NBSIR 76-1005

A Comparison of Two Testers in Evaluating the Slip-Resistance of Bathtub and Shower Base Surfaces

Robert J. Brungraber
Theresa J.R. Raper

Center for Building Technology
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U.S. DEPARTMENT OF COMMERCE

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ABSTRACT

The report describes a program of tests planned by ASTM Committee F15.03 on Safety Standards for Bathtub and Shower Structures, and conducted at the National Bureau of Standards for the purpose of comparing the NBS-Brungraber and the Kollsman tester with respect to their effectiveness in evaluating the slip-resistance of bathtub and shower base surfaces. This program represents a contribution by the National Bureau of Standards to the efforts of the American Society for Testing and Materials and the Consumer Product Safety Commission in developing safety standards for bathrooms and bathroom fixtures. Both testers employ the same material (drumheads of "slunk") to simulate human skin, and the report concludes that both testers will satisfactorily discriminate between different bathroom surfaces on the basis of slip-resistance. The conclusion may be made that the NBS-Brungraber tester is considerably more convenient to use.

Key words: Kollsman tester; NBS-Brungraber tester; safety of bathrooms; slip-resistance of bathtub and shower base surfaces; slip-resistance testers.

1. INTRODUCTION

The Building Safety Section has been conducting an extensive study of the slip-resistance of walkway surfaces. A significant contribution of this study has been the design of a new portable tester, the NBS-Brungraber tester, for evaluating the slip-resistance of in situ floor surfaces. This tester was intended for the evaluation of surfaces that are usually used by people with shod feet and thus the sensor facing elements selected were typical of materials used for shoe-sole surfaces. The interest of The American Society for Testing and Materials (ASTM) Committee F15.03, with the support of the Consumer Product Safety Commission, in the slip-resistance of bathtub and shower base surfaces provided the Building Safety Section with an opportunity to apply the new tester to another class of surfaces. For this application it has been necessary to select a new sensor facing material that might simulate the sole of a bare human foot.

As requested by ASTM Task Committee F15.03.01 and the Consumer Product Safety Commission, the Building Safety Section performed a series of tests to assist ASTM F15.03.01 in selecting a suitable tester for evaluating the slip-resistance of bathtub and shower base surfaces. The task as specified in the minutes of the ASTM F15.03.01 (Appendix A) meeting of June 5-6, 1975, and then later revised by ASTM F15.03.01 (Appendix B) on July 16, 1975, and by the investigators, (Appendix C) August 8, 1975, was to conduct a series of tests on five representative bathtub or shower base surfaces using the NBS-Brungraber tester and the Kollsman tester.

2. TEST PROGRAM

The test program was organized to execute the task as specified and modified.

2.1 Testers

2.1.1 The NBS-Brungraber Tester

This tester, shown in figure 1, was designed to measure the static coefficient of friction between a representative walkway surface and a piece of shoe soling or heel material. For the program of the present report the sensor shoe of the tester was modified for use with a material intended to simulate human skin and be representative of a bare foot. Appendix D contains a description of this tester with an illustration and operating instructions. The tester, as designed, is able to employ one, two, or three 5-pound circular weights so that the vertical or normal force can be varied between the limits of approximately 8 pounds and 18 pounds. For the tests of the present report two weights were used so that the total vertical force, including the weights of both struts and the shoe sensor assembly, was 13.32 pounds.

2.1.2 Kollsman Tester

This tester, shown in figure 2, has been described by its inventor and his representative as a mechanical analog that represents the action of a person slipping in a bathtub or shower. A report describing the design of this tester is attached as appendix E, and the instructions for the use of the tester are attached as appendix F. These instructions reflect modifications made, under the supervision of Kollsman, during the first half day of testing. Significant modifications include:

a) number of measurements in a series of tests and the total number of tests (though not consistently described in the appended document),

b) increasing the screw adjustment on the sensor pad from two turns, as was required by the original instructions, to three and one half turns.

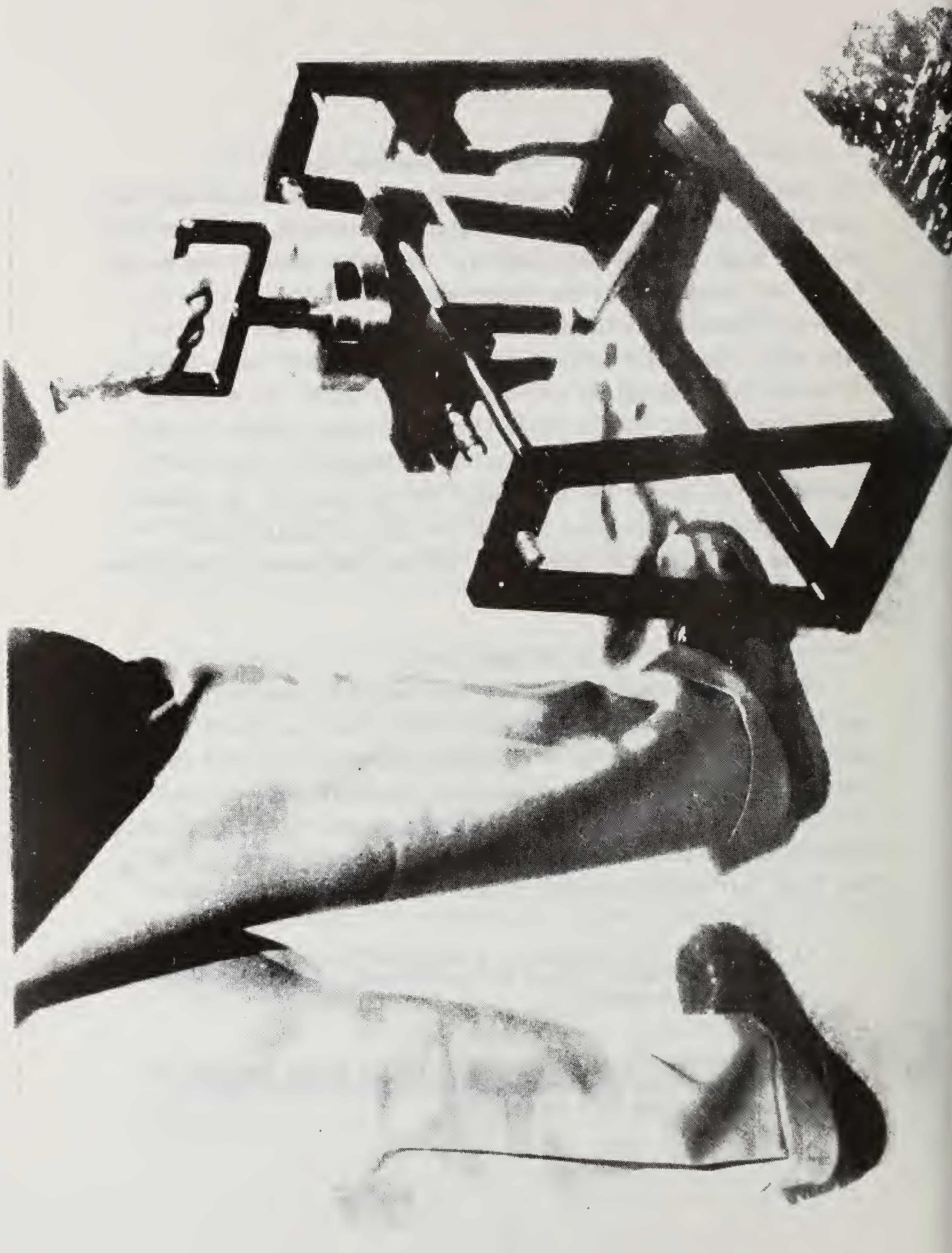

Figure 1. NBS-Brungraber Tester

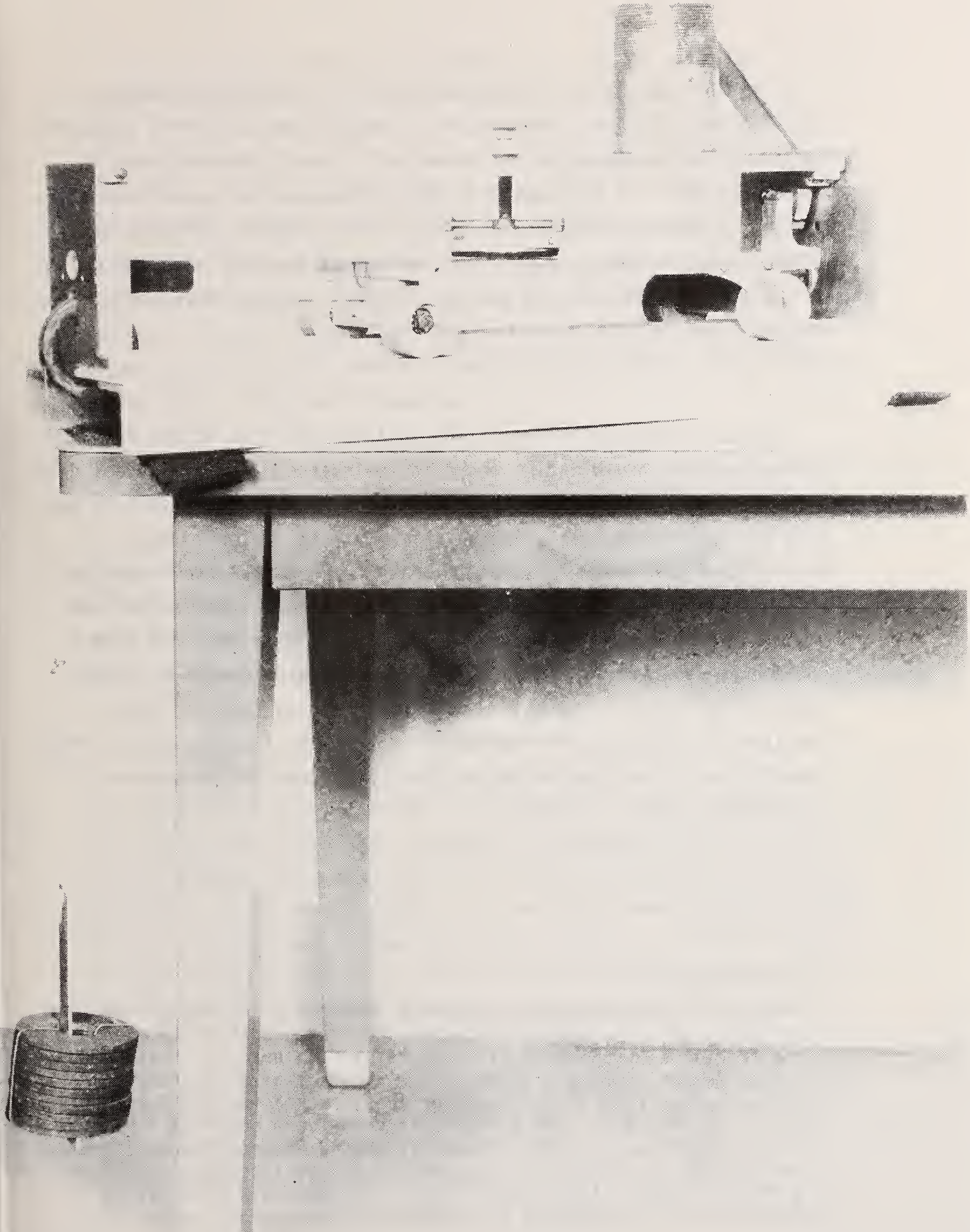

Figure 2. Kollsman Tester

The Kollsman tester can be operated in three separate modes - static, static/dynamic, and dynamic. However, in accordance with the specified test program, the Kollsman tester was to be evaluated in only two modes. As instructed by Mr. Kollsman and his representative, the static mode was eliminated from the test program. For the program of the present report the Kollsman tester was operated with the weight in the position intended to develop a normal force of 25 pounds; however, the magnitude of this force was not checked.

2.2 Sensors

Based on the experience of Mr. Kollsman and that of the Building Safety Section in evaluating the slip-resistance of swimming pool decks, a material thought to be suitable for simulating the bare skin on the sole of a human foot was selected. The material selected was a natural drumhead known as "slunk," which is made from the hide of an unborn calf. The particular skin selected was one intended for the lower or snare side of a snare drum. This skin was measured with a micrometer caliper and found to have an average thickness of 0.008 inch ± 0.002 inch. This skin was selected since, based on prior qualitative studies by Mr. Kollsman, it had been found to be the least susceptible to swelling and stretching under tension when soaked in warm water or soap solution.[1]

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[1] Subsequent investigations have shown that the frictional properties of slunk vary from sample to sample and that, contrary to expectations, the frictional properties vary as the skin is used for testing or simply soaked in pure or soapy water. When evaluating the slip-resistance of relatively rough surfaces, such as surfaces used for swimming pool decks, the slunk surface could be observed sloughing off, indicating that the material was being affected by use. However, such sloughing off was not observed on the surfaces tested for the program described in the present report. In appendix C the slunk is incorrectly identified as kip.

A 3-inch wide strip of skin was cut to fit the sensor of the NBS-Brungraber tester and a 5-inch diameter circle was cut to fit the sensor of the Kollsman tester. After soaking in distilled water at 100° ± 10°F for at least 15 minutes, the skin specimens were attached to the proper sensors and returned to the water bath for at least 15 minutes before starting the slip-resistance measurements. For both testers, the skin was backed by a 3/16-inch thick layer of closed cell neoprene sponge. Contrary to the instructions of item D(1) of appendix B, it was found that only 15 minutes of soaking was needed to make the skins sufficiently pliable to permit their installation on the sensor of either tester.

For the Kollsman tester, the sensor was a 3 1/2-inch diameter circle and for the NBS-Brungraber tester, the sensor was a 3-inch square. This results in a contact area of 9.6 square inches for the Kollsman tester and 9 square inches for the NBS-Brungraber tester. A single skin was used to provide the sensor covers for both testers and a single cover was used on each instrument throughout the entire test program.

2.3 Sample Materials

As specified in appendix B, the materials to be tested were: porcelained cast iron - smooth; porcelained cast iron - textured, with a sand blasted surface; textured, gel-coated fiberglass-reinforced plastic (FRP) having a pebble grained surface; dot-pattern appliques applied to smooth, porcelained cast iron; and flower-pattern appliques applied to smooth, porcelained cast iron. However, the cast iron specimens were replaced by similarly finished porcelain-enameled steel specimens, because of the ready availability of the latter.

Two specimens of each material were provided: one 12 x 30 inches for use with the NBS-Brungraber tester, and one 6 x 12 to 13 inches for use in the Kollsman tester. The porcelain-enameled steel specimens were supplied by the Porcelain Enamel Institute. In order to insure that these specimens would remain flat throughout the test procedure, they were bonded with an epoxy adhesive to 1/4 inch thick cement-asbestos board, which was backed with light-gage, sheet aluminum. The FRP material, a textured shower base, was used as supplied by the manufacturer. The dot-pattern appliques were supplied and installed by the developer. The flower-pattern appliques were supplied by the manufacturer and installed at the National Bureau of Standards (NBS) according to the manufacturer's instructions. The two patterns of the applique treatments are illustrated at full size in figure 3. The dot-pattern appliques were made of a sheet vinyl having a smooth surface and the flower pattern appliques were made of a synthetic rubber sheet material having a pebble-grained surface. Both types of appliques were attached with pressure sensitive adhesive which had been applied by the manufacturer.

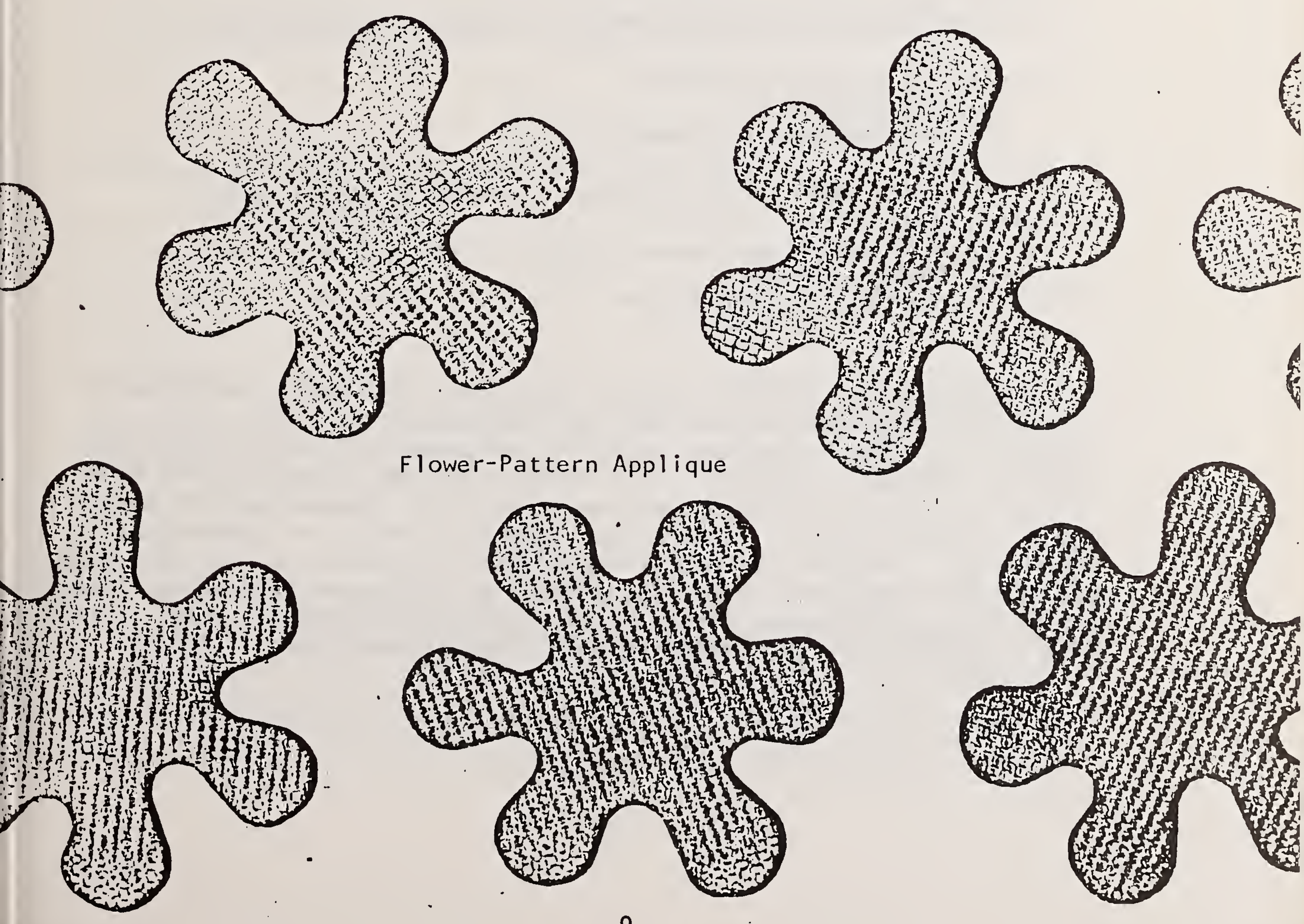
All specimens were prepared for testing by conditioning them in distilled water at 100° ± 10°F for at least 15 minutes. Conditioning was conducted in a covered, insulated and temperature-controlled galvanized steel tank. The sensors, with slunk attached, for both testers were also kept in the water bath except when they were being used in a test.

2.4 Soap Solution

The soap solution was a mixture, by weight, of 90% distilled water and 10% soap flakes, as specified by the ASTM Committee (per appendix B). The soap flakes, a mild white laundry type, were intended to be representative of pure white bath-type soap as would meet ASTM D499-69 (Reapproved 1974) "Standard Specification for White Floating Toilet Soap." The soap solution was kept in plastic wash bottles, and maintained at 100° ± 5°F on a temperature-controlled hot plate, except when the solution was being applied to the sensors or the surface of the specimens. It was found necessary to maintain this temperature in order to prevent precipitation of the soap and formation of a gel. The use of a closed plastic wash bottle was to prevent evaporation of the mixing water so that the soap concentration would be the same for all of the specimens tested.

FIGURE 3. CONFIGURATION OF APPLIQUE TREATMENTS

Dot-Pattern Applique



Flower-Pattern Applique

2.5 Experimental Schedule

The order for testing, determined as described in "Procedure for Testing," appendix G, was:

1) Textured porcelain-enamel on steel

   a) Kollsman-static/dynamic mode
   b) NBS-Brungraber
   c) Kollsman-dynamic mode

2) Smooth porcelain-enamel on steel

   a) Kollsman-dynamic mode
   b) NBS-Brungraber
   c) Kollsman-static/dynamic mode

3) Flower-pattern appliques on smooth, porcelain-enameled steel

   a) Kollsman-static/dynamic mode
   b) NBS-Brungraber
   c) Kollsman-dynamic mode

4) Dot-pattern appliques on smooth, porcelain-enameled steel

   a) Kollsman-dynamic mode
   b) NBS-Brungraber
   c) Kollsman-static/dynamic mode

5) Textured, gel-coated, fiberglass reinforced plastic (FRP)

   a) Kollsman-static/dynamic mode
   b) NBS-Brungraber
   c) Kollsman-dynamic mode

This alternating of the test order from material to material was adopted to help eliminate unnecessary bias from the testing procedure. The sequence of using the Kollsman tester in two modes and the NBS-Brungraber tester in one mode on each of the five materials was repeated three times so that a total of 15 observations was to be made for each mode of each tester on each material. A complete sequence of tests took approximately three hours. In order to meet or exceed the requirement of ten replicates specified in item B of appendix B, a total of 15 observations or replicates was made by going through the order of testing three complete times, making five observations or replicates at each stage of each test.

2.6 Laboratory Procedure

Prior to testing, the sensors (with the slunk) and specimens were immersed in distilled water at 100° ± 10°F for at least 15 minutes to bring them up to temperature. This was judged to be an adequate immersion period since no apparent signs of gelation of the soap solution occurred during any of the tests. For all materials, tests began with one of the two modes of the Kollsman tester. A specimen and sensor were removed from the bath and placed in the Kollsman tester. The screw adjustment was made, as described in appendix F. The specimen and sensor were returned to the bath for at least 15 seconds to restore them to a satisfactory lathering temperature. The specimen and sensor were then replaced in the tester, soap solution applied to both sensor and specimen, and either a static/dynamic or a dynamic test performed. The same type of test was repeated without any additional soaping or soaking for a total of five observations. That is, at each increment of weight on the support rod, five distinct repeat operations of the tester were performed. Thus five distinct readings were made for each increment of the Kollsman test, however many increments might be required to achieve a full travel of 6.5 inches, indicating attainment of uncontrolled slip. Upon completion of the first Kollsman test sequence, the specimen and sensor were then returned to the bath to soak while the specimen and sensor for the NBS-Brungraber tester were removed from the bath and soap applied. Five measurements with the NBS-Brungraber tester were then performed without any additional soaping or soaking. The specimen and sensor were returned to the bath while the Kollsman specimen and sensor were reinstalled and the alternate type of Kollsman test performed. All specimens and sensors were thoroughly rinsed in warm tap water before they were returned to the bath of distilled water.

The test program was conducted at ambient conditions in a laboratory in which the temperature and relative humidity were controlled by the central heating and ventilating system of NBS. The temperature and relative humidity were continuously monitored by a device capable of measuring to within ± 2°F and ± 2% relative humidity (rh). During this test program the atmospheric conditions ranged between a low of 72°F with 58% rh and a high of 75°F with 66% rh. Since all tests were conducted using a soap solution and specimens which were preheated to 100° ± 10°F, the atmospheric conditions in the laboratory were not considered to be critical.

3. RESULTS OF TESTS

A summary of the test results is presented in tables 1 and 2. Both tables include means and standard deviations for use in later statistical analysis. These calculations are only made for continuous variables, the static coefficient of friction for the NBS-Brungraber tester and the displacement of the carriage (in inches) for the Kollsman tester. (The raw data is included in this report as appendix H.)

Table 1, for the NBS-Brungraber tester, presents the average static coefficient of friction (X) and the standard deviation (s) for the five observations in each replicate as well as overall, a total of 15 or 20 observations.[2] The overall mean and deviations from the overall mean are used in calculating the 95 percent confidence interval. This interval would be expected to bracket the true mean (of the population) 95 percent of the time. The upper and lower confidence limits, X_{upper} and X_{lower}, are shown in table 1.

The Kollsman tester measures the displacement of the carriage for discrete test loads and uses the attainment of a displacement of 6 1/2 inches as an indication of the onset of uncontrolled slip. The displace-

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[2] At the conclusion of the first day of testing, during which the two enameled surfaces (smooth and textured) and the flower-pattern appliques were tested, it was found necessary to change the technique for adjusting the Kollsman tester (see section 2.1.2). For this reason, the original data taken with the Kollsman tester was discarded and the test program reinitiated. However, the data for the NBS-Brungraber tester was satisfactory and retained for analysis; four replicates, 20 observations, are reported.

ment values for respective test loads are given in table 2, showing the average and standard deviation for the five observations in each replicate as well as overall, for a total of 15 observations. In the cases where all five observations in a replicate were greater than 6 1/2 inches, a notation to this effect was made, in table 2, in the column. In cases where some, but not all, of the observations were greater than 6 1/2 inches no average is reported and the letters "N.A." are entered in the columns where mean and standard deviations are normally reported. For the purpose of analysis, the averages and standard deviations are reported to two decimal places though the displacement had been determined and recorded to the nearest 1/16-inch. In many cases using the Kollsman tester, the carriage would move rapidly a certain distance, slow down distinctly and then creep on, sometimes to the end of travel, approximately 6 13/16 inches. Whenever there was a temporary halt, so that the displacment could be read at the point, this value was recorded. Otherwise the result, greater than 6 1/2 (>6.5) inches, was entered. This indicates that there is a need for some interpretation of the performance of the Kollsman tester. No instructions for such an interpretation were supplied with the tester.

It is noted that the load, as applied for the Kollsman tester, is a discrete rather than a continuous variable and that the goal of the test is attaining a limiting value (see 3.14, 4.23, and 5.23 of appendix F). It is also noted that the standard deviation of the displacement data tends to increase as the load increases, which can be seen in table 2.[3].

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[3] Kollsman and his representative have reported that a technique has been developed for analyzing data from the Kollsman tester that involves plotting the value of the applied test load versus the resulting displacement. However, this technique was not reported to the NBS investigators. Depending upon the criteria used to indicate uncontrolled slip, this technique could be used to establish slip-resistance as a continuous variable. However, in view of the dilemma of continuous versus discrete data and the variability of the displacement measurements, the application of this technique did not appear to be justified.

Table 1. NBS-BRUNGRABER TESTER RESULTS _ STATIC COEFFICIENT OF FRICTION AS AN INDICATOR OF SLIP RESISTANCE*

Test Surface	Test Data Identification	Static Coefficient of Friction		95% Confidence Limits	
		$\overline{X}$	s	X_{lower}	X_{upper}
Smooth Porcelain-Enamel on Steel	Rep #1	.07	.004		
	Rep #2	.07	.006		
	Rep #3	.08	.006		
	Rep #4	.09	.008		
	Overall	.08	.008	.074	.082
Textured Porcelain-Enamel on Steel	Rep #1	.11	.013		
	Rep #2	.12	.011		
	Rep #3	.14	.008		
	Rep #4	.14	.008		
	Overall	.13	.018	.120	.136
Textured Gel-Coated Fiberglass Reinforced Plastic	Rep #1	.13	.013		
	Rep #2	.13	.018		
	Rep #3	.13	.016		
	Overall	.13	.015	.121	.137
Dot-Pattern Appliques on Smooth Porcelain-Enameled Steel	Rep #1	.23	.021		
	Rep #2	.19	.016		
	Rep #3	.20	.013		
	Overall	.20	.023	.191	.217
Flower-Pattern Appliques on Smooth Porcelain-Enameled Steel	Rep #1	.22	.023		
	Rep #2	.22	.011		
	Rep #3	.23	.019		
	Rep #4	.22	.019		
	Overall	.22	.018	.212	.228

*There are 5 observations in each replication; 15 or 20 observations for each material.

Test Surface	Test Mode	Test Data Identification	Test Load Applied in Grams: 150		237		340		648		952		1249		1563		1876		2187		2488		2801		3115		3425	
			X̄	s	X̄	s	X̄	s	X̄	s	X̄	s	X̄	s	X̄	s	X̄	s	X̄	s	X̄	s	X̄	s	X̄	s	X̄	s
Smooth	Static/	Rep #1	.84	.16	5.08	.75	>6.5	N.A.																				
Porcelain Enamel	Dynamic	Rep #2	2.36	.28	>6.5	N.A.																						
on Steel		Rep #3	2.50	.18	4.98	1.12	6.5	N.A.																				
		Overall	1.90	.80	N.A.	N.A.																						
	Dynamic	Rep #1	6.12	.20	>6.5	N.A.																						
		Rep #2	5.62	.32	>6.5	N.A.																						
		Rep #3	6.5	N.A.																								
		Overall	N.A.	N.A.																								
Textured	Static/	Rep #1	.40	.03	.79	.07	1.96	.39	5.40	.38	6.5	N.A.																
Porcelain Enamel	Dynamic	Rep #2	.20	.03	.41	.03	1.46	.13	5.53	.35	6.5	N.A.																
on Steel		Rep #3	.29	.03	.86	.05	1.24	.32	6.5	N.A.																		
		Overall	.30	.09	.69	.21	1.55	.42	N.A.	N.A.																		
	Dynamic	Rep #1	3.30	.23	3.68	.11	6.05	.03	6.5	N.A.																		
		Rep #2	2.86	.03	5.45	.11	5.92	.23	6.5	N.A.																		
		Rep #3	3.70	.11	4.30	.19	6.5	N.A.																				
		Overall	3.29	.38	4.48	.77	N.A.	N.A.																				
Textured	Static/	Rep #1	.41	.06	1.06	.06	2.28	.38	5.00	.00	6.5	N.A.																
Gel-Coated	Dynamic	Rep #2	.34	.03	1.72	.49	3.28	.26	>6.5	N.A.																		
Fiberglass		Rep #3	.30	.03	1.46	.23	2.82	.11	6.5	N.A.																		
Reinforced Plastic		Overall	.35	.06	1.42	.40	2.79	.49	N.A.	N.A.																		
	Dynamic	Rep #1	3.10	.56	3.81	.10	N.A.	N.A.	>6.5	N.A.																		
		Rep #2	3.45	.07	3.32	.15	3.89	.24	>6.5	N.A.																		
		Rep #3	4.29	.15	5.58	.37	6.12	.12	6.5	N.A.																		
		Overall	3.61	.52	4.24	1.02	N.A.	N.A.	>6.5	N.A.																		
Dot-Pattern	Static/	Rep #1	.16	.03	.20	.03	.28	.03	.49	.08	.74	.05	1.06	.06	1.66	.10	1.94	.32	2.64	.23	3.65	.21	4.58	.46	N.A.	N.A.	>6.5	N.A.
Appliques	Dynamic	Rep #2	.08	.03	.12	.00	.12	.00	.32	.03	.40	.03	.78	.10	1.50	.22	1.98	.30	3.00	.42	5.55	1.20	N.A.	N.A.	>6.5	N.A.		
on Smooth		Rep #3	.12	.00	.12	.00	.20	.03	.38	.00	.62	.00	.95	.07	1.22	.09	1.85	.24	3.00	.34	4.60	.67	>6.5	N.A.				
Porcelain-Enameled Steel		Overall	.12	.04	.15	.04	.20	.07	.40	.08	.59	.15	.93	.14	1.46	.23	1.92	.27	2.88	.36	4.60	1.09	N.A.	N.A.	N.A.	N.A.		
	Dynamic	Rep #1	.75	.00	.88	.00	.78	.06	1.32	.07	1.94	.04	2.02	.16	2.66	.16	3.78	.16	5.10	.27	5.70	.47	>6.5	N.A.				
		Rep #2	.45	.05	.72	.06	.66	.03	1.21	.03	1.85	.08	2.22	.16	3.24	.31	4.82	.42	5.32	.53	N.A.	N.A.	>6.5	N.A.				
		Rep #3	.75	.00	.72	.03	.72	.03	1.51	.05	2.32	.18	2.84	.23	4.59	.30	N.A.	N.A.	>6.5	N.A.								
		Overall	.65	.15	.78	.08	.80	.14	1.35	.14	2.04	.24	2.36	.40	3.50	.87	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.						
Flower Pattern	Static/	Rep #1	.12	.00	.18	.03	.25	.00	N.A.	N.A.	>6.5	N.A.																
Appliques On	Dynamic	Rep #2	.09	.03	.12	.00	.19	.00	N.A.	N.A.	>6.5	N.A.																
Smooth Porcelain-		Rep #3	.08	.03	.14	.03	.35	.03	2.45	1.23	>6.5	N.A.																
Enameled Steel		Overall	.10	.03	.15	.03	.26	.07	N.A.	N.A.																		
	Dynamic	Rep #1	1.29	.03	1.59	.08	2.34	.06	>6.5	N.A.																		
		Rep #2	1.15	.06	1.36	.05	1.98	.11	N.A.	N.A.	>6.5	N.A.																
		Rep #3	1.19	.08	1.56	.11	2.20	.11	5.10	.28	>6.5	N.A.																
		Overall	1.21	.08	1.50	.13	2.17	.18	N.A.	N.A.																		

*Displacement is given in inches. There are 5 observations in each replication; 15 observations for each material at each test load.

4. DISCUSSION

4.1 Discussion of Data

The discussion of the results focuses on the ability of the two testers to discriminate between different test materials. For the NBS-Brungraber tester, a statistical *q*-test was selected.[4] This technique is used to show whether the test procedure can detect differences among the materials. The data from the Kollsman tester were not suitable for the application of this technique.

The average results from the NBS-Brungraber tester are plotted in figure 4, along with the 95 percent confidence interval. In this figure, the data is reported for the materials in the order of increasing slip-resistance: smooth porcelain-enamel, textured porcelain-enamel, gel-coated FRP (textured), dot-pattern appliques, and flower-pattern appliques.

The results of a *q*-test, indicating statistical differences between test materials, are provided in table 3. Fifteen measurements were used in the calculations for all materials; 5 observations were selected randomly to be discarded for materials having 20 measurements. The results of the *q*-test ($\alpha = 0.05$) indicate that, with respect to slip-resistance, the two manufactured, textured surfaces are not significantly different; and that the two applique treatments are also not different. Figure 4 also illustrates the similarity of these types of materials. The *q*-test demonstrates that the NBS-Brungraber tester can discriminate, on the basis of slip-resistance, between smooth and textured surfaces and between manufactured, textured surfaces and applique treatments.

In figure 5, the data from the Kollsman tester are plotted in the same order as in figure 4. For the Kollsman tester, load at which slip

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[4] Natrella, M. G. Experimental Statistics, National Bureau of Standards Handbook 91, 1963

Table 3. q - TEST FOR NBS-BRUNGRABER TESTER DATA

	Group 1	Group 2	Group 3	Group 4	Group 5
	Smooth, Porcelained Enamel	Textured, Porcelained Enamel	Textured, Gel-coated FRP	Dot-Pattern Appliques	Flower-Pattern Appliques
n_i	15	15	15	15	15
$\overline{X}_i$	0.078	0.125	0.129	0.203	0.221
s_i^2	0.00007	0.00036	0.00021	0.00055	0.00034

$$s_e^2 = \frac{\sum_{i=1}^{t} s_i^2}{t} = 0.00031 \ ; \ t = \text{Number of groups} = 5$$

$$s_e = 0.01749$$

$$\upsilon = \sum_{i=1}^{t} n_i - t = 70 \ ; \ n_i = 15 \text{ for all } i = n$$

$$q_{1-\alpha}(t,\upsilon) = 3.97 \ ; \ \text{for } \alpha = 0.05$$

$$\omega = \frac{q\, s_e}{\sqrt{n}} = 0.0179$$

$\overline{X}_1 - \overline{X}_2 = 0.047 > \omega$; thus averages differ.

$\overline{X}_1 - \overline{X}_3 = 0.015 > \omega$; thus averages differ.

$\overline{X}_1 - \overline{X}_4 = 0.125 > \omega$; thus averages differ.

$\overline{X}_1 - \overline{X}_5 = 0.143 > \omega$; thus averages differ.

$\overline{X}_2 - \overline{X}_3 = 0.004 < \omega$; thus averages do not differ.

$\overline{X}_2 - \overline{X}_4 = 0.078 > \omega$; thus averages differ.

$\overline{X}_2 - \overline{X}_5 = 0.096 > \omega$; thus averages differ.

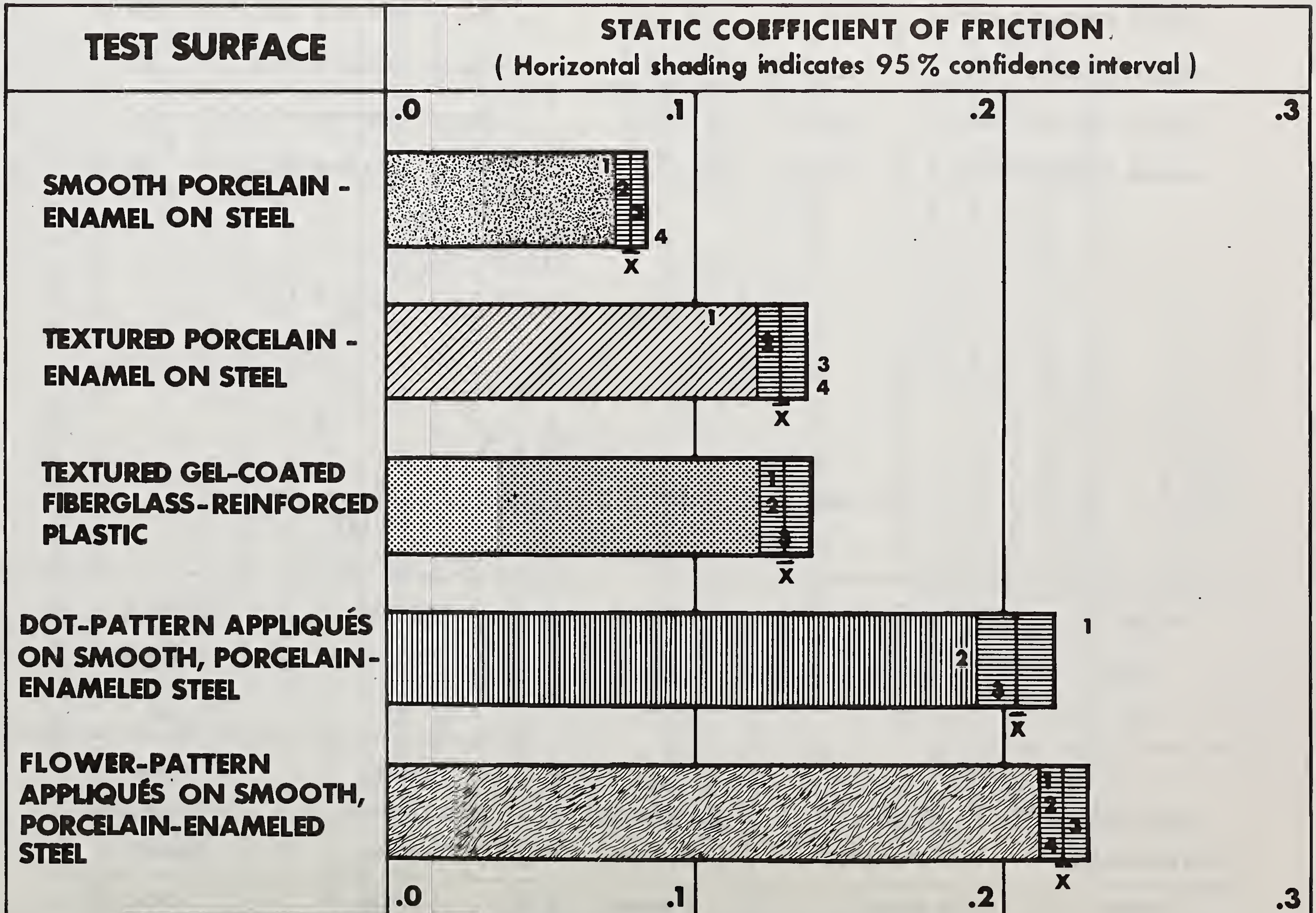
$\overline{X}_3 - \overline{X}_4 = 0.074 > \omega$; thus averages differ.

$\overline{X}_3 - \overline{X}_5 = 0.092 > \omega$; thus averages differ.

$\overline{X}_4 - \overline{X}_5 = 0.018 = \omega$; thus averages do not differ.

Figure 4

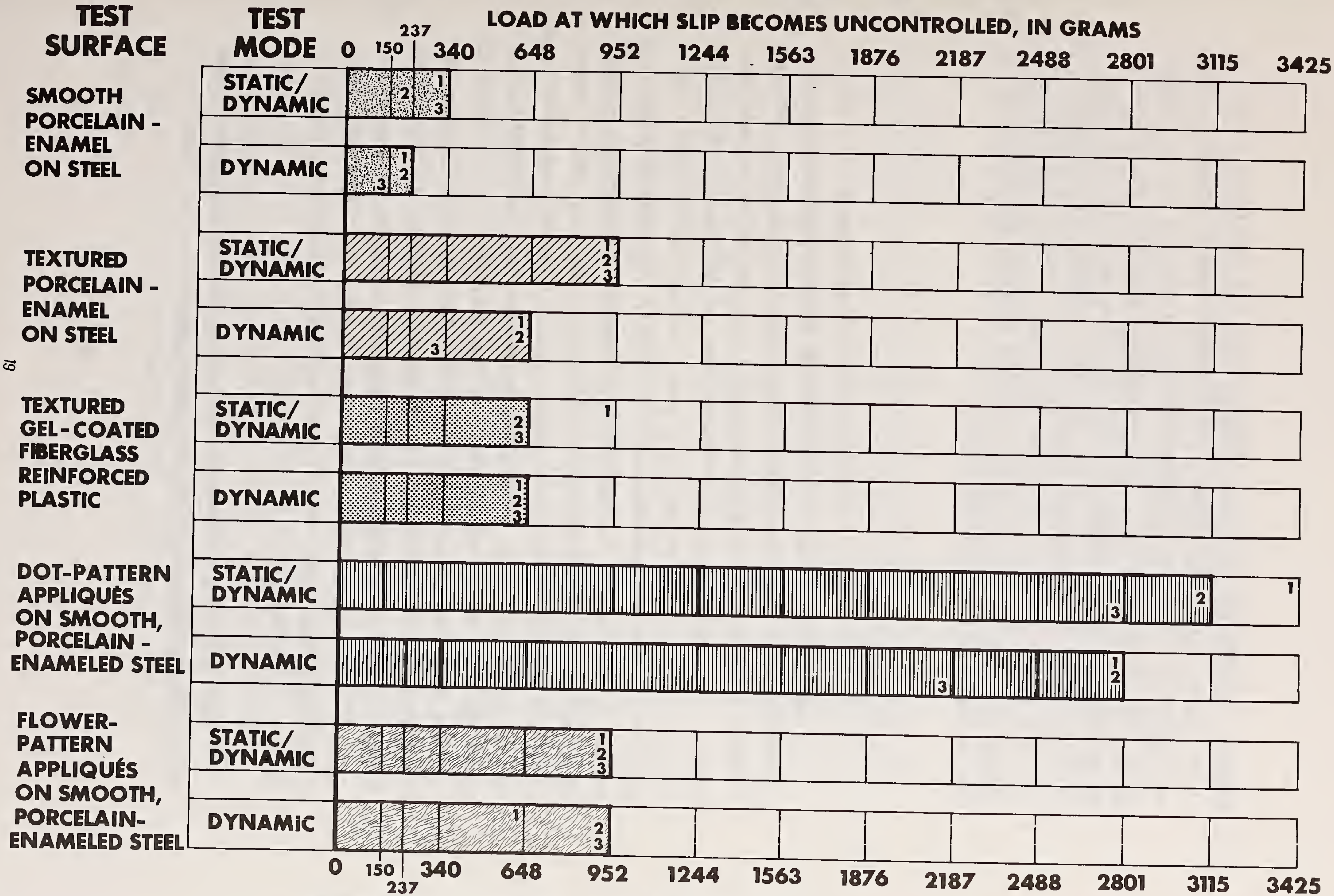
NBS - BRUNGRABER TESTER RESULTS - STATIC COEFFICIENT OF FRICTION AS AN INDICATOR OF SLIP - RESISTANCE



NOTE : 1. Data was plotted to three significant figures and rounded for use in table 1.

2. The numbers locate the average static coefficient of friction for each replicate.

KOLLSMAN TESTER RESULTS - FORCE INDUCING UNCONTROLLED SLIP AS AN INDICATOR OF SLIP-RESISTANCE



The numbers locate the average load at which uncontrolled slip occurred for each replicate becomes uncontrolled, which is related to dynamic friction, is used as an indicator of slip-resistance. The Kollsman tester produces a rank-order different from the NBS-Brungraber tester only in its assessment of the dot-pattern applique. The dot-pattern applique required about three times the test load required by any other material to attain uncontrolled slip. It should be noted that both operating modes of the Kollsman tester result in the same rank-order. The Kollsman tester also showed that the two manufactured, textured surfaces had approximately the same slip-resistance characteristics.

4.2 Discussion of the Two Testers

A review of the results shown for the most slippery surface, the smooth porcelain-enamel on steel, reveal that, for low values of coefficient of friction, the NBS-Brungraber tester yields relatively high results. The reported value of coefficient of friction, 0.08, would indicate that slip would not occur on an inclined surface until the angle of inclination had exceeded 4°. Such an angle of inclination is greater than reported, but unpublished, research observations made by other members of ASTM Committee F15.03. This indicates that in order to achieve acceptable accuracy for small values of coefficient of friction such as those that occur on soapy bathroom surfaces, the NBS-Brungraber tester must be calibrated against a reliable standard. Such a standard has been developed by obtaining a low friction, ball-bearing shoe for the NBS-Brungraber tester and then simulating variable friction forces by using standard weights to apply a known lateral force to the shoe. The ratio of simulated friction force to the known normal force developed by the Brungraber tester results in a reliable standard for static coefficient of friction.

There are three fundamental differences in the operation of the NBS-Brungraber tester and the Kollsman tester:

1. The NBS-Brungraber tester makes a direct measurement of a fundamental property of the foot-floor interaction, the static coefficient of friction. The Kollsman tester is a mechanical analog that compares the performance of different bathroom surfaces in a way that involves the dynamic coefficient of friction. In fact, if you define dynamic coefficient of friction as the ratio of lateral force to normal force when uncontrolled slip occurs, the Kollsman tester can be used to approximate the value of the dynamic coefficient of friction.

2. The NBS-Brungraber tester employs the movement of a trigger to establish when slip has occured or when the static coefficient of friction has been reached. Although there is no statement to this effect in the instructions supplied with the Kollsman tester, it appears that uncontrolled slip is considered to have occurred and the dynamic coefficient of friction exceeded when the carriage goes to the end of its travel, greater than 6 1/2 inches.

3. The NBS-Brungraber tester employs a variably inclined strut to apply a continuously increasing lateral force. The tangent of the angle of this strut at the beginning of slip is the static coefficient of friction. Thus, the static coefficient of friction as measured by the NBS-Brungraber tester is a continuous variable that can be recorded to any calibrated degree of precision. In view of the variability of conditions likely to be met in the field, the scale of the Brungraber tester is graduated in divisions of 0.05 units of coefficient of friction so values can be conveniently interpolated to the nearest 0.01 units. The Kollsman tester employs a lateral activating force that is increased in units of approximately 300 gms or 0.67 lbs so that, considering that the normal force is approximately 25 lbs, the ratio of horizontal to vertical force can be determined. However, in view of the fact that the carriage is not known to be moving at a constant velocity, there is no assurance that such a ratio would be the dynamic coefficient of friction.

4.3 Checklist for Evaluation of a Tester for Determining Slip-Resistance of Bathtub and Shower Base Surfaces

Based on a study of a variety of slip-resistance testers and the general problem of slip-resistance of walkway and bath surfaces, a checklist suitable for evaluating such testers, has been devised. This checklist, presented as table 4, is used to compare the two testers in question.

5. CONCLUSIONS

The test program and subsequent data analysis affords the following conclusions concerning the NBS-Brungraber and Kollsman testers:

1. With one exception, the dot-pattern applique, both testers rank the materials in the same order according to slip-resistance.

2. Both the dynamic and static/dynamic modes of the Kollsman tester rank the materials in the same order.

3. Both testers are sufficiently sensitive to discriminate between the various materials on the basis of slip-resistance.

4. The NBS-Brungraber tester is considered easier to use than the Kollsman tester in that it requires less time to conduct a test and less continual clean-up and maintenance.

5. The NBS-Brungraber tester directly measures static coefficient of friction, a fundamental property related to the slip resistance of walking surfaces. The Kollsman tester demonstrates the relative slip-resistance of surface materials in a dynamic situation but does not currently measure a fundamental property related directly to slip-resistance.

TABLE 4

CHECKLIST FOR EVALUATION OF
A TESTER FOR DETERMINING
SLIP-RESISTANCE OF BATHTUB AND SHOWER BASE SURFACES

Requirement	NBS-Brungraber Tester	Kollsman Tester
The tester measures a fundamental, interpretable property, eg., coefficient of friction	yes	not directly
The tester is capable of using an actual tub or shower base as a sample	yes	no
The tester is capable of discriminating between different surfaces	yes	yes
The tester is easily transportable	yes	yes
The tester is convenient to use	The tester is a permanent assembly having only two easily removable parts	The tester is an assembly consisting of numerous easily separable parts
The tester is easily adjusted and serviced	yes	yes
The tester employs a sensing surface that acceptably resembles human skin	yes	yes
The vital parts of the tester (bearings and operating surfaces) are free from contamination by water or soap solution	yes	no
The data is capable of being readily treated statistically	yes	no
The tester is capable of considering both static and dynamic effects	Static only	Dynamic (as evaluated) Static (with the introduction of additional techniques)
The time for conducting a test is relatively brief	Less than five minutes (regardless of the material tested)	Five minutes to 30 min. (depending upon the material being tested, smooth materials take the least time)
The tester measures in SI units	yes (nondimensional parameter)	no (could be so modified)
The tester is available and at a reasonable cost	Two samples of the tester are presently available and a third is being made. Additional examples could be delivered within eight weeks of order at an estimated cost of $3,000	A pilot model of this tester is presently available; cost and delivery information for finished examples is not known
The operating procedure is available and capable of being followed by a representative technician	yes	The operating procedure is available but in need of refinement

6. RECOMMENDATIONS

Based on the present study, the following items are recommended for further study:

1. Representative levels of soap concentration occurring in bathing situations should be determined. It may be found that lower concentrations of soap could and should be used. This might make the test conditions less slippery so that any tester could more readily discriminate between different surfaces. It might also lessen the tendency for the soap solution to precipitate out and gel as the temperature is lowered and thus permit tests to be conducted more nearly at room temperature. These determinations should probably concentrate on soaps meeting ASTM D499-69 specifications, since these are currently the most popular bath soaps.

2. The need for distilled water for soaking specimens and for making the soap solution should be evaluated. If deionized water or water of controlled hardness would be satisfactory, this would considerably reduce the cost of any test program.

3. The need for including dynamic effects should be studied by evaluating actual accident situations.

4. Other ways of including dynamic effects, that would meet more of the criteria of the checklist, should be sought.

5. The quest for a suitable material to use as a sensor to simulate human skin should be continued. For the present, slunk is recommended; but with the knowledge that it has shortcomings and is, therefore, not the ideal material for this purpose.

7. SI CONVERSION UNITS

In view of present accepted practice in this technological area, primarily U.S. customary units of measurement have been used in this report. It should be noted that the U.S. is a signatory to the General Conference on Weights and Measures which gave official status to the International System of Units (SI) in 1960. Readers interested in making use of the coherent system of SI units will find conversion factors in ASTM Standard Metric Practice Guide, ASTM Designation E380-72 (Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103). Conversion factors for units used in this paper are:

Length:

1 in = 2.54 cm

1 ft = 30.480 cm

Area:

1 sq in = 6.451 sq cm

Weight:

1 lb = 453.00 g

Temperature:

°C = 5/9 (Temperature °F - 32)

PROGRAM PROPOSAL

Task Group #1 on Slip Resistance wishes to propose the following program to the CPSC. This program is to evaluate the Brungraber and Kollsman Slip Resistance Testers.

Work to be performed at NBS (Building Safety Section, Center for Building Technology) with the following guide lines:

A. Program to be set up statistically by NBS to provide test values at a 95% confidence level.

B. Test Condition wet at standard laboratory atmosphere (72°F - 60% R.H.) using the following two test solutions:

(1) Distilled water

(2) 10% soap solution (by weight) using distilled water and soap defined in ANSI Spec. Z124 on Plastic Bath Tubs.

C. Skin used in both the testing machines to be of the same material (animal skin - goat, cowhide, etc.) but should be 0.015 to 0.020 inches thick and transluscent. Smooth side of skin to be contact surface.

D. Test surfaces to be supplied to NBS by manufacturers. The following surfaces to be used:

(1) Porcelain Steel - Smooth & Textured - Peerless Pottery
(2) Porcelain Cast Iron - Smooth & Textured - American Standard
(3) Post Coated SMC - Smooth - Owens Corning Fiberglas
(4) SMC (uncoated) - Smooth & Textured - OCF
(5) Gel Coated FRP - Smooth - Snyder Industries
(6) Gel Coated FRP - Textured - Universal Rundle
(7) Acrylic - Smooth - Powers Fiat
(8) Acrylic - Textured - Powers Fiat
(9) Kollsman Applique - Al Shaines
(10) 3M Applique - Al Shaines
(11) Rubber Maid Applique - Al Shaines
(12) Porcelain Steel - Smooth - Verson Home Products

Panel size 12" x 30" to be shipped as soon as feasible after acceptance of Program. Applique to be applied by NBS to smooth Porcelain Steel Panel.

Final selection of test machine will be made by Task Group after reviewing test results. Additional tests on selected surfaces may be made after reviewing data and at the discretion of the Task Group, if further clarification is required.

In order to meet the time table set up by Task Group #1, the results from this program must be available for the July 16th meeting.

Task Group #1

W. C. Krieger
Vice Chairman

PROGRAM PROPOSAL - Revised 7/16/75

The original proposal, reported in the June 1975 meeting minutes, was revised after being reviewed by NBS and Task Group 1. The revised proposal will have two phases -- Phase I - Evaluation of the Brungraber and Kollsman Slip Resistance Testers and Phase II - Material Evaluation using the results from Phase I.

Phase I to be performed at NBS (Building Safety Section, Center for Building Technology) will be conducted along the following guidelines:

A. Program to be set up statistically by NBS to provide test results at a 95% confidence level.

B. Ten replicates per test will be used in all tests.

C. Test will be conducted at ambient temperature and humidity.

D. Skin used on all tests to be same. NBS to make selections.

   (1) Skin to be soaked in distilled water for 24 hours prior to use.

   (2) Same amount of soap to be used in all tests.

   (3) Soap to be applied to wet skin rubbed in for 5 to 15 seconds.

   (4) Test surface to be wet with soap solution and then rinsed off with distilled water before test. (Rinsed or left on at discretion of NBS).

E. Soap Solution to be used - 10% (by weight) Ivory Flakes and Distilled water stored in plastic tub or container to prevent contact with air, maintained at 100°F.

F. Test surfaces to be supplied by manufacturers are as follows:

(1)	Porcelain Cast Iron - Smooth	3 pcs.	(2' x 3')	Eljer Plumbingware
(2)	Porcelain Cast Iron - Textured	1 pc.	(2' x 3')	Eljer Plumbingware
(3)	Gel Coated FRP - Textured	1 pc.	(2' x 3')	Universal Rundle
(4)	Kollsman dot-patterned applique applied to smooth cast iron			Kollsman
(5)	Rubbermaid flower-patterned applique applied to smooth cast iron			Rubbermaid

Total Number of specimens needed for Kollsman tester in the 6" x 13" size are as follows: three (3) smooth porcelain cast iron, one (1) textured porcelain cast iron, and one (1) gel coated FRP.

G. Address for Shipping

Dr. R. J. Brungraber
National Bureau of Standards
Quince Orchard Road
Gaithersburg, Maryland 20760

Address for Mail:

Dr. R. J. Brungraber
Room B362
Building 226
Washington, D.C. 20234

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

APPENDIX C

August 8, 1975

MEMORANDUM TO: Members of Committee F15.03

FROM: R. J. Brungraber, Building Safety Section

R.E.: Program Proposal - Revised 7/16/75

The tests are currently being conducted with some necessary modification in test procedure that should be noted. These will be noted with reference to the above referenced proposal.

A. Although the specifications that the test results be at a 95% confidence level is incomplete without also stating a desired band-width or data tolerance, sufficient replications are being made so that S, the standard deviation of the sample, can be expected to be an unbiased estimator of at least 95% of the standard deviation of the population.

B. Based on preliminary tests conducted with both testers, it was found that good repeatability could be achieved by making five repeat tests on a given sample without removing it from the tester or resoaping it. Thus the procedure was changed to:

1) Soak the sample and skin covered sensor in distilled water at 100 ± 10°F for 15 seconds or more.

2) Place the sample in the carriage of the Kollsman tester or on the floor for the Brungraber tester and install the skin covered sensor on the appropriate tester.

3) Apply the 10% soap solution at 100 ± 10F to both the sensor and the sample.

4) Conduct five repeat tests as quickly as possible generally in a few seconds.

5) Wash soap from the specimen and return it to the water bath until all tests have been completed on the other four specimens and then repeat steps one through four two or more times. This provides three replications, fifteen observations.

C. This being monitored and recorded to ± 2°F and ± 2% R.H.

D. The skin selected was identified as kip, suitable for the "transparent snare side of a snare drum. A sensor covering for each of the testers was cut from the same skin and used throughout the test program.

1) It was found that soaking in distilled water at 100 ± 10°F for at least 15 minutes was sufficient to soften the skins.

4) Upon removal from the water bath both the skin covered sensor and the specimen had the soap solution applied and rubbed in for 5 to 15 seconds. After each series of five tests, the skin and specimen were both rinsed or wiped free of soap and returned to soak in the water (warm) bath until the next series of five tests.

E. The soap solution was stored in a plastic wash bottle at 100 ± 10°F.

F. At the time of writing of this memo, August 8, 1975, the cast iron specimens had not yet been received so that substitute steel specimens, both smooth and textured, were used.

A complete description of the test procedure will be included in the test report.

APPENDIX D

INSTRUCTIONS FOR THE OPERATION OF THE NBS-BRUNGRABER PORTABLE SLIP-RESISTANCE TESTER

Description of Components (Referring to Figure 3)

A. Main frame
B. Travel bars
C. Carriage
D. Linear splined shaft
E. Articulated shaft
F. Recording shaft with magnet
G. Recorder clamp
H. Trigger
I. Sensor shoe, with magnetic strip for retention of sensor facing clip, Q
J. Weight
K. Handle
L. Retainer plate
M. Control springs
N. Shock absorber
O. Attraction plate for magnet
P. Adjustable stop for shock absorber
Q. Sensor facing clip (not shown)
R. Initial position stop (not shown)

Principal of Operation

The NBS-Brungraber portable slip-resistance tester is designed to measure the static coefficient of friction between a representative sample of shoe sole material, such as leather, and a flooring surface; under true field conditions. It does this by applying a predetermined vertical force, (the weights, J) through a vertical splined shaft, D, and an articulated shaft, E, to the sensor shoe, I.

At the start of a test the carriage, C, is brought forward to a stop position such that the articulated shaft is not vertical but set at a slight angle towards the back of the tester (approximately equivalent to a tangent or coefficient of friction of 0.1). This establishes an unbalanced lateral force against the carriage. At the instant that the handle, K, is released and the vertical load is applied, the carriage begins to move back along the travel bars, B, inducing an increasing lateral load on the shoe as the angle between the articulated shaft and the vertical increases. The tangent of this angle at the moment that slip occurs is the static coefficient of friction. This angle is measured by the recording shaft, F, which is magnetized and drawn along by attachment of the attraction plate, O, as the carriage moves backwards. When slip occurs, the shoe sole, I, hits the trigger, H, so that the recorder

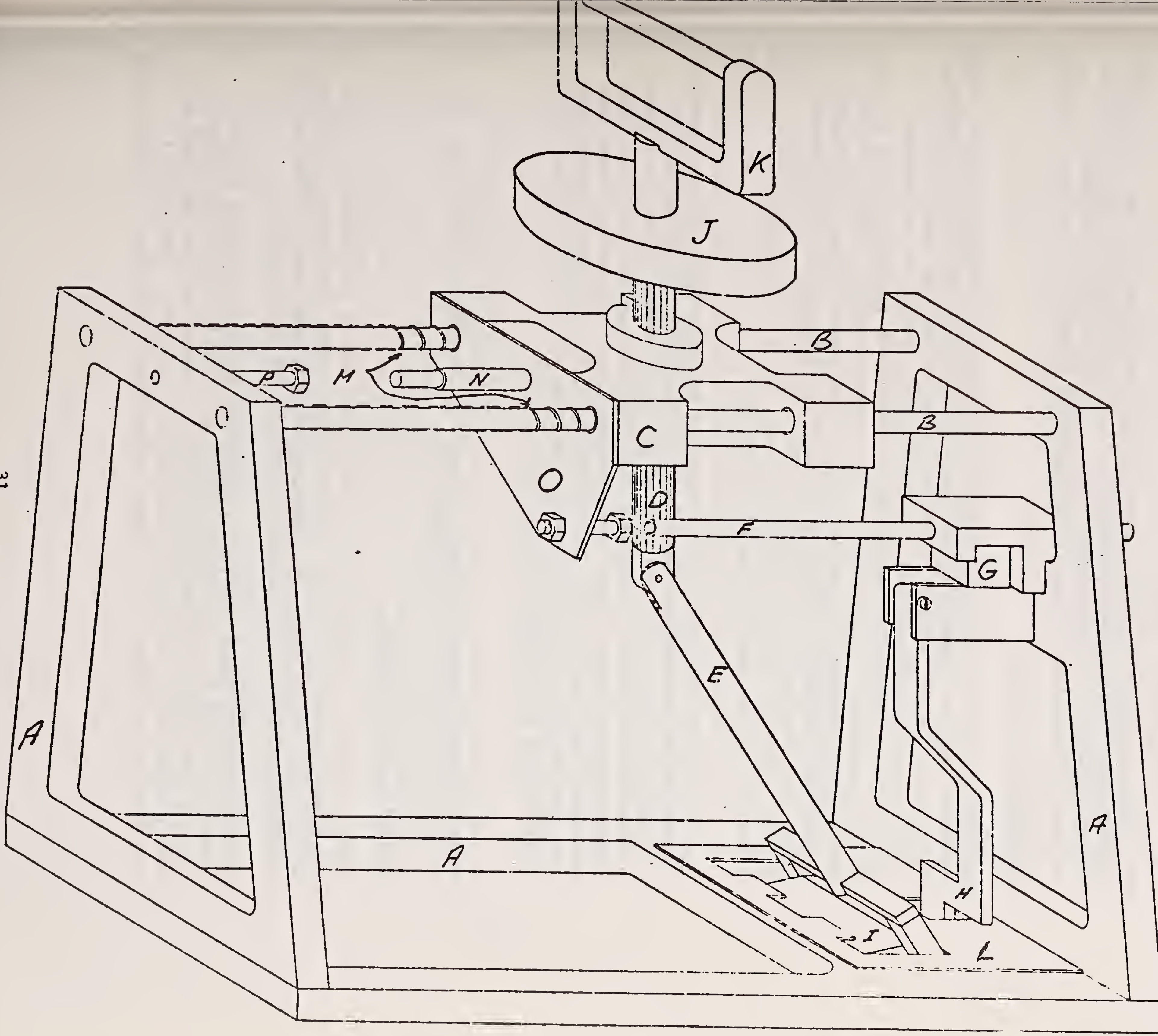


FIGURE 3.

NBS-Brungraber Tester

clamp, G, grips the recording shaft, F, retaining the shaft in its position at the time of slip. The value of coefficient of friction (tangent of the angle of the articulated shaft with the vertical) is read at the front end of a short piece of transparent tubing protruding from the front of the recorder clamp from a graduated scale imprinted along the length of the recorder shaft.

The motion of the carriage is controlled by the springs, M, and the shock absorber, O, which contacts an adjustable stop, P, attached to the main support frame, A. The retaining plate, L, helps to keep the shoe in position while the tester is being lifted and moved to a new test location.

Preparation for a Test

In order to obtain consistent results with any slip-resistant tester, it is essential that the sensor facing be maintained in a consistent condition. This is done on the Brungraber tester by unclipping the sensor facing clip, Q, from the shoe, I, so that the facing surface can be stroked four times in each of two perpendicular directions against a sheet of 400 grit sandpaper held against a flat, uniform surface. This must be done at least before each series of tests for a given floor surface and a given test condition. In the event that lack of repeatability demonstrates that the facing is picking up wax, dirt or other extraneous material from the surface being evaluated, it may be necessary to resurface or recondition the shoe facing more frequently.

The floor surface should be in a condition representative of the service conditions to be evaluated; waxed or bare, buffed or unbuffed, wet or dry, dirty or clean, etc. An area large enough to permit at least three independent tests must be selected such that the service conditions are uniform over the entire area. The NBS-Brungraber tester is a sensitive instrument and inconsistency or nonrepeatability of results demonstrates that either the floor surface being tested is not uniform or else the sensor facing is picking up extraneous material.

If a wet floor surface is to be tested, the sensor facing should be soaked in water before the test to simulate the likely condition of the shoe sole or heel on a wet and rainy day.

Operation of the Tester

Before starting a series of tests the tester should be checked for free and proper movement of all of the parts and proper adjustment of the trigger, H. In the event the tester appears to have been knocked out of adjustment, refer to the section of service and adjustment.

With the sensor facing properly conditioned and in place, the entire tester is lifted by means of the handle so that the weight is lifted, and the shoe lifted, releasing the trigger, permitting the carriage and the recorder shaft to return to the initial position. Care should be taken not to force the carriage forward before the shoe is lifted clear of the floor permitting the release of the trigger, as this will cause the forced movement of the recorder shaft through the clamped recorder clamp, causing excessive wear of the recorder clamp and recorder shaft. A convenient way to assure the release of the trigger is to push the shoe back to its starting position with one hand while lifting the tester by the handle with the other hand. With the tester suspended from the hand, it is gently placed on the floor surface to be evaluated and the handle immediately released. The tester is self-activating and as soon as the carriage comes to rest against the shock absorber, the reading can be made on the recorder shaft at the front of the recorder clamp. The recorder shaft is graduated in divisions of 0.05 units of coefficient of friction* and thus the reading can easily be interpolated to the nearest 0.01 unit of coefficient of friction. The procedure may now be repeated for the next test.

*Note: Coefficient of friction just as the tangent of an angle is a ratio and thus, strictly speaking, has no units or dimension.

Service and Adjustments

The Brungraber tester is a fairly simple and rugged device and should require very little maintenance; however, the following information may be of help:

1) The proper vertical and rotational alignment of the splined and articulated shafts is essential to the correct operation of the tester. This alignment can be checked by visually noting the orientation of the sensor shoe with respect to the hole in the base plate. There is supposed to be a modest amount of free rotational play of the splined and articulated shafts and when the sensor shoe is in the center of the travel permitted by this play it should also be in the center of the lateral dimension of the hole in the base plate and the front and rear edges respectively, of the hole in the base plate. If this is not the case, first check for possible bending of the articulated shaft, which is unlikely unless the tester has been severely abused.

   If there is misalignment that is not caused by bending of the shafts and other parts, this can be corrected by rotating the splined linear ball bushing with respect to the carriage in which it is supported. This can be done by first loosening the four Allen set screws, one in each face of the carriage.

2) The trigger, H, lifts the recorder clamp, G, by means of an adjustable screw in the upper portion of the trigger. There are four light coil springs controlling the motion of the recorder clamp so that the "free" motion of the trigger meets a slight resistance. When the shoe is in the initial or rearward position this "free" travel of the trigger should be in the range of 1/16 in to 1/8 in. In

the event these limits are exceeded, the amount of free travel can be controlled by the previously mentioned adjustment screw. A convenient way of determining the free travel of the trigger is to observe the resulting free travel of the recorder clamp.

3) The recorder shaft should be lubricated with silicone spray and checked for free movement after prolonged storage (1 week or more). From time to time there may be enough dirt accumulation on the recorder shaft as to make it difficult to read the graduations. In this event the shaft should be wiped with a clean cloth or napkin and relubricated.

4) It may be necessary to adjust the shock absorber so that the carriage is free to travel its full stroke while at the same time it does not induce a shock at the end of its travel. This adjustment is effected by turning the screw in the end of the shock absorber with either a screw driver or a small wrench.

5) When carrying the tester for a considerable distance, it may be found desirable to remove the handle and weights so that they can be carried in one hand and the rest of the tester in the other. Another convenient and satisfactory way to carry the tester is to first pick up the tester by the handle, thus fully withdrawing the splined shaft, and then grasping the splined shaft just below the weights. This suspends the tester so that it clears the floor with the arm in a fully extended and thus more comfortable position.

ADDENDUM

TO THE OPERATING PROCEDURE

FOR THE NBS-BRUNGRABER SLIP-RESISTANCE TESTER

Modification of the Tester to Accommodate the Simulated Human Skin

In order to attach the piece of "slunk" to the NBS-Brungraber tester, a slightly modified clip-shoe combination must be fitted. The clip has full width up-turned portions at the front and the rear rather than the trigger-tripper at the front and the two hooks at the rear, that the standard clip has. The up-turned portion at the rear accommodates a brass retainer that holds one end of the skin to the clip. The other end of the skin is brought down over the closed-cell neoprene sponge, that has been glued to the bottom of the clip, and up over the up-turned portion of the front of the clip. The leather is then retained at the front by a heavier brass clip-angle, secured with two small machine screws. The brass clip-angle also incorporates a trigger-tripper similar to that which is part of the standard clip.

In order to accommodate the modified clip, a slightly modified shoe must also be fitted. The major modification is that the magnetic strip extends only to within 3/8 in of the front of the shoe, leaving space to accommodate the heavy brass clip-angle on the front of the clip. After the skin is properly installed on the clip and the modified shoe installed on the tester, the clip should be fitted to the shoe and the trigger adjusted to provide 1/16 - 1/8 in of free travel before the clutch is activated.

APPENDIX E

THE KOLLSMAN TEST FOR BATHTUB SLIP-RESISTANCE

The Kollsman test for evaluating the slip-resistance of various bathtub materials is essentially a mechanical analog of the human forces and movements under the conditions in which slipping occurs in a bathtub.

Slipping and the concomitant loss of balance and falling usually occur when a) the surface of either the bottom of the foot or the bathtub is soapy or oily and b) the bather is in the process of moving his foot from one position to another. This can occur when he is either moving the foot forward in a standing position or when he is to stand up from a sitting position. In the act of making either of these movements, the bottom of his foot comes into contact with a soapy, oily film on the surface of the bathtub.

During the initial stages of these movements very little force or weight is applied to the moving foot, almost all of the body weight being taken up by the other foot (in the standing position) or by the other parts of the body (in the sitting position).

The weight on the moving or adjusting foot is never applied vertically down, but at some angle to the normal, giving it a horizontal as well as a vertical component.

There is a very little resistance to the horizontal component since the coefficient of friction between the bottom of the foot and the soapy film is very low. The foot will therefore slip at an accelerated rate unless the vertical force can be applied in such a way as to break through the film and bring the foot into contact with the bathtub material itself with which it often has a much higher coefficient of friction, or until the film of soapy liquid has been squeezed thin enough to produce viscous drag.

It is estimated that a man or woman will put about 15% of his or her body weight on the moving foot. For an average man weighing 180 pounds this is 26 pounds and for an average woman weighing 113 pounds this is 17 pounds.

If the angle the foot or leg makes with the normal in moving from one position to another is as little as 10°, then the vertical force applied by the average man would be 25 pounds and the horizontal force 7.33 pounds. In the case of a woman the vertical force would be 15 pounds and the horizontal force 7.33 pounds. If the angle is greater than 10° as it normally is, the horizontal force would be proportionately greater.

It is further estimated that if the bather starts to slip, his or her foot will move across the bathtub surface at about 2 feet per second.

The effectiveness of a bathing surface in preventing slipping can best be determined by simulating the human slipping action and this in turn can be done by applying the forces, angles and velocities cited above to a soapy or oily bathtub surface.

The Kollsman Test Equipment does just this. It applies a vertical force to a 2 3/4-in diameter x 3/16-in thick soft neoprene closed cell sponge covered with an animal skin which has about the same texture and hydrophilic properties as human skin. At some fixed but controlled period of time preceding the application of the vertical force, the bathtub surface is moved forward by the application of a horizontal force, the relationship between the two forces being such as to define the angle of the "moving" foot and the forces themselves defining the weight applied. The forward velocity of the "moving" foot is controlled by the horizontal force applied to the bathtub surface before the "foot" makes contact with it.

The effectiveness of the surface in preventing slipping is determined by the distance the surface moves before it is stopped by the application of the vertical force.

The Kollsman Test Equipment is shown diagramatically in the attached figure. The equipment is made up of a base (25), a post (26) on which a beam (27) is pivoted at point (28). The beam carries a pad (29) which is 3 inches in diameter and is made up of a neoprene rubber sponge covered with beef skin epidermis 0.01 - 0.04-in thick when dry. The pad is mounted on the beam by means of spindle (30) and nut (31) so that its height can be adjusted.

The beam is mounted above a carriage (32) which can move horizontally along the base by means of rollers (33). The carriage supports and carries a piece of the bathtub surface to be tested (34) which rests against the rear shoulder (35) of the carriage. The carriage has a cord (36) attached to it which passes over a pulley (37) having a weight carrier (38) attached to its other end. The carrier is loaded with stackable disc type weights (39), thereby producing a predetermined pull on the carriage.

The beam carries a weight (46) which serves to place a load on the pad (29). The beam is raised slightly so that the pad is positioned above the test piece 1/8 - 1/4 in by means of a cam (41) which is operated by a lever (45).

The cam and lever arrangement are so constructed that they can operate in either one of two ways:

1. The cord (36) can be released and the beam dropped simultaneously. This would represent a condition in which a person slips from a stationary or static condition. While this is not a normal case, it is possible.

2. The cord (36) can be released <u>before</u> the beam drops. Since the velocity the carriage attains before the pad drops is a function of the distance it travels, the velocity can be controlled by controlling the distance the carriage is permitted to move before the beam is released. If, for example, the carriage moves one inch, it will attain a velocity of about 2 feet per second. This system more nearly represents the conditions most conducive to slipping in a bathing area.

Thus this equipment permits the control of:

1. the vertical force applied to the 'foot'

2. the angle which the foot makes with the normal (the relative vertical and horizontal forces)

3. the horizontal force applied

4. the horizontal velocity of the moving 'foot'

5. the condition of the surface to be tested - soapy, oily, dry, etc.

This equipment, essentially as described, was used to test a number of bathtub surfaces under the following test conditions:

1. the surfaces of both the pad (29) and the surface to be tested (34) were thoroughly wet with an Ivory Liquid Soap solution consisting of one part soap solution and six parts water

2. the pad had a diameter of 3 inches, slightly larger than the heel of the average foot

3. the pad material was beef skin epidermis 0.01 - 0.04-in thick when dry

4. the tests were conducted at room temperature

5. two vertical weights (46) were used, 25 pounds and 15 pounds

6. the pad was always suspended 1/8 - 1/4 in above the test surface

7. the horizontal force (weight on the cord) was 7-1/3 pounds

8. tests were conducted with the carriage released and the weight dropped simultaneously (static) and with the weight dropped after the carriage had moved one inch and had achieved a velocity of 2 feet per second.

The attached table gives the results for nine different surfaces, each tested under these four conditions.

SURFACE	DISTANCE CARRIAGE MOVED AFTER CONTACT			
	25 pound Vert. Force		15 pound Vert. Force	
	SURFACE Stationary on Contact	SURFACE Moving on Contact	SURFACE Stationary on Contact	SURFACE Moving on Contact
1. Rubbermaid Petals Applique (2)	(c)	(c)	(c)	(c)
2. 3M Strips Applique (2 strips 1" apart)	1/4" (a)	(c)	(c)	(c)
3. 3M Strips Applique (full surface covered)	1/2" (a)	5-1/4" (a)	(b)	(b)
4. Contra Slip Applique 3/4" x 0.016"	3/4"	1-5/8"	7/8" (a)	2-1/8" (a)
5. Contra Slip Applique 3/4" x 0.013"	3/4"	2-1/4"	1-1/4"	3-1/4"
6. Molded Gel Coat Dots 3/8" x 0.012"	1/2"	1-1/4"	3/4"	2-5/8"
7. Molded Vinyl Surface Dots 3/8" x 0.012"	1/2"	1-1/8"	1/2"	1-5/8"
8. Glass Sandblasted in Zigzag Pattern	(c)	(c)	(c)	(c)
9. Glass Sandblasted in 1/4" Dots x 0.01"	3/4"	2-3/4"	1-1/2"	7"
10. Ceramic Sandblasted in 1/4" Dots x 0.01"	3/4"	2"	1-3/4"	5-3/4"

Notes:

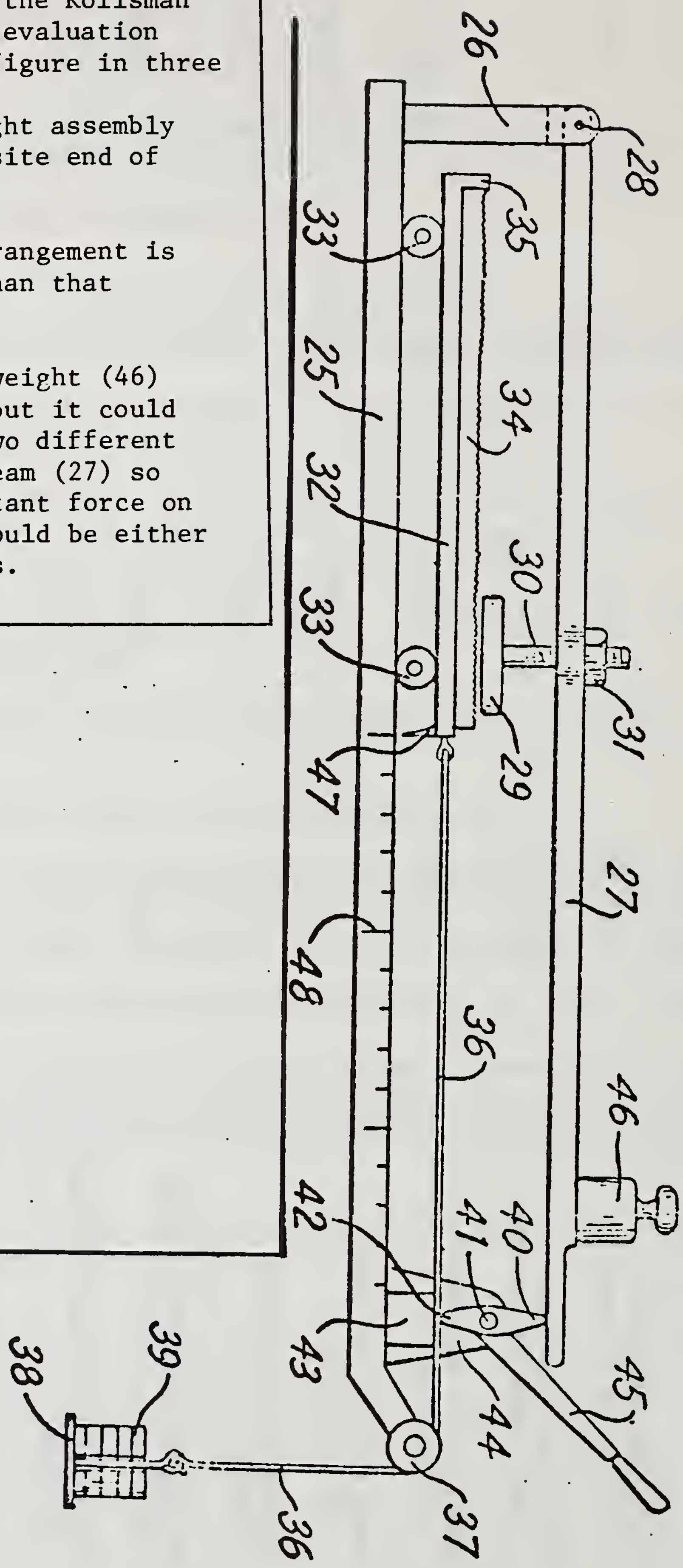
(a) Slides slowly before stopping
(b) Slides slowly but doesn't stop
(c) Slides fast but doesn't stop

NOTE: The model of the Kollsman tester supplied for evaluation differed from this figure in three respects:

(1) The pulley-weight assembly is at the opposite end of the tester.

(2) The trigger arrangement is more complex than that illustrated.

(3) Only a single weight (46) was supplied, but it could be placed at two different locations on beam (27) so that the resultant force on the pad (29) would be either 15 or 25 pounds.



APPENDIX F

Kollsman Apparatus

Operating Instructions

Introduction

The Kollsman Apparatus tests the slip-resistance of bathtub surfaces under three different conditions:

1. Static in which the full vertical force is applied to the foot with no horizontal force for a period of time long enough to squeeze out the soapy film beneath the film and then a horizontal force slowly applied until slippage occurs. This would be the condition of a person standing in a bathtub or shower and leaning over.

2. Static/Dynamic in which the full horizontal force is applied simultaneously with the full vertical force. This condition would exist if a person took a deliberate step forward or perhaps in arising from a sitting position.

3. Dynamic in which the full horizontal force is applied at a given velocity before any vertical force is applied. This condition would exist if a person gingerly stepped into a bathtub or moved from one place to another within the tub.

To limit the extent of the test series and to avoid involvement in a development program for either tester, ASTM Committee F15.03 requested that the Kollsman tester be evaluated in only two of its three possible modes of operation, the choice to be Mr. Kollsman's. Mr. Kollsman selected the Static/Dynamic and the Dynamic modes as the ones to be evaluated.

Operating Procedure

See last page for test procedure amendments.

1.0 Equipment Preparation

1.1 Set the equipment on a table so that the pulley end overhangs the table 3 inches.

1.2 Level the equipment using a spirit level on the base.

1.3 Check the bearings on the 4 wheels and lubricate if necessary. Check the bearing on the release roller on the top of the carriage and lubricate if necessary. Clean the surfaces of all the wheels of any dirt or soap accumulation.

1.4 Condition all skins to be used by placing them in distilled water at 100° ± 10°F for approximately 15 minutes before using.

1.5 Place the neoprene sponge pad on the 3 1/2" diameter circular plate and place a conditioned skin on the pad.

1.6 Draw the skin retaining ring over the skin so that it draws the skin snugly against the neoprene pad so that there is a minimum of air trapped between the skin and the neoprene sponge and so that there is very little skin pinched in the ring opening. Draw the ring down so that its 'bottom' edge is about even with the bottom edge of the 3 1/2" circular plate.

1.7 Place the foot (skin, sponge rubber pad and plate) on the threaded rod which passes through the support plate and lock it in place with the threaded pin provided.

1.8 Wipe the skin with a soft wet cloth or a sponge substantially free of soap.

1.9 Weigh and number each of the weights. There is one 150 gm wt.; subsequent weights, a 36 gm weight and eleven weights of about 300 gms. each, are supported by a T ring support.

2.0 Sample Preparation

2.1 Wash sample with soap and water. Rinse with clean water.

2.2 Immerse sample in warm distilled water at 100 ± 10°F for at least 5 minutes and keep it in the water until it is ready to be tested.

2.3 Fold back the support plate and place the sample on the bed of the carriage.

2.4 Fold the support plate back to its operating position and move the carriage so that the foot is just above the sample.

2.5 Release the foot lock-nut on the top side of the support plate and lower the foot by rotating the knurled knob until the skin touches the top surface of the sample. Rotate the knob an additional 3 1/2 complete turns clockwise so that the foot will press down onto the sample.

3.0 Static Measurements

(Note: The measurements described in this section were not made as part of the test procedure discussed in this report.)

3.1 Apply the 100 gm weight.

3.2 Place the sample to be tested in distilled water maintained at 100 ± 10°F for 15 seconds or more.

3.3 Place the sample on the carriage.

3.4 Wet the skin with distilled water at 100 ± 10°F.

3.5 Sponge the sample surface with the standard soap solution maintained at 100 ± 10°F.

3.6 Move the carriage to the right until the pointer on the carriage is even with the 0 mark on the guage on the base. The release lever should be in the forward position and slide lock pushed back. Hold the carriage in this position.

3.7 Fold the support plate so that the foot comes to rest on the sample. Continue to hold the carriage at the 0 position.

3.8 Place the vertical weight at the 25 pound position. Hold for 2 seconds.

3.9 Release the carriage.

3.10 Record the distance traveled by the carriage before it comes to a stop, describe its travel, e.g. 3 inches quickly, 3 1/2 inches very slowly.

3.11 Remove the vertical weight and fold back the support plate. Wipe the soap off the skin with warm distilled water. Wash the sample by placing it in warm water (100 ± 10°F).

3.12 Repeat steps 3.2 through 3.11 nine more times. If the distance traveled is less than 6 1/2 inches 8 of the 10 times go on to step 3.13. If the distance traveled is equal to or greater than 6 1/2 inches 8 of the 10 times go on to step 4.0.

3.13 Add a second weight to the support rod and repeat steps 3.2 through 3.11 ten times.

3.14 Continue this procedure until either all eleven weights have been added or the distance traveled by the carriage is equal to or greater than 6 1/2 inches for 8 or more times in the 10 tests.

4.0 Static/Dynamic Measurements

4.1 Place the 150 gm weight on the hook provided.

4.2 Place the sample to be tested in distilled water maintained at 100 ± 10°F for 15 seconds or more.

4.3 Place the sample on the carriage.

4.4 Sponge the skin with a 10% soap solution at 100 ± 10°F.

4.5 Sponge the sample surface with the standard 10% soap solution maintained at 100 ± 10°F.

4.6 Move the carriage to the right until the second hole in the rod at the end of the carriage passes through the end plate. Lock the carriage in this position by pushing the metal dowel attached to the metal slide through the second hole.

4.7 Fold over the support plate until it comes to rest on the release roller on the carriage.

4.8 Place the vertical weight at the 25 pound position.

4.9 Release the carriage by rotating the release lever 90°.

4.10 Record the distance traveled.

4.11 Without lifting the support plate or removing the 25 pound weight repeat steps 4.6, 4.9 and 4.10 four more times for a total of 5 tests.

4.12 Remove the vertical weight and fold back the support plate. Wipe the soap off the skin with water. Wash the sample thoroughly with water and place it in warm water at 100 ± 10°F.

4.13 Repeat steps 4.2 through 4.12 four more times. This will give a total of 25 tests at the 150 gm weight. If the distance traveled is less than 6 1/2 inches for 20 of the 25 tests go on to step 4.14. If the distance traveled is equal to or greater than 6 1/2 inches 20 of the 25 times, go on to step 5.0.

4.14 Remove the 150 gm weight. Place the 201 gm weight on the T ring support and place the T ring support on the hook provided.

4.15 Repeat steps 4.2 through 4.12.

4.16 Repeat steps 4.2 through 4.12 four more times with the 201 gm weight. This will give a total of 25 tests with the 201 gm weight. If the distance traveled is less than 6 1/2 inches for 20 of the 25 tests go on to step 4.17. If the distance traveled is equal to or greater than 6 1/2 inches for 20 of the 25 tests, go on to 5.0.

4.17 Remove the 201 gm weight. Place one of the eleven 300 gm weights on the T ring support and place the T ring support on the hook provided.

4.18 Repeat steps 4.2 through 4.12.

4.19 Repeat steps 4.2 through 4.12 four more times with the 300 gm weight. This will give a total of 25 tests with the 300 gm weight. If the distance traveled is less than 6 1/2 inches for 20 of the 25 tests go on to step 4.20. If the distance traveled is equal to or greater than 6 1/2 inches for 20 of the 25 tests go on to 5.0.

4.20 Add a second 300 gm weight to the T ring support for a total of 600 gms.

4.21 Repeat steps 4.2 through 4.12.

4.22 Repeat steps 4.2 through 4.12 four more times.

4.23 Continue this procedure of adding 300 gm weights to the T ring support and carrying out 25 tests with each weight in the manner described until either all 11 weights have been added or the distance traveled by the carriage is equal to or greater than 6 1/2 inches for 20 of the 25 tests at a given weight.

5.0 Dynamic Measurements

Note: The preparation and introduction of specimens for the dynamic tests is to be the same as for the static/dynamic tests.

5.1 Place the 150 gm weight on the hook provided.

5.2 Place the sample to be tested in distilled water maintained at 100 ± 10°F for 15 seconds or more.

5.3 Sponge the sample on the carriage with the standard 10% soap solution heated to 100°F ± 10°F.

5.4 Wet the skin with water.

5.5 Sponge the skin surface with the standard 10% soap solution maintained at 100 ± 10°F.

5.6 Move the carriage to the right until the fourth hole in the rod at the end of the carriage passes through the end plate. Lock the carriage in this position by pushing the metal dowel attached to the metal slide through the fourth hole.

5.7 Fold over the support plate until it comes to rest on the release roller on the carriage.

5.8 Place the vertical weight at the 25 pound position.

5.9 Release the carriage by rotating the release lever 90°.

5.10 Record the distance traveled.

5.11 Without lifting the support plate, or removing the 25 pound weight, repeat steps 5.6, 5.9 and 5.10 four more times for a total of 5 tests.

5.12 Remove the vertical weight and fold back the support plate. Wipe the soap off the skin with water. Wash the sample thoroughly with water and place it in warm water at 100 ± 10°F.

5.13 Repeat steps 5.2 through 5.12 four more times. This will give a total of 25 tests at the 150 gm weight. If the distance traveled is less than 6 1/2 inches for 20 of the 25 tests go on to step 5.14. If the distance traveled is equal to or greater than 6 1/2 inches for 20 of the 25 tests, the test is completed.

5.14 Remove the 150 gm weight, Place the 201 gm weight on the T ring support and place the T ring support on the hook provided.

5.15 Repeat steps 5.2 through 5.12.

5.16 Repeat steps 5.2 through 5.12 four more times with the 201 gm weight This will give a total of 25 tests with the 201 gm weight. If the distance traveled is less than 6 1/2 inches for 20 of the 25 tests go on to step 5.17. If the distance traveled is equal to or greater than 6 1/2 inches for 20 of the 25 tests, the test is completed.

5.17 Remove the 201 gm weight. Place one of the eleven 300 gm weights on the T ring support and place the T ring support on the hook provided.

5.18 Repeat steps 5.2 through 5.12.

5.19 Repeat steps 5.3 through 5.12 four more times with the 300 gm weight. This will give a total of 25 tests with the 300 gm weights. If the distance traveled is less than 6 1/2 inches for 20 of the 25 tests, go on to step 5.20. If the distance traveled is equal to or greater than 6 1/2 inches for 20 of the 25 tests, the test is complete.

5.20 Add a second 300 gm weight to the T ring support for a total of 600 gms.

5.21 Repeat steps 5.2 through 5.12

5.22 Repeat steps 5.3 through 5.12 four more times.

5.23 Continue this procedure adding 300 gm weights to the T ring support and carrying out 25 tests with each weight in the manner described until either all 11 weights have been added or the distance traveled by the carriage is equal to or greater than 6 1/2 inches for 20 of the 25 tests at a given weight.

APPENDIX G

Procedure for Testing (August 5)

Laboratory Notes

1. The order in which materials were to be tested was obtained by a blind drawing of lots, labeled for the four samples, by an independent person. The following order was established: (1) abrasive, (2) smooth, (3) Rubbermaid appliques, (4) Kollsman dot appliques. the slip-resistant fiberglass tub surface had not arrived at the time of the drawing (4:30 p.m.).

2. In order to provide the most nearly similar conditions during replications for all materials, it was decided to undertake the first series of tests for all materials, then the second for all; then a third. Should the fiberglass tub arrive, it can be placed fifth in the rotational sequence; if it does not arrive, it will be tested separately, still alternating from Kollsman to Brungraber tester. (Only three replications, instead of the original five, will be conducted for each of the materials.)

3. The samples will be tested first in one mode of the Kollsman tester; then the other mode of the Kollsman tester. Five sequential replications will take place on a sample for the Kollsman tester; then five with the Brungraber tester, moving down the length of the sample enough to be similar to the operation over a length of material made by the Kollsman device. Alternating between devices will also enable the reheating of the samples for the Kollsman tester between static/dynamic and dynamic measurements.

   (August 6 Note: The fiberglass sample has arrived and will be placed fifth in the rotational sequence.)

APPENDIX H. RESULTS OF TEST PROGRAM - RAW DATA TABULATIONS

DATA OBSERVED WITH NBS-BRUNGRABER TESTER

Entries are the Static Coefficient of Friction

Replicate Number	Observation Number	Smooth, Porcelained Enamel		Textured Porcelained Enamel		Textured Gel Coated Fiberglass Reinforced Plastic		Dot-Pattern Appliqués		Flower-Pattern Appliqués	
		Test Conditions	Observation	Test Conditions	Observation	Test Conditions	Observation	Test Conditions	Observation	Test Conditions	Observation
1	1		0.08		0.12		0.14		0.26		0.25
	2	72°F	0.07	72°F	0.12	72°F	0.11	75°F	0.23	72°F	0.20
	3		0.07		0.10		0.13		0.21		0.22
	4	66%rh	0.07	66%rh	0.09	62%rh	0.12	66%rh	0.21	66%rh	0.22
	5		0.07		0.10		0.14		0.22		0.19
2	1		0.07		0.12		0.11		0.20		0.20
	2	75°F	0.07	75°F	0.14	74°F	0.13	72°F	0.20	75°F	0.21
	3		0.08		0.13		0.15		0.17		0.23
	4	66%rh	0.08	66%rh	0.11	62%rh	0.11	62%rh	0.20	66%rh	0.22
	5		0.07		0.12		0.14		0.17		0.22
3	1		0.08		0.13		0.11		0.19		0.23
	2	74°F	0.08	72°F	0.14	72°F	0.12	74°F	0.18	74°F	0.22
	3		0.07		0.14		0.13		0.22		0.20
	4	62%rh	0.07	62%rh	0.15	58%rh	0.15	62%rh	0.19	62%rh	0.25
	5		0.08		0.15		0.14		0.20		0.24
4	1		0.10		0.15						0.25
	2	74°F	0.08	74°F	0.15					74°F	0.21
	3		0.09		0.13						0.21
	4	62%rh	0.09	62%rh	0.14					62%rh	0.22
	5		0.08		0.14						0.20

DATA OBSERVED WITH KOLLSMAN TESTER
STATIC/DYNAMIC MODE OF OPERATION

(Entries are the Displacement of the Carriage, in Inches)

MATERIAL	REPLICATE NUMBER	TEST CONDITIONS	OBSERVATION NUMBER	LATERAL DRIVING FORCE IN GRAMS 150	237	340	648	952
Smooth Porcelain Enamel on Steel	1	75°F 66%rh	1	1	4 7/16*	>6 1/2		
			2	3/4	4 7/16	>6 1/2		
			3	13/16	5	>6 1/2		
			4	1	5 1/4	>6 1/2		
			5	5/8	6 1/4	>6 1/2		
	2	74°F 62%rh	1	2 9/16	>6 1/2			
			2	2 3/8	>6 1/2			
			3	2	>6 1/2			
			4	2 1/8	>6 1/2			
			5	2 1/2	>6 1/2			
	3	74°F 62%rh	1	2 1/4*	6 1/2	>6 1/2		
			2	2 1/2*	4*	>6 1/2		
			3	2 1/2*	5 3/8*	>6 1/2		
			4	2 1/2*	3 3/4*	>6 1/2		
			5	2 3/4*	5 1/4	>6 1/2		
Textured Porcelain Enamel on Steel	1	75°F 66%rh	1	7/16	7/8	1 5/8	5 7/16	>6 1/2
			2	7/16	13/16	1 5/8	5	>6 1/2
			3	3/8	13/16	1 13/16	6	>6 1/2
			4	3/8	3/4	2 1/4	5 3/16	>6 1/2
			5	3/8	11/16	2 1/2	5 3/8	>6 1/2
	2	72°F 62%rh	1	3/16	3/8	1 1/4	5 1/8*	>6 1/2
			2	3/16	7/16	1 7/16	5 1/4	>6 1/2
			3	3/16	7/16	1 1/2	5 5/8	>6 1/2
			4	1/4	7/16	1 9/16	5 5/8	>6 1/2
			5	3/16	3/8	1 9/16	6	>6 1/2
	3	74°F 62%rh	1	1/4	7/8	7/8	>6 1/2	>6 1/2
			2	1/4	15/16	1	>6 1/2	>6 1/2
			3	5/16	7/8	1 1/4	>6 1/2	>6 1/2
			4	5/16	13/16	1 3/8	>6 1/2	>6 1/2
			5	5/16	13/16	1 11/16	>6 1/2	>6 1/2
Textured Gel-Coated Fiberglass Reinforced Plastic	1	72°F 62%rh	1	3/8	1 1/8	1 5/8	5*	>6 1/2
			2	3/8	1 1/8	2 9/16	5*	>6 1/2
			3	3/8	1	2 5/16	5*	>6 1/2
			4	7/16	1	2 3/8	5*	>6 1/2
			5	1/2	1 1/16	2 1/2	5*	>6 1/2
	2	74°F 62%rh	1	5/16	7/8	3*	>6 1/2	
			2	5/16	1 3/4*	3*	>6 1/2	
			3	3/8	2*	3 3/8*	>6 1/2	
			4	3/8	2	3 1/2	>6 1/2	
			5	5/16	2	3 1/2	>6 1/2	
	3	72°F 58%rh	1	5/16	1 1/16	2 5/8*	>6 1/2	
			2	5/16	1 1/2*	2 7/8*	>6 1/2	
			3	5/16	1 1/2*	2 7/8*	>6 1/2	
			4	1/4	1 5/8*	2 7/8	>6 1/2	
			5	5/16	1 5/8	2 7/8	>6 1/2	

* The skin creeps along after the noted displacement, where it stops temporarily.

DATA OBSERVED WITH KOLLSMAN TESTER
STATIC/DYNAMIC MODE OF OPERATION

(Entries are the Displacement of the Carriage, in Inches)

(Continuation)

MATERIAL	REPLICATE NUMBER	TEST CONDITIONS	OBSERVATION NUMBER	LATERAL DRIVING FORCE IN GRAMS 150	237	340	648	952
Dot-Pattern	1	75°F	1	1/8	3/16	5/16	7/16	3/4
Appliqués		66%rh	2	1/8	3/16	5/16	5/8	13/16
on Smooth			3	3/16	3/16	1/4	7/16	11/16
Porcelain-			4	3/16	1/4	1/4	1/2	3/4
Enameled			5	3/16	3/16	1/4	7/16	11/16
Steel**	2	74°F	1	1/16	1/8	1/8	5/16	3/8
		62%rh	2	1/16	1/8	1/8	5/16	3/8
			3	1/16	1/8	1/8	5/16	3/8
			4	1/8	1/8	1/8	5/16	7/16
			5	1/16	1/8	1/8	3/8	7/16
	3	74°F	1	1/8	1/8	1/4	3/8	5/8
		62%rh	2	1/8	1/8	3/16	3/8	5/8
			3	1/8	1/8	3/16	3/8	5/8*
			4	1/8	1/8	3/16	3/8	5/8*
			5	1/8	1/8	3/16	3/8	5/8*
Flower Pattern	1	75°F	1	1/8	1/8	1/4	5 1/2*	
Appliqués		66%rh	2	1/8	3/16	1/4	5 1/2	
on Smooth			3	1/8	3/16	1/4	>6 1/2	
Porcelain-			4	1/8	3/16	1/4	>6 1/2	
Enameled			5	1/8	3/16	1/4	>6 1/2	
Steel*	2	74°F	1	1/8	1/8	3/16	3 1/16*	
		62%rh	2	1/8	1/8	3/16	>6 1/2	
			3	1/16	1/8	3/16	>6 1/2	
			4	1/16	1/8	3/16	>6 1/2	
			5	1/16	1/8	3/16	>6 1/2	
	3	74°F	1	1/16	1/8	5/16	1*	>6 1/2
		62%rh	2	1/16	1/8	3/8	2*	>6 1/2
			3	1/16	1/8	3/8	3*	>6 1/2
			4	1/16	1/8	3/8	2*	>6 1/2
			5	1/8	3/16	5/16	4 1/4	>6 1/2

The skin creeps along after the noted displacement, where it stops temporarily.

See Extension Sheet of Lateral Driving Force for Dot-Pattern Appliqués.

DATA OBSERVED WITH KOLLSMAN TESTER
STATIC/DYNAMIC MODE OF OPERATION

(Entries are the Displacement of the Carriage, in Inches)

(Extension Sheet for Dot Pattern

LATERAL DRIVING FORCE IN GRAMS							
1249	1563	1876	2187	2488	2801	3115	3425
1	1 1/2	1 3/8*	2 3/8*	3 5/8*	3 7/8*	6 1/8*	
1	1 5/8*	2 3/16*	2 7/16*	3 5/8*	4 1/2*	6 1/8*	
1 1/16*	1 11/16*	2*	2 3/4*	3 1/2*	4 3/4*	>6 1/2	
1 1/8*	1 3/4*	2*	2 11/16*	4*	5 1/8*	>6 1/2*	
1 1/8*	1 3/4*	2 1/8*	2 15/16	3 1/2*	4 5/8*	>6 1/2	
5/8	1 3/16*	1 1/2*	2 5/16*	3 1/2*	4 3/4*		
3/4	1 3/8	1 7/8*	2 15/16*	5 1/2*	6 1/2*		
7/8	1 9/16*	2 1/16	3 1/8*	6*	>6 1/2		
3/4	1 5/8	2 3/16*	3 1/4*	6 1/4*	>6 1/2		
7/8	1 3/4*	2 1/4	3 3/8*	6 1/2*	>6 1/2		
7/8*	1 1/8*	1 7/16*	2 1/2*	3 1/2*	>6 1/2		
7/8*	1 1/4*	1 15/16*	2 7/8*	4 1/2*	>6 1/2		
1*	1 1/4*	1 7/8*	3*	5 1/8*	>6 1/2		
1*	1 5/16*	2*	3 1/4*	4 3/4*	>6 1/2		
1*	1 5/16*	2*	3 3/8*	5 1/8*	>6 1/2		

DATA OBSERVED WITH KOLLSMAN TESTER
DYNAMIC MODE OF OPERATION

(Entries are the Displacement of the Carriage, in Inches)

MATERIAL	REPLICATE NUMBER	TEST CONDITIONS	OBSERVATION NUMBER	LATERAL DRIVING FORCE IN GRAMS 150	237	340	648	952
Smooth Porcelain Enamel on Steel	1	75°F 66%rh	1	6	>6 1/2			
			2	6 3/8	>6 1/2			
			3	6 1/4	>6 1/2			
			4	5 7/8	>6 1/2			
			5	6 1/8	>6 1/2			
	2	72°F 62%rh	1	5 1/8	>6 1/2			
			2	5 5/8	>6 1/2			
			3	5 5/8	>6 1/2			
			4	5 3/4	>6 1/2			
			5	6	>6 1/2			
	3	74°F 62%rh	1	>6 1/2				
			2	>6 1/2				
			3	>6 1/2				
			4	>6 1/2				
			5	>6 1/2				
Textured Procelain Enamel on Steel	1	75°F 66%rh	1	2 15/16	3 13/16	6	>6 1/2	
			2	3 1/2	3 11/16	6 1/16	>6 1/2	
			3	3 1/4	3 3/4	6 1/16	>6 1/2	
			4	3 3/8	3 9/16	6 1/16	>6 1/2	
			5	3 7/16	3 9/16	6 1/16	>6 1/2	
	2	72°F 62%rh	1	2 7/8	5 1/4	5 5/8	>6 1/2	
			2	2 7/8	5 1/2	5 3/4	>6 1/2	
			3	2 7/8	5 1/2	6	>6 1/2	
			4	2 7/8	5 1/2	6 1/8	>6 1/2	
			5	2 13/16	5 1/2	6 1/8	>6 1/2	
	3	74°F 62%rh	1	3 1/2	4	>6 1/2		
			2	3 3/4	4 3/8	>6 1/2		
			3	3 3/4	4 3/8	>6 1/2		
			4	3 3/4	4 1/2	>6 1/2		
			5	3 3/4	4 1/4	>6 1/2		
Textured Gel-Coated Fiberglass Reinforced Plastic	1	72°F 62%rh	1	3 1/16	3 11/16	6 1/4*		
			2	3 1/16	3 3/4	6*		
			3	3 3/16	3 7/8	>6 1/2		
			4	3 1/8	3 13/16	>6 1/2		
			5	3 1/16	3 15/16	6*		
	2	74°F 62%rh	1	3 9/16	3 1/16	3 1/2	>6 1/2	
			2	3 7/16	3 3/8	3 15/16*	>6 1/2	
			3	3 7/16	3 3/8	4*	>6 1/2	
			4	3 7/16	3 3/8	3 7/8*	>6 1/2	
			5	3 3/8	3 7/16	4 1/8*	>6 1/2	
	3	72°F 58%rh	1	4 3/16	5 1/4	6*	>6 1/2	
			2	4 1/8	5 1/8	6*	>6 1/2	
			3	4 1/2	5 3/4	6 1/8*	>6 1/2	
			4	4 3/8	5 3/4	6 1/4*	>6 1/2	
			5	4 1/4	6	6 1/4	>6 1/2	

*The skin creeps along after the noted displacement, where it stops temporarily.

DATA OBSERVED WITH KOLLSMAN TESTER
DYNAMIC MODE OF OPERATION

(Entries are the Displacement of the Carriage, in Inches)

(Continuation)

MATERIAL	REPLICATE NUMBER	TEST CONDITIONS	OBSERVATION NUMBER	LATERAL DRIVING FORCE IN GRAMS 150	237	340	648	952
Dot-Pattern Appliqués on Smooth Porcelain-Enameled Steel**	1	75°F 66%rh	1	3/4	7/8	3/4	1 1/4	1 7/
			2	3/4	7/8	3/4	1 1/4	1 1
			3	3/4	7/8	7/8	1 3/8	1 1
			4	3/4	7/8	3/4	1 3/8	1 1
			5	3/4	7/8	3/4	1 3/8	2
	2	74°F 62%rh	1	3/8	5/8	5/8	1 3/16	1 1
			2	1/2	3/4	11/16	1 1/4	1 1
			3	1/2	3/4	11/16	1 1/4	1 1
			4	7/16	3/4	11/16	1 3/16	1 3/
			5	7/16	3/4	5/8	1 3/16	1 1
	3	74°F 62%rh	1	3/4	11/16	7/8	1 7/16	2
			2	3/4	3/4	1	1 9/16	2 3/
			3	3/4	3/4	1	1 9/16	2 3/
			4	3/4	3/4	1	1 1/2	2 7/
			5	13/16	11/16	15/16	1 1/2	2 7/
Flower Pattern Appliqués on Smooth Porcelain-Enameled Steel*	1	75°F 66%rh	1	1 1/4	1 7/16	2 1/4	>6 1/2	
			2	1 1/4	1 5/8	2 5/16	>6 1/2	
			3	1 5/16	1 5/8	2 5/16	>6 1/2	
			4	1 5/16	1 5/8	2 3/8	>6 1/2	
			5	1 5/16	1 5/8	2 3/8	>6 1/2	
	2	74°F 62%rh	1	1 1/16	1 5/16	1 13/16	5 1/8	>6 1
			2	1 3/16	1 5/16	2	5 3/16	>6 1
			3	1 1/8	1 3/8	1 15/16	6 1/2	>6 1
			4	1 3/16	1 7/16	2	>6 1/2	>6 1
			5	1 3/16	1 3/8	2 1/8	>6 1/2	>6 1
	3	74°F 62%rh	1	1 3/16	1 3/8	2	4 3/4*	>6 1
			2	1 5/16	1 9/16	2 1/8	5*	>6 1
			3	1 3/16	1 5/8	2 1/4	5*	>6 1
			4	1 1/8	1 5/8	2 1/4	5 1/4*	>6 1
			5	1 1/8	1 5/8	2 1/4	5 1/2	>6

*The skin creeps along after the noted displacement, where it stops temporarily.

**See Extension Sheet of Lateral Driving Force for Dot-Pattern Appliqués.

DATA OBSERVED WITH KOLLSMAN TESTER
DYNAMIC MODE OF OPERATION

(Entries are the Displacement of the Carriage, in Inches)

(Extension Sheet for Dot-Pattern Appliqués)

LATERAL DRIVING FORCE IN GRAMS							
1249	1563	1876	2187	2488	2801	3115	3425
1 3/4	2 1/2	3 1/2	4 5/8	4 7/8	>6 1/2		
2 1/8	2 5/8	3 7/8	5 1/4	5 3/4	>6 1/2		
2 1/8	2 5/8	3 7/8	5 1/4	6	>6 1/2		
2	2 5/8	3 3/4	5 1/8	6	>6 1/2		
2 1/16	2 15/16	3 7/8	5 1/4	5 7/8	>6 1/2		
2	2 3/4	4 1/8	4 1/2	6 1/4			
2 1/8	3 3/16	5	5 1/8	>6 1/2			
2 1/4	3 1/4	4 7/8	5 1/2	>6 1/2			
2 3/8	3 1/2	4 7/8	5 3/4	>6 1/2			
2 3/8	3 1/2	5 1/4	5 3/4	>6 1/2			
2 7/16	4 1/8*	5 3/8*	>6 1/2				
2 7/8	4 1/2*	>6 1/2	>6 1/2				
3	4 5/8	>6 1/2	>6 1/2				
2 15/16	4 7/8	>6 1/2	>6 1/2				
2 15/16	4 13/16*	>6 1/2	>6 1/2				

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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 report describes a program of tests planned by ASTM Committee F15.03 on Safety Standards for Bathtub and Shower Structures, and conducted at the National Bureau of Standards for the purpose of comparing the NBS-Brungraber and the Kollsman tester with respect to their effectiveness in evaluating the slip-resistance of bathtub and shower base surfaces. This program represents a contribution by the National Bureau of Standards to the efforts of the American Society for Testing and Materials and the Consumer Product Safety Commission in developing safety standards for bathrooms and bathroom fixtures. Both testers employ the same material (drumheads of "slunk") to simulate human skin, and the report concludes that both testers will satisfactorily discriminate between different bathroom surfaces on the basis of slip-resistance. The conclusion may be made that the NBS-Brungraber tester is considerably more convenient to use.

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)* Kollsman tester; NBS-Brungraber tester; safety of bathrooms; slip-resistance of bathtub and shower base surfaces; slip-resistance testers.

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