Methods and Equipment for Testing Printed-Enamel Felt-Base Floor Covering

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Building Materials and Structures Report 130

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Methods and Equipment for Testing Printed-Enamel Felt-Base Floor Covering

George G. Richey, Elizabeth H. McKenna, and Robert B. Hobbs

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Foreword

Printed-enamel felt-base floor coverings form the largest class of resilient non-textile floor coverings, which include linoleum, rubber tile, asphalt tile, and plastic tile and sheeting. The annual production of printed-enamel floor coverings, known in the trade as "felt-base rugs", amounts to more than 200 million square yards, valued at over 80 million dollars at the factory. Despite this large volume of production, no generally accepted methods for the evaluation of the properties of this material have been established. This paper describes methods and equipment for measuring the weight, over-all thickness, thickness of enamel and of seal coat, resistance to scrubbing with cleaning compound, resistance to kerosine, flexibility, and tearing strength. The results of laboratory tests are correlated with results of service tests of eleven proprietary products. The correlation was significant for all properties studied except thickness of seal coat, but no single property was outstanding in its level of significance. Thus it appears that these tests will be useful for manufacturers, purchasers of large quantities, and others interested in evaluating printed-enamel felt-base floor coverings.

A. V. Astin, *Acting Director.*

Contents

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This paper describes methods and equipment for measuring the weight, over-all thickness, thickness of enamel and of seal coat, resistance to scrubbing with cleaning compound, resistance to kerosine, flexibility, and tearing strength of printed-enamel felt-base floor covering. Results of laboratory tests are correlated with results of service tests of 11 proprietary products. The correlation was significant for all properties studied except thickness of seal, coat, but no single property was outstanding in its level of significance.

1. Introduction

Procedures for the evaluation of the properties of some nontextile floor coverings, such as linoleum, rubber tile, and asphalt tile, have been established for many years. These methods and the equipment associated with them have been accepted generally by consumers and manufacturers. Printed-enamel felt-base floor covering attains an annual volume of production amounting to 200 million square yards, valued at 80 million dollars at the factory, according to the 1947 Census of Manufactures. Although this volume of production exceeds that of any other type of nontextile floor covering, no generally accepted methods of tests have been established for the evaluation of the properties of printed-enamel felt-base floor coverings.

The purpose of this investigation was to develop such methods of laboratory tests, and to correlate the results of laboratory tests with the behavior of the material in actual service, insofar as practicable.

The methods reported here are suitable for the evaluation of the following properties: Weight, flexibility, tear resistance, thickness of enamel coating, over-all thickness, resistance to cleaning compounds, and resistance to kerosine. These methods and the results given in this paper may also be employed in the development of improvements in this type of floor covering.

2. Materials Tested

Eleven samples of printed-enamel felt-base floor covering purchased on the open market from retail outlets in Washington, D. C., were included in this investigation. They represented all available grades from all the manufacturers whose products were obtainable at retail at the time. The samples included materials from all price ranges.

Each floor covering consisted of a prepared felt backing to one side of which was applied an enamel coating, which constituted the wearing surface. The under side of the felt was painted. Microscopic examination of sections cut from the floor coverings showed, on all except one, that a paint coating had also been applied on the upper side of the felt backing before application of the enamel coat. Descriptions of the materials are given in table 1.

TABLE 1. *Manufacturer, size, and other identification of printed-enamel felt-base floor coverings tested*

Designation	Manufacturer	Size	Form	Other identification by manufacturer	Description of color and pattern
		ft.			
C-1	S	9 x 12	Rug	Deluxe, heavy weight	Leaf pattern in various shades of red with slight amounts of green, yellow, and black.
C-2	T	12 x 12	do	Standard, second	Gray, black, blue, and red tile pattern on ivory background.
C-3	T	12 x 12	do	Standard, regular	Light tan, black, blue, and red tile pattern on ivory background.
C-4	T	9 x 12	do	Deluxe	Tan and brown dot pattern with some red and black and scattered blocks of green, yellow, black, and red on cream background.
C-5	U	9 x 12	do	do	Tile pattern in various shades of gray with contrasting gray dots; a few solid blocks of yellow, blue, red, and green on ivory background.
C-6	V	9 x 12	do	do	Floral pattern in blue, green, brown, tan, and orange on background of two shades of red.
C-7	W	9 x 12	do	None	Tile pattern in gray, black, ivory, red, and tan.
C-8	X	6	Roll	do	Block pattern in gray, red, and black on ivory background.
C-9	Y	9 x 12	Rug	do	Floral pattern in various shades of red with green, yellow, brown, and red on a background predominately tan and gray.
C-10	X	9 x 12	do	First grade	Leaf pattern in tan and brown shades, with slight amounts of red, orange, ivory, and green on chocolate background.
C-11	Z	9 x 12	do	None	Floral pattern in black, white, and tan with slight amount of green on red background.

3. Test Methods and Equipment

3.1. Atmospheric Conditions

Measurements of all properties were made with specimens conditioned in an atmosphere of 65 ±2 percent relative humidity at a temperature of 70° ±2° F for at least 48 hr. The specimens were also tested under these atmospheric conditions. These conditions were adopted simply because they were the ones most conveniently available at the time the tests were made. There seems to be no reason to prefer them over the present standard conditions of 73° F and 50-percent relative humidity.

3.2. Weight

The weight of each floor covering was obtained by weighing and measuring specimens approximately 4 by 4 in. in size cut from the full thickness of the material. Weighings were made to the nearest gram, and lineal dimensions were measured to the nearest 0.02 in. From the weight and measurements so obtained, using three specimens, the average weight per square yard was calculated.

3.3. Flexibility

Specimens, each 2 by 8 in., were cut longitudinally and transversely from each of the floor coverings, then bent over a series of mandrels of decreasing size, ranging in diameter from 4 to 1 in., by increments of ½ in., until cracking of the enamel coating was observed. Each strip was bent at its center over the mandrel, with the felt backing on the inside, through an arc of 180° in approximately 5 sec. and at approximately a uniform speed. Two specimens were tested from each of the floor coverings.

3.4. Tear Resistance

In the study of tear resistance, the Elmendorf tear tester modified to double its capacity, as described by Carson and Snyder,[1] was used. The method of operation of the tester was similar to that described in the ASTM test for tearing resistance of paper,[2] except for the number, size, and shape of specimens used. This method determines the average force, in grams, required to tear a single rectangular specimen by measuring the work done in tearing the specimen through a fixed distance. The scale of the tester is graduated to indicate the ratio of the work done (in gram-centimeters) in tearing the specimen to the total tearing length of 16 sheets. This total tearing length is 16 times 4.3 cm times 2, that is, 137.6 cm. The factor 2 is included because, in order to tear a sheet through a given distance, the tearing force must be exerted through twice that distance.

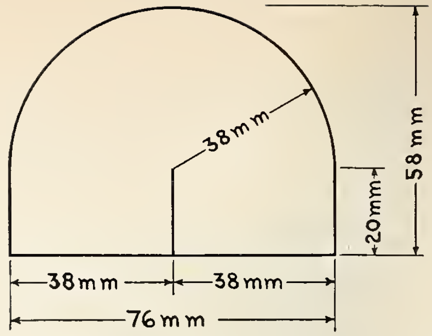

Figure 1. *Dimensions of specimen for test of tear resistance.*

Preliminary tests were made to compare, with the rectangular specimen, one having a semicircular shape, with a radius of 38 mm, above the top of the initial slit. The dimensions of the specimen are shown in figure 1.

For the rectangular specimen, the length of tear was 43 mm. As the capacity of the instrument was doubled, the indicated scale readings were multiplied by the factor 16×2 to obtain the average tearing force in grams.

For the specimen with the semicircular area, the radius of curvature, 38 mm, was equal to the length of tear. Hence, the indicated scale readings were multiplied by the factor $(16 \times 2 \times 4.3)/3.8$, that is, 36.2, to obtain the average tearing force for the specimen.

The results of comparative tests on the two shapes of specimens for two varieties of floor covering are given in table 2. Each mean represents eight determinations. The variability for the rectangular specimens is much greater than for those with the semicircular area. For this reason, further tests on all the floor coverings were made with the semicircular specimens.

[1] F. T. Carson and L. W. Snyder, Paper Trade J. 86, 13 (1928).
[2] ASTM Designation D689–44, ASTM Standards, Part III–B (1946).

Table 2. *Tearing strength, in grams, of rectangular and semicircular specimens*

Sample	Rectangular specimen				Semicircular specimen			
	Machine direction		Cross-machine direction		Machine direction		Cross-machine direction	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
C-5	954	64	1,274	130	915	40	1,170	79
C-6	965	46	1,356	144	898	22	1,025	83

In making subsequent tests, five specimens were cut from each of the two principal directions of the floor covering and tested. The indicated scale reading was multiplied by the factor 36.2 to obtain the tearing force in grams. This value was rounded off to the nearest 10, and in the mean of the five determinations for each direction was recorded.

3.5. Thicknesses of the Seal Coat and of the Enamel Coat

Thicknesses of the seal coat and the enamel coat were determined by observation with a measuring microscope on sections cut at a right angle to the surface of the floor covering. The equipment used was capable of making measurements accurate to 0.0005 in. The arithmetic mean of 10 measurements was taken as the thickness of the seal coat. The arithmetic mean of 10 measurements of sections comprising at least three different colors of the pattern was taken as the thickness of the enamel.

3.6. Over-all Thickness

The over-all thickness of the floor covering under a load of 3.0 ± 0.1 oz exerted by a weight through a flat contact foot 0.25 ± 0.01 in. in diameter was determined by means of a dial micrometer. Measurements were made to the nearest 0.001 in. The arithmetic mean of five measurements was taken as the over-all thickness of the material.

3.7. Resistance to Cleaning Compound

The resistance of the enamel coating to scrubbing with an alkaline soap solution was determined with a modified Schiefer abrasion machine.[3] This apparatus was modified to use a nylon bristle brush as the abradant, and to accommodate a brass cup to retain the test specimen and the solution. Figure 2 shows the brush, cup, and specimen in position on the machine.

The brush, shown schematically in figure 3, was made from a commercial article by sawing it in half transversely and cutting the slots by which the brush is engaged in the holder. Each tuft consists of 34 nylon bristles, each 0.014 in. in diameter, and the backing is of polymethyl methacrylate. The bristles were worn to a uniform length before use by rotating the brush 1,000 times in the Schiefer machine against B–A flint paper 1/0, with a load of 4.14 lb. In order to keep the solution distributed over the surface of the specimen during operation of the machine, a distributor plate of acrylic plastic, ¾ in. wide, was fixed along a radius of the cup, so as to just clear the surface of the specimen and the side of the cup. The total load on the brush was 4.14 lb.

The solution used for the test contained 0.5 percent of soap, conforming to the Federal Specification for chip soap,[4] and 0.5 percent of chemically pure sodium carbonate. It had a pH of about 10.6.

In order to simulate more closely the conditions of scrubbing in actual service, the temperature of the solution was maintained at $45° \pm 2°$ C during the test. This was accomplished by keeping the entire apparatus in a heated enclosure, with the temperature of the solution being measured by a thermocouple immersed in it.

The test specimen was cut with a circular steel die having a diameter of $4\frac{15}{32}$ in. It was placed in position and the cup was attached. Approximately 50 ml of the solution, previously warmed to 50° C, was placed in the cup. The machine was then operated for 9,000 revolutions of the specimen against the brush. The specimen was removed, rinsed with tap water, allowed to dry at room temperature, and the area of seal coat or felt exposed was measured to the nearest 0.01 in.^{2} with a planimeter. The areas in square inches exposed on five test specimens from each material

[3] Herbert F. Schiefer, Lawrence E. Crean, and John F. Krasny. J. Research NBS **42**, 481 (1949) RP1988.

[4] Federal Specification P-S-566a for Soap; Chips.

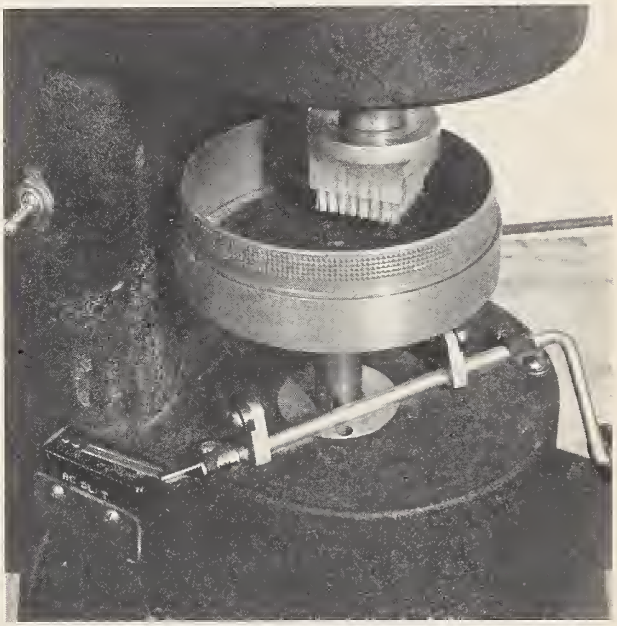

FIGURE 2. *Schiefer abrasion machine with cup and brush for measuring resistance to cleaning compound.*

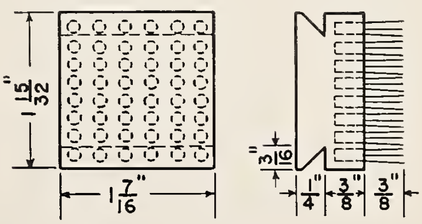

FIGURE 3. *Brush used with Schiefer abrasion machine.*

were added, and the result taken as the effect of scrubbing with the cleaning compound.

In order to study the effect of variations between the brushes on the results of this test, a comparison was made of one brush that had been used for tests of 70 specimens (600,000 rotations in the Schiefer abrasion machine, representing approximately 40 hr of service in the machine) and three new brushes. Twelve strips were cut at random from sample C–5, and four test specimens were cut from each strip. A specimen from each strip was tested with each brush. The test procedure was identical with that described previously. A statistical analysis of the results showed there were no significant differences in the results obtained with the used brush in comparison with the new brushes, and there were no significant differences in the effects produced by the three new brushes in comparison with each other. The tabulation of this analysis is given in table 3.

TABLE 3. *Analysis of variance of effect of cleaning compound on sample C–5, using an old brush and three new brushes*

Source of variation	Degrees of freedom	Sum of squares	Mean square
Between means of strips	11	2.1460	0.1951
Between means of brushes	3	0.1960	.0653
Interaction	33	2.5774	.0781
Total	47	4.9194	0.1047

In a few instances it was necessary to add about 10 ml of solution during the test because of losses from evaporation, leakage, and absorption of solution by the specimen. Test specimens from two of the floor coverings were run for less than the prescribed 9,000 rotations because the enamel coating was removed relatively rapidly from both of these materials.

3.8. Resistance to Kerosine

A metal ring of approximately 4 in. inside diameter was cemented to the enameled surface of floor covering by means of cellulose nitrate adhesive. The adhesive was applied on the outer surface of the ring and the floor covering. Care was taken to prevent any of this adhesive from getting on the test area enclosed by the ring. After a 24-hr drying period (minimum), 25 ml of kerosine was placed on the test area, and this expose was allowed to continue for 72 hr. At the end of this period the kerosine was removed, the test area was rinsed with tap water, and any blistering of the enamel noted.

4. Service Tests

4.1. Test of Materials Laid in Corridor

The corridor connecting the second floors of the Munitions Building and the Navy Department Building in Washington, D. C. was selected for this installation. This corridor is about 100 ft long and 7½ ft wide, with no doors except those at each end. The existing tongued-and-grooved wood floor in the corridor was repaired and the entire area was sanded to remove high spots. Each specimen installed was approximately 60 in. long and 84 in. wide, placed so that its greater dimension extended across the width of the corridor. The specimens were separated from each other by means of 1-in. strips of floor covering, nailed to the wood floor. A clearance of ¼ in. was allowed between the edge of the specimen and the adjacent edge of the strip. These strips served as furring under strips of galvanized sheet metal 3 in. in width, which were used to cover the edges of adjacent specimens. The sheet-metal strips were nailed to the wood floor through the furring strips. By this method of installation linear dimensional changes of the floor coverings could occur without causing buckling of the specimens.

The test installation was opened to traffic in February 1947. The specimens were mopped twice each week with water to which 2 percent (by weight) of cleaning compound was added. The analysis of the cleaning compound used is given in table 4.

TABLE 4. *Analyses of cleaning compounds used in service tests*

Property	Munitions Building installation	National Bureau of Standards installation
Matter volatile at 105° C	3%	10%
Neutral inorganic salts	59%	
Sodium chloride (NaCl)	1%	
Free alkali (NaOH)	None	None
Rosin, sugar, etc	do	Do.
Anhydrous soap	None detected.	14
Synthetic detergent	37%	
Insoluble siliceous material		56%
Alkaline salts (Na_2CO_3)		20%
Total	100%	100%

After approximately 12 months of service, 14 observers rated the specimens in comparison with each other, on the basis of distinctness of pattern, gloss, resistance to soiling, and general appearance. These observers included scientific personnel of the National Bureau of Standards, representatives of manufacturers of printed-enamel felt-base floor covering, and consumers. A relative rating of A, B, C, or D, was assigned to each specimen by each observer. An "A" rating indicated the best floor coverings, and "B", "C", or "D" ratings progressively poorer materials. These ratings were then tabulated.

Numerical values of service ratings were obtained on the basis that each observer had an equal number of total points to assign (a total of 50 points was arbitrarily selected). In addition, ratings of A, B, C, and D were credited in the proportion of 4:3:2:1, respectively, for every observer. By this method the over-all influence of each observer's rating was equal, regardless of whether the particular observer tended to rate high or low.

Traffic counts taken in the corridor on various days indicated approximately 16,000 people traversed the corridor per week.

4.2. Test of Materials Laid on Stairway

Specimens of the floor covering, each 10 by 36 in., were installed on a stairway at the National Bureau of Standards. All specimens were cemented directly to the existing marble treads with a commercial linoleum paste adhesive. (Two specimens came loose during the test period. These were relaid with a rubber-resin adhesive.) The specimens were mopped twice each week with water containing 1 percent of (by weight) cleaning compound. The analysis of the cleaning compound used is given in table 4.

The test installation was in service from March 1947 to February 1948. At the end of this period, the test specimens were taken up and washed with water to which 1 percent of the cleaning compound was added. They were rated with respect to appearance in comparison with each other as A, B, C, or D. An "A" rating indicated the best floor coverings and "B", "C", or "D" progressively poorer materials. Photographs of some of the specimens, when rated, are shown in figure 4.

5. Results of Tests

5.1. Correlation of Results of Laboratory and Service Tests

The results of laboratory and service tests are given in tables 5, 6, and 7. The results of the service tests are of primary importance as correlation with these results is used as an index of the usefulness of any laboratory test in evaluating durability. The test in the Munitions Building is thought to be the better criterion of the durability of the specimens, both because use as a floor covering more nearly simulates actual use in the home than does use as a stair covering, and because the evaluations of the worn materials represented the opinions of a larger number of observers with more varied personal background. An analysis of variance of the service ratings, summarized in table 7, shows that there are highly significant differences between specimens, but not between observers. The results of the service test on the stairway can be taken as confirming the results of the Munitions Building test. The same two specimens, C–4 and C–6, are ranked as best, and the same two, C–7 and C–11, as "worst." Results for the other specimens in the stairway test were inconclusive.

In comparing the results of the floor service test with the results of laboratory tests, correlations were based on rank as the evaluations by the different observers rated the specimens in order of

TABLE 6. *Results of service tests of printed-enamel felt-base floor covering*

Designation	Rating	
	National Bureau of Standards installation	Munitions Building installation
C–1	C	45.0
C–2	B	45.0
C–3	B	47.6
C–4	A	58.0
C–5	B	56.5
C–6	A	67.0
C–7	D	21.6
C–8	C	37.1
C–9	C	54.2
C–10	C	54.3
C–11	D	17.1
C–2A	----------	42.7
C–3A	B	50.2
C–10A	----------	56.7

TABLE 7. *Analysis of variance of adjusted service ratings for 11 printed-enamel felt-base floor coverings by 14 observers*

Source of variation	Degrees of freedom	Sum of squares	Mean square
Between means of floor coverings	10	167.72	16.77
Between means of observers	13	1.37	0.11
Interaction	130	70.97	.55
Total	153	240.06	1.57

TABLE 5. *Physical properties and performance tests of floor coverings*

Sample	Average weight	Flexibility	Tearing strength		Thickness—average			Effect of cleaning compound	Effect of kerosine
			Machine direction	Cross-machine direction	Seal coat	Enamel coat	Over-all		
	*lb/yd*²	*in.*[a]	*g*	*g*	*Mils*	*Mils*	*Mils*	*in.*²	
C–1	3.1	3	900	1,060	0.0	5.0	65	5.44	None
C–2	3.0	3½	890	1,270	7.0	5.5	55	0.06	Do.
C–3	2.8	<1	900	1,320	5.0	5.0	51	.02	Do.
C–4	3.3	2	1,110	1,280	6.0	5.5	66	.01	Do.
C–5	3.2	<1	920	1,170	5.0	6.5	61	1.41	Do.
C–6	3.2	2	900	1,020	3.5	6.0	72	0.00	Do.
C–7	2.0	3½	590	590	4.0	2.0	47	[b] 57.2	Blistered
C–8	2.7	4	830	1,130	6.0	5.0	51	0.67	None
C–9	3.6	1	920	940	4.5	4.0	71	.20	Do.
C–10	2.5	3½	570	750	6.0	4.5	53	.06	Do.
C–11	2.3	<1	630	700	4.0	0.5	49	[c] 57.2	Blistered

[a] Diameter of mandrel on which cracking was first observed. [b] 6,500 rotations instead of 9,000. [c] 4,000 rotations instead of 9,000.

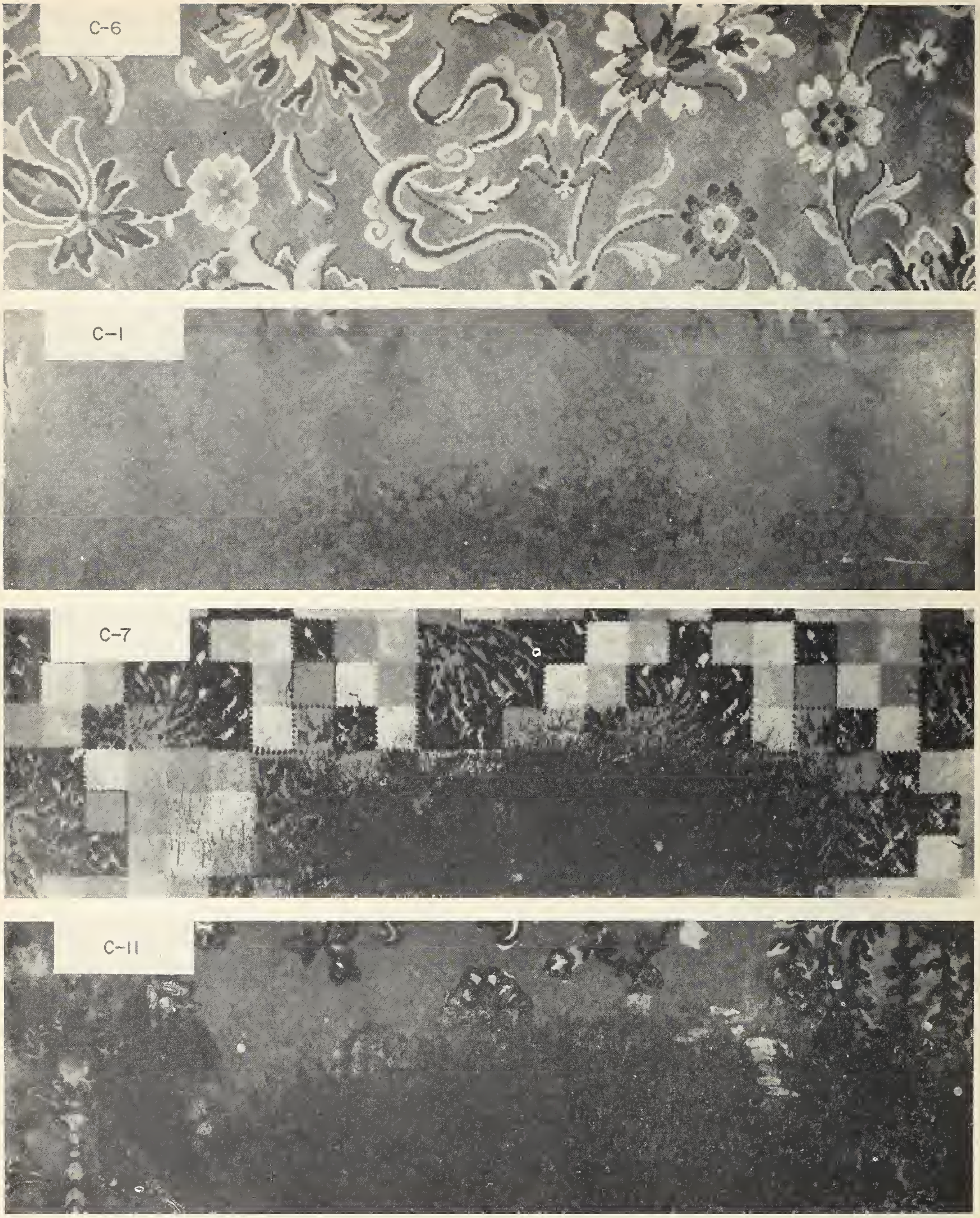

FIGURE 4. *Specimens of floor covering after service test on stairway.*

C-7 and C-11 show greatest deterioration, C-6 the least; others are intermediate.

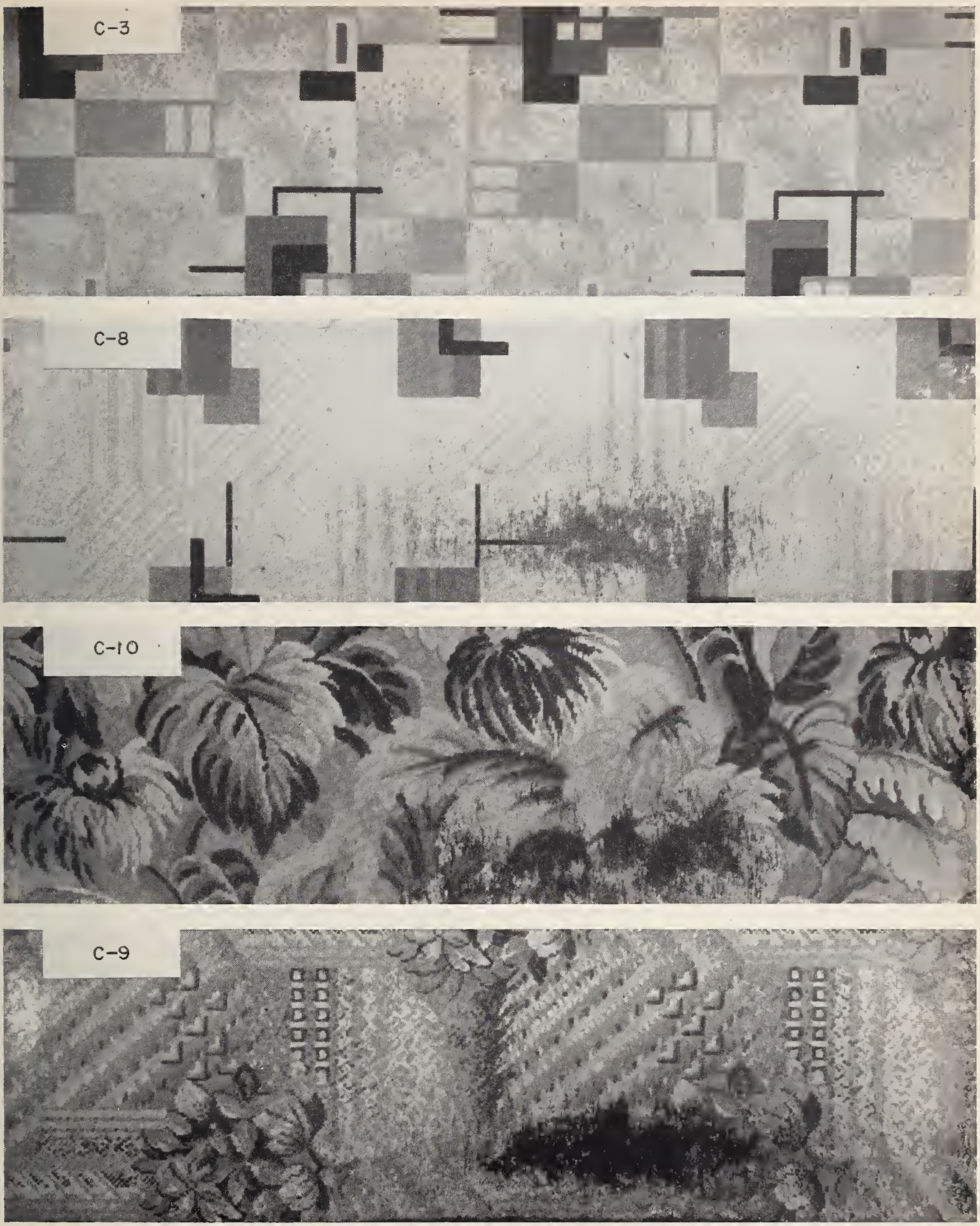

FIGURE 4. *Specimens of floor covering after service test on stairway.*—(Continued)

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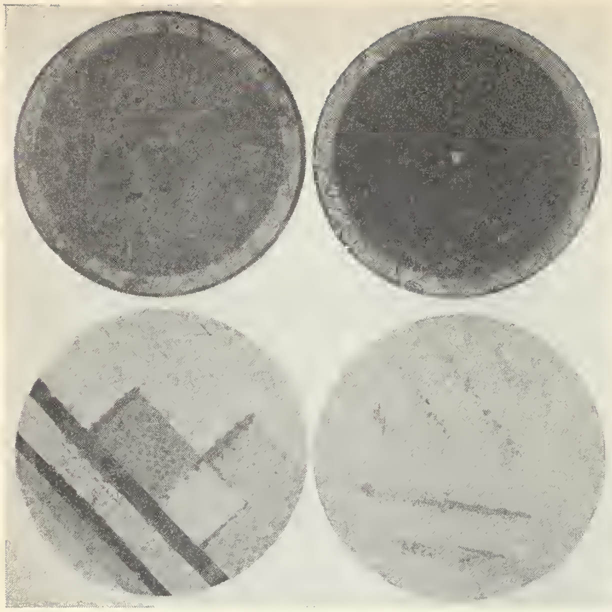

FIGURE 5. *Rank correlation of service and laboratory test results.*

durability rather than giving quantitative results, and the final ratings, given in table 6, represent an integration of these rankings. Diagrams in which the ranks for each sample in six laboratory tests are plotted against the ranks in the floor service test are shown in figure 5.

From these diagrams it is apparent that there is practically no correlation between seal-coat thickness and durability in service, but that there is some correlation between each of the other properties and the behavior of the material in service. These conclusions were checked by calculating measures of correlation from ranks, using the formula

$$\rho = 1 - \frac{6D^2}{N(N^2-1)},$$

where

ρ = the measure of correlation from ranks for a given property

D = the difference between the rank in the laboratory test for a given property and the rank in the service test for each floor covering

N = the number of materials in the test, that is 11.

The values of ρ so obtained were as follows for the various properties measured:

Weight per unit area	0.73
Tearing strength (machine direction)	.62
Thickness of enamel coat	.69
Thickness of seal coat	.08
Over-all thickness	.80
Resistance to cleaning compound	.75

Each of these values of ρ, except that for thickness of seal coat, shows a significant positive correlation.

5.2. Measurements of Weight and Thickness

As measurements of weight and over-all thickness are the easiest and quickest to make of all the tests described in this paper, it is interesting that they show rather high degrees of correlation with the results of service tests. As the two samples giving by far the poorest wear in the service tests had weights of 2.0 and 2.3 lb/yd^2, it it would seem that a weight of at least 2.5 lb/yd^2 is the minimum that would be expected for a material giving good service. Similar considerations lead to a minimum value of 0.050 in. for over-all thickness.

The durability of the enamel coat is highly important as the decorative effect of the floor covering depends entirely on this layer. When it has become so badly worn as to impair the decorative effect, the consumer usually wishes to replace it. The significant correlation between the thickness of enamel coat and the service rating reflects this circumstance. From the results it would appear that the enamel coat must be at least 4 mils thick to give satisfactory service.

The purpose of the seal coat is to prevent "bleeding" of the saturant in the felt base into the enamel coating. It appears that when the minimum thickness necessary to perform this function is applied, any greater thickness of seal coat adds nothing to the serviceability of the floor covering. As one sample had no seal coat, yet showed no adverse effect from this omission, there is no conclusive evidence from this experiment that a seal coat must be required.

5.3. Flexibility

Printed-enamel felt-base floor covering is furnished to retail outlets in roll form. Hence it is necessary that the enamel coating be sufficiently flexible to withstand unrolling of the floor covering without cracking of the coating. Yard goods, in addition, are often purchased for use as wall-to-wall floor covering, and bending of the material will usually be necessary during fitting at the time of installation. On the basis of requirements in existing Federal specifications,[4] felt-base floor covering that can be bent without cracking over a mandrel 4 in. in diameter or smaller is desirable. Of the floor coverings included in this investigation only sample C–8 failed to have this degree of flexibility. After a 3-week period of installation, the specimen of this floor covering in the service installation at the Munitions Building exhibited marked cracking of the enamel coating. All the other specimens in the service installation at this same time showed either no cracking or slight cracking of the coating. It was to be expected that the enamel coatings would harden and lose flexibility with age. This tendency was evident in the test at the Munitions Building, for after approximately 1 year of service, all specimens,

[4] Federal Specification LLL–F–471 for Floor Coverings; Felt-Backed.

except that from sample C–1, exhibited cracking on some areas of the surface.

5.4. Tearing Strength

The tearing strength is a property of importance in connection with the unrolling and laying of a floor covering, as well as its resistance to tears caused by stubbing the toe of one's shoe or a similar hard object against the edge of the covering. This property also shows a significant correlation with serviceability. Two of the three samples having tearing strengths of less than 700 g were the two showing the poorest durability. The majority of manufacturers apparently have no difficulty in making a product with a tearing strength of 800 g or more.

5.5. Resistance to Cleaning Compound

The statement is sometimes heard in the floor-covering trade that "more floor coverings are worn out by scrubbing than by being walked on." It seems to be a substantiation of this view that the results of the test for resistance to scrubbing with cleaning compound showed a significant correlation with serviceabliity. It should be noted that the two floor coverings that recieved the lowest service ratings were also the poorest in resistance to cleaning compound, and the two floor coverings that recieved the highest service rating were also the best in resistance to cleaning compound.

Photographs of certain specimens subjected to the test for resistance to cleaning compound are shown in figure 6. The areas of localized exposure of seal coat or felt on some of the floor coverings can be seen. In certain instances this failure has occurred at the junction of two colors. This is to be expected on floor coverings when the printing is accomplished by means of die blocks as each color is applied to individual areas without overlapping. Hence it is necessary for the enamel to flow slightly to obtain complete coverage of the seal coat. This resultant flow tends to make the enamel coating thinner at the areas where colors join. In other instances, failure appears to have occurred at individual colors, probably because these colors were actually less resistant to the action of the cleaning compound. Other factors that might cause localized exposure of the seal coat or backing material are poor felting of the backing material and nonuniformity of thickness of the enamel coating during printing.

The results show that the total area of seal coat or felt exposed on eight test specimens after 9,000 rotations each should not exceed 50 in.^{2} as a maximum, and it is probable that this value should be set much lower, perhaps about 8 in.^{2}

5.6. Resistance to Kerosine

At the beginning of this investigation, the subject of properties to be evaluated was discussed with manufacturers of printed-enamel felt-base

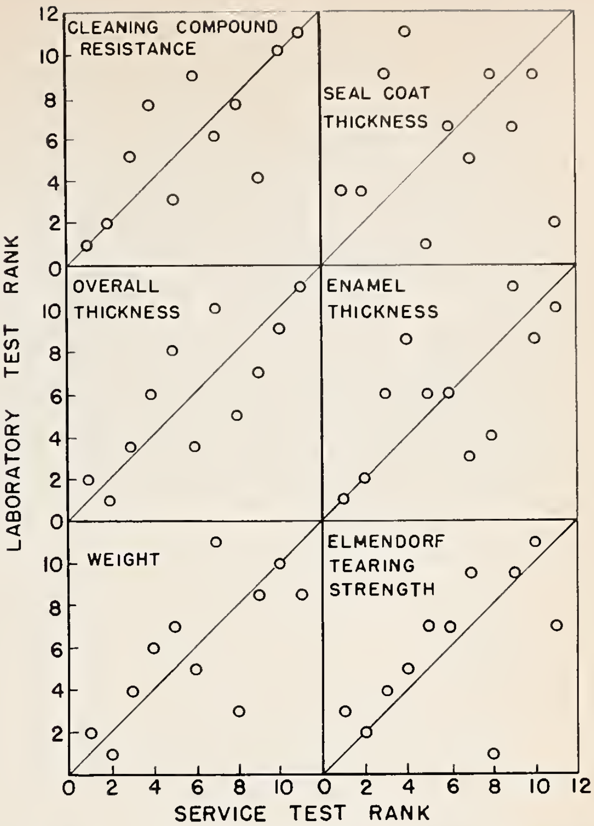

Figure 6. *Specimens after test for resistance to cleaning compound.*

Upper left, C–1; right, C–11. Lower left, C–5; right, C–8.

floor covering. It was indicated that a large volume of this floor covering was used in homes in rural areas and in summer cottages, where kerosine stoves and lamps are frequently used. In view of the likelihood of spilling of kerosine or seepage from a container placed on the floor covering, it was decided to include an evaluation of kerosine resistance of the enamel coating.

The results of tests indicated that all the enamel coatings except two, samples C–7 and C–11, were excellent in resistance to kerosine. Samples C–7 and C–11 exhibited blistering of the enamel coating in the test and can not be considered suitable for an exposure of this type.

5.7. Service Tests

The corridor at the Munitions Building, selected for the service installation, serves only as a means for connecting the Munitions Building and the Navy Department Building. It is used primarily for pedestrian traffic, but lightweight hand trucks are occasionally taken through the corridor. Doors are placed at each end of the corridor only, hence an equal number of people walked over each of the floor coverings. At the time the specimens were rated, they had been subjected to 100 cleanings, and it is estimated that more than 800,000 pedestrians had traversed the corridor. Only specimens C–7 and C–11 had shown a marked loss in decorative effect at the time the ratings were assigned. The service ratings of replicate specimens of floor coverings C–2, C–3, and C–10 agree very well; the maximum difference between any two was found to be 3 units.

An analysis of variance of the ratings of specimens C–1 through C–11 (the replicates were not included) was made. This analysis showed that practically all the variability in the ratings could be attributed to the floor coverings, and that very little could be attributed to the observers and other causes.

The specimens installed on the East stairway, Industrial Building, National Bureau of Standards, were subjected to much more severe conditions than those in the corridor at the Munitions Building. The relatively rapid rate of wear of flooring materials on stair treads is well recognized, but in this instance the cleaning compound also contained a large percentage of siliceous material, which probably further accelerated deterioration. Although the exposure conditions were widely different in the two service tests, the relative order of results was essentially the same in both tests.

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Washington, August 24, 1951.

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