

Duplicate specimens are prepared by application of the coatings to the highly permeable portion of penetration chart forms at a wet film thickness of 0.125 mm. The specimens are cured for 7 days at 23 ± 2°C and 50 ± 5% rh.

A disc (100 mm in diameter) cut from the chart with the cured film is sealed over the mouth of a permeability cup (figure 5) containing 30 gms of calcium chloride and placed in an atmosphere of 23 ± 2°C and 50 ± 5% rh. The assembly is weighed once every 24 hours, and the results for the period in which the gain in weight is linear with time is used to calculate the rate, in perms, of water vapor movement through the membrane.

Commentary

The sealing of moisture-laden masonry walls by coatings may cause cracking and peeling of the coating or cracking, spalling and disruption of the wall. The above criteria provide guidance in the selection of coatings suitable for application to areas where either the transfer of water vapor or its exclusion is desired; however, an analysis of the water vapor movement in the structure may be necessary to determine the type of coating required.

A high water vapor transmission is usually required on exterior surfaces while a low transmission may be required on some interior surfaces. Only one of the 19 coatings tested met the requirement for restricting the flow of water vapor, while 18 met the requirement for permitting it.

Criterion 4 - Flexibility

Coatings applied to sheet metal or other easily deformed material shall pass the 3.125 mm mandrel test [8].

Test

Duplicate specimens of the coatings are applied to metal panels (Fed. Spec. QQ-S-698) at a wet film thickness of 0.125 mm by doctor blade** (a precision instrument designed for the application of uniform films of organic coatings). The coatings are cured for 7 days at 23 ± 2°C and 50 ± 5% relative humidity. The samples are removed and tested as outlined in Method 6221 of Fed. Test Method 141 [9]. The specimens are subjected to both the 3.13 mm and the 6.250 mm mandrel tests (figure 6).

Commentary

This criterion was selected to ensure that the selected coatings are suitable for application to building materials subjected to dimensional changes or deformation. Generally, building materials are subjected to dimensional changes when exposed to variations in environmental conditions. Field experience with coatings which met the above criterion has shown that they retain an acceptable level of flexibility.

Thirteen of the 19 coatings evaluated met the criterion. This requirement may be waived for coatings to be used on substrates characterized by little or no deformation.

Criterion 5 - Resistance to Graffiti Removers

When tested as outlined below, the coatings shall not wrinkle, blister or discolor.

**Doctor blades may be obtained from the Gardner Laboratory, Inc., 5521 Landy Lane, Bethesda, Maryland.

Test

Duplicate specimens are prepared by brush application of each coating to 100 x 100 x 6.25 mm matte tile, and allowed to cure for 7 days at 23 ± 2°C and 50 ± 5% rh. One cm^3 of the following household and/or industrial products (Big Wally, Knapp All Kleen, Janitor in a Drum and Novo Clean)*** is placed in a 2.54 cm^2 area on each coating and covered immediately with a watchglass. After one hour, the watchglass is removed, the solution washed away and the panel examined for wrinkling, blistering, lifting and discoloration of the coating.

Commentary

Generally, a graffiti remover that attacks most common marking materials is also likely to affect the surfaces of organic coatings. Coatings that resist the action of graffiti removers are likely to have longer useful service life and reduced maintenance costs. This criterion is intended to identify coatings which are able to resist common removers. Eleven of the 19 coatings evaluated met the criterion.

***Identification of commercial products is included only to adequately specify the test conditions. Identification does not imply recommendation or endorsement by the National Bureau of Standards.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The performance of graffiti-resistant coatings was evaluated and performance tests and criteria were developed to aid the selection of these materials.

From preliminary test of 48 commercially-available coatings, 19 were selected for more detailed tests. The 19 coatings were evaluated for ability to release common markings and to resist ultraviolet radiation, high humidity, condensing moisture, abrasion and graffiti removers. The flexibility and water vapor permeance of the coatings were also determined. The substrates used were clay brick and a matte tile. Seven of the coatings were highly resistant to defacement by spray paint, and five were highly resistant to felt-tip pen, crayon and lipstick.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Color retention; ease of removal; graffiti; graffiti-resistant coatings; performance

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