NBSIR 74-613

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U. S. DEPARTMENT OF COMMERCE
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A. P. Cramp and L. W. Masters

The National Commission on Product Safety reported in 1970, that falls in the home each year kill about 12,000 and injure 6,000,000 in the U.S.A. Slippery floors are listed as a large contributor to these very high casualty figures. Although there are some standardized test methods that are or may be made suitable for such standards, there are no slipperiness standards for flooring. There is an immediate need for studies aimed at the development and establishment of such standards. Consequently, a preliminary study of floor slipperiness was sponsored by the Building Safety Section of the Center for Building Technology. The study included a state-of-the-art investigation on flooring slipperiness research and a laboratory evaluation of three existing test methods for measuring floor slipperiness. Samples of the three most commonly used resilient flooring materials, vinyl asbestos, vinyl, and linoleum were used in the study. The sliding material components for the frictional tests were leather and a commonly used styrene butadiene sole and heel rubber. The tests were performed on both dry and wet surfaces. The results from this study were used in planning a large comprehensive study for the development of accepted floor slipperiness standards. This report contains the results of the preliminary study.

Key words: Floor slipperiness; resilient flooring; slipperiness standards; frictional tests; slip tests; coefficient of friction; human perambulation.

SI CONVERSION UNITS

In view of the present accepted practice in this country for building technology, common U.S. units of measurement have been used throughout this paper. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measures, which gave official status to the metric SI system of units in 1960, assistance is given to the reader interested in making use of the coherent system of SI units by giving conversion factors applicable to U.S. units used in this paper.

Length

1 in = 0.0254 meter (exactly)

1 ft = 0.3048 meter (exactly)

Mass

1 lb = 453.59 grams

Temperature

$^{\circ}C = 5/9\ (\text{Temperature}\ ^{\circ}F - 32)$

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS

1.0 INTRODUCTION

The final report of the National Commission on Product Safety, issued in June 1970, states that falls in the home each year kill about 12,000 people and injure 6,000,000 in the United States. The precise causes of the falls are uncertain, but slippery floors are listed as a large contributor to these high casualty figures. Consequently, a preliminary study of floor slipperiness was sponsored by the Building Safety Section of the National Bureau of Standards. The study was intended as a basis for a comprehensive future study of the subject. This report contains the results of the preliminary study.

1.1 Slipperiness Standards

Because of the seriousness of the problems resulting from floor slipperiness and the large number of individuals involved, this subject has been the source of many scientific investigations by flooring, floor finish and shoe manufacturers; research laboratories; and also insurance companies for many years. Nevertheless, no national standards for floor slipperiness have yet been established in the U.S.A. Thus, there is an immediate need for the development of such standards. The problems involved in the development of slipperiness standards are complicated. For meaningful standards to be developed, the test methods upon which the standards would be based should yield results which relate logically and directly to results obtained from human perambulation tests.

A number of laboratory test methods for determining the slipperiness, skid resistance or coefficient of friction of flooring and pavement surfaces have been developed. However, little work has been devoted to the intercomparison of results from these test methods or to their relationship with tests and investigations involving human perambulation and reaction.

From contacts with the flooring and floor finishing industries, it has been determined that little, if any, work is presently being done in research on floor slipperiness by them.

Although such ASTM committees as F-6 on resilient floor coverings and D-21 on polishes have worked on the floor slipperiness problem, they are not currently active in this area. By contrast, the footwear industry has recently become very active in the study of safety of footwear insofar as the relative slipperiness of sole and heel materials is concerned.

A new ASTM Committee, F-13, Safety in Footwear, was formed in October 1973. The present task of subcommittee F-13.10, Traction in Footwear, is to determine whether or not two established test methods for evaluating the frictional properties of pavements and floor finishes, or modifications of these, might be suitable for adoption as standard tests for the frictional properties of sole and heel materials.

The Committee hopes to have a standard test established for the evaluation of the fractional properties of sole and heel materials by the end of 1974.

1.2 Biomechanical Studies of Walking

According to Carlet [1][1/], the study of the mechanics of walking can be traced back as far as Aristotle. The earliest author to explain the process of walking in terms of levers and forces was Borelli [2] in 1679. In the nineteenth century, Marey [3] and Fischer [4] used photography to further study the subject. A study of the dynamic anatomy of the foot and leg in connection with the development of artificial limbs was made shortly after World War II at the University of California [5].

An extensive study of human locomotion and the interaction between walkways and footwear was conducted by R. B. Hunter and later P. A. Sigler and coworkers at the National Bureau of Standards. Moving pictures were taken of people walking to serve as a basis for their conclusions about the mechanics of human perambulation. Instrumentation for the measurement of the relative slipperiness of walkways was also developed. This work was reported in a series of publications [6], [7], [8], [9] and [10].

In England, F. C. Harper conducted extensive studies on the mechanics of walking and the forces applied by the foot to floors. This was reported in 1961 [11]. He suggested that the coefficient of friction between floor surfaces and shoe materials should be a minimum of 0.4 for safe walking. However, he did not specify a test method to be used in determining the coefficient of friction.

Using the apparatus developed by Hunter at NBS in 1930 [6], S. James [12] established a standard method which was originally used for testing the static coefficient friction of shoe heels in the mid 1950's. The James Static Friction Test is described in Section 5.2.1. This test was subsequently established as the Standard ASTM Method D2047 for measuring the coefficient of friction of floor finishes. James believed that a coefficient of friction of 0.5, as determined by his test, should be established as the minimum requirement for friction between sole and heel materials and floor surfaces to ensure safety against slipping.

When D. F. Ekkebus and W. Kelley [13] could find no published account as to why James had decided that the 0.5 figure was an appropriate minimum for slipperiness safety, they set out to validate its use. They measured the leg and stride length of a number of subjects, and then calculated how much larger each individual's stride would have to be before the horizontal force would be more than half the vertical force, i.e., the ratio would exceed 0.5. No normal stride was found to be nearly long enough for the horizontal force exerted to exceed half the vertical force. Consequently, the 0.5 coefficient of friction specified by James was concluded to be a very conservative level for slipperiness of floor finishes (polishes) and flooring surfaces.

2.0 Current Methods for Determining Floor Slipperiness

The need for experimental data relating to floor slipperiness has lead to the development of many types of devices for measuring slipperiness.

The most commonly used technique involves the determination of the sliding coefficient of friction, or some sort of "index of slipperiness" or "skid resistance index" related to the coefficient of friction between flooring material and other materials such as footwear sole and heel material.

[1/] Numbers in brackets refer to references in the Bibliography.

The coefficient of friction between two surfaces is defined as the ratio of the force required to move one surface over the other to the total force pressing the two surfaces together. Thus,

$$\text{the Coefficient of Friction} = \frac{\text{Horizontal Force}}{\text{Vertical Force}}$$

Two types of friction must be considered in measuring floor slipperiness, namely, static and dynamic (kinetic) friction. Static friction is the amount of friction between two surfaces at the precise instant when one commences to move over the other. Dynamic friction is the friction between two surfaces when movement is occurring without interruption. The coefficient of static friction is usually equal to or greater than that for dynamic friction.

The wide variety in types of machines for measuring floor slipperiness is probably best catagorized by the principle by which the apparatus works. The two principles upon which flooring or pavement slipperiness testers on record are based, are either the horizontal plane track or swinging pendulum. A number of such test methods are described in Federal Construction Council Technical Report No. 43 [14]. Table I, which was taken from reference 14, contains pertinent information about these test methods.

Two tests being evaluated by the ASTM Safety in Footwear Committee are the existing British Portable Skid-Resistance Test (Pavements) and the existing James Static Coefficient Test (floor finishes).

The Committee is also investigating the use of an experimental test method for measuring frictional properties which operates on the principle of a weighted glider shoe, with the material under test for frictional properties being pulled horizontally at different rates across standard flooring samples.

3.0 Method of Conducting the Study

The following tasks were performed in this study:

1) A literature survey.

2) Meetings with representatives of the flooring and footwear industries and appropriate ASTM Committees to determine what technical developments had recently been made, or are now in progress on the subject of floor slipperiness, and subjects related to it.

3) Selection of three test methods for this study, from the variety of surface frictional property tests available, which appeared to hold most promise for the evaluation of floor slipperiness.

4) Determination of the reproducibility of the three selected tests when determining the frictional properties of three standard types of resilient flooring tile; vinyl asbestos, vinyl, and linoleum. The frictional properties for the flooring were determined with standard shoe leather and sole and heel rubber as the sliding surfaces material. The frictional properties of the flooring were determined wet as well as dry.

5) Formulation of plans for a large comprehensive study intended to follow this preliminary study.

4.0 Equipment and Materials

4.1 Equipment

The three test methods selected for evaluation and use in the preliminary study were those which utilized the following apparatus:

a) The James Static Friction Tester (Fig. 1)

b) The British Portable Skid Resistance Tester (Fig. 2)

c) The Horizontal Pull Slipmeter (Fig. 3)

Test methods utilizing these testing machines were selected for this study because they appeared to hold the most promise of any surface frictional property tests available for use in floor slipperiness testing.

The James Machine is the basis for ASTM Method D2047 for Determining Static Coefficient of Friction of Polish-Coated Surfaces and has been used by General Services Administration (GSA) and Underwriters' Laboratories Inc. for evaluating floor coatings, although no criteria or standards have been developed. This method is only suitable for specimens of flooring which can be mounted on the machine, and is not a field method. The British Portable Tester is the basis of ASTM Method E 303 [15], which is intended for testing roadways. The Horizontal Pull Slipmeter is much lighter and less bulky than the British Portable Tester and favorable results have been reported in articles published in ASTM Standardization News.

4.2 Flooring Materials

The flooring materials selected for the study were the three most commonly used types of resilient flooring. They were:

a) Vinyl asbestos tile, 9" by 9" (22.9 x 22.9 cm) samples.

b) Vinyl tile, 12" x 12" (30.5 x 30.5 cm) samples.

c) Linoleum, 9" x 6" (22.9 x 15.2 cm) samples.

4.3 Slider Shoe Materials

Two commonly used shoe sole and heel materials were selected for the sliding component materials in the preliminary study. They were:

a) 100% cowhide, sanded to a smooth flat surface and

b) Styrene butadiene rubber meeting the requirements of ASTM D 1630 Standard Method of Test for Abrasion Resistance of Soles and Heels [16].

Materials from the same sheets were used in the three different test methods.

5.0 Test Procedures

5.1 General Test Procedures

The flooring samples were tested with dry surfaces and also with wetted surfaces using distilled water. Before testing, the flooring materials were washed with a mild soap and water solution, rinsed with distilled water, and dried thoroughly at room temperature.

It was found that the first few determinations made on new flooring samples with both the James and British Portable testers, yielded decreasing values. It was obvious that during these determinations the flooring samples were being conditioned (i.e., possible superficial asperities being removed) because after two to four determinations the decrease stopped and the values obtained became approximately consistent with one another. Thus, the results of test runs which showed that surface conditioning was taking place were discarded.

No surface conditioning of the flooring appeared to take place in the Horizontal Slipperiness Test. Possibly the effect of the conditioning on the test results may have been small, because of the comparatively small area of the feet of the testing device and its slow speed.

At least five determinations were made on each of five samples of the three types of flooring being tested. This procedure was followed for all three test methods.

All of the samples were tested in the machine direction of the flooring. This is the longitudinal direction of the flooring during the fabrication process and is the direction of the pattern of the flooring. In addition, some of the samples were also tested transverse to the machine direction. The transverse testing was curtailed for the James Test and Horizontal Pull Slipmeter, because, like the results from the British Portable Test, they all agreed closely with those from the machine directional tests.

The ambient temperature of the room in which the tests were conducted was 74 $\pm$ 1°F (23.3°C) and the relative humidity, 45 $\pm$ 3%.

5.2 Detailed Test Procedures

The following are descriptions of the specific procedures followed in this study in evaluating the James Static Friction Test, the British Portable Skid Resistance Test, and the Horizontal Pull Slipperiness Test.

5.2.1 James Static Friction Test

The James Tester used in this study is similar to the Tester shown in Figure 1, except that the machine used in this study has a motor-driven test table, making it more versatile than the illustrated model, which is hand cranked.

The test device has a 3 x 3 in. (7.6 x 7.6 cm) steel shoe. The two shoe materials which were studied by placing them on the steel shoes were:

a) 100% cowhide sole leather, 1/4 in (0.64 cm) thick, sanded to a smooth flat surface with No. 400A carborundum paper and

b) Styrene butadiene rubber, meeting ASTM D 1630 requirements.

5.2.1.1 Tests of Dry Surfaces

Preparation of Slider (Shoes)

Leather shoe. A 3 in. x 3 in. (7.6 x 7.6 cm) piece of leather was bonded with an adhesive to each of the steel shoes. The leather shoe was sanded by gently moving it four times back and forth, about 4 in. (10.2 cm) over a sheet of 400A carborundum paper, then repeating this procedure at an angle of 90°. The dust and loose material were then removed from the shoe surface by rubbing it lightly with a clean cotton cloth.

This procedure was repeated before each determination.

Rubber shoe. A 3 in. x 3 in. (7.6 x 7.6 cm) piece of test rubber was bonded adhesively to each of the steel shoes used for the tests with rubber. The rubber shoe was dusted free of any loose material prior to each determination.

Test Procedure. The standard procedure described in ASTM D 2047 was followed in general, except that the tests described in this report were of flooring instead of floor coatings.

The test device was leveled by placing shims under the legs as it was not equipped with leveling screws. Three 25 lb. (11.3 kg) weights were placed on the weight platform to give a total load of 80 lbs. (36.3 kg) on the shoe (j) (see figure 1).

A copy of the James Tester Chart (c) was fastened to the chartboard (d) so that the spring-fitted recording pencil would be at zero when the test started. This chart is graduated directly in terms of the tangent of the angle assumed by the strut, or the static coefficient of friction.

The table was then moved to the starting position. By means of the small wheel in figure 1, the weighted column was raised, the flooring specimen placed on the test table against the retaining bar (l), and the shoe (j) inserted in the yoke in such a position that the strut was 90° to the flooring sample. The recording pencil (f) was released and checked for zero position on the chart.

The speed of the test table was arbitrarily set at about 100 in (254 cm) per min by means of a speed control dial. Preliminary studies indicated that varying the test table speed did not cause a significant change in results for the flooring tested.

The test was started by setting the test table in motion and the strut angle with the flooring sample became progressively smaller. When the angle reached a critical size, which is a function of the static coefficient of friction between the foot and the floor specimen, the foot slipped, and the column dropped.

The line drawn by the recording pencil during the test was a smooth descending curve until the foot slipped, at which point there was a fairly sharp break, and the line dropped more or less vertically. The coefficient of friction is the point at which the curve changes sharply downward. The readings were taken to the nearest 0.01 units of static coefficient of friction.

If the foot did not slip, there was no break in the curve, and the coefficient of friction between the two surfaces was too high for the scope of the test device.

5.2.1.2 Tests of Wet Surfaces

The procedure for the wet tests was basically the same as for the dry tests, except for the following modifications:

a) The leather shoe was not sanded before each test. Instead, it was soaked in distilled water for at least one half hour before being used for testing.

b) The leather and rubber shoes and the flooring samples were thoroughly wetted with distilled water prior to each test.

c) It was found that if the time period between the placing of the wet leather shoe on the wet flooring sample and the start of the test table movement was increased, the coefficient of friction value increased. This effect did not appear to be as pronounced between the wet rubber and the wet flooring. It was decided that in order to minimize this effect on the test results, the period between the placement of the wet shoes on the wet flooring and the start of the test should be as short as possible and constant. Fifteen seconds was established for this period, because it was just long enough to enable the operator to place the recording pencil in position on the chart after the shoe had been placed on the flooring, without being unnecessarily hurried.

5.2.2 British Portable Skid Resistance Test

This test method, intended for measuring the frictional properties of surfaces, is suited for laboratory as well as field use. The values obtained, British Portable Tester Numbers, represent the frictional properties determined with the apparatus, and do not necessarily agree or correlate with values from other slipperiness measuring equipment.

The tester (figure 2) is a dynamic pendulum impact type tester which measures the energy loss when the edge of a slider attached to the bottom of the pendulum is propelled over a test surface. During its forward swing, the pendulum engages and pushes a drag pointer to the highest point of its travel, at which time the pointer stops to indicate the Test Number on a scale.

The pendulum with slider and slider mount weighs 3.31 ± 0.07 lb (1500 ± 30 g). The distance of the center of gravity of the pendulum from the center of oscillation is 16.2 ± 0.2 in (411 ± 4 mm). The tester is capable of vertical adjustment to provide a slider contact path length of 4 15/16 ± 1/16 in (125 ± 1.6 mm). The slider load applied to the flooring under test is 5.51 ± 0.22 lb (2500 ± 100 g). The slider load, however, is not constant throughout the contact path because of the circular path of the pendulum. The slider assembly consists of an aluminum backing plate to which is bonded a 1/4 by 1 by 3 in (6.35 by 25.4 by 76.2 mm) strip of the shoe sole-and-heel materials required for the study. The leather and rubber materials used were the same type as described in Section 5.2.1.

A contact path gage consisting of a thin ruler suitably marked for measuring contact path length between 4 7/8 and 5.0 in (12.4 and 12.7 cm) was used.

The instrument was levelled by means of levelling screws, and the pendulum adjusted as described in ASTM E 303. The drag pointer was adjusted so that it would register zero as required when the pendulum was released to swing with the slider not contacting a surface.

5.2.2.1 Tests of Dry Surfaces

Preparation of Sliders (Shoes)

A 1 x 3 in (25.4 x 76.2 mm) piece of slider material was bonded to each of the aluminum shoes. The leather slider was then swung ten times across No. 400 A carborundum paper in order to condition it for the tests. This broadened the line of contact. The rubber sliders were conditioned in the same way as the leather slider, except that the abrasive surface used for conditioning was No. 80 grade silicone carbide cloth.

NOTE: Wear on the striking edges of the sliders should not exceed 1/8 in (3.2 mm) in the plane of the slider or 1/16 (1.6 mm) vertical to it (15).

Test Procedure. The flooring samples to be tested were fixed in position on an aluminum platform on which the British Portable Tester was placed. They were dusted free of any dirt or grit. The pendulum was released and its height adjusted so that the slider had a contact path length of 4 7/8 in to 5.0 in (12.4 to 12.7 cm) on the flooring samples.

To perform tests, the pendulum arm was first locked in the horizontal position and the drag pointer was rotated clockwise until it stopped against the plastic screw of the pendulum arm in the horizontal position. Normally the pointer would be in this position prior to each release of the pendulum arm.

The test determinations were made by releasing the pendulum, letting it take its full swing, and stopping it on its return swing as soon as possible (the slider should never be allowed to swing back over the test surface). The point on the scale at which the slider stops was recorded.

Multiple determinations were made and the results obtained for the first two to four determinations were discarded. Subsequent readings obtained were in good agreement with one another and were recorded. The slider and floor sample were dusted free of any grit or dirt before each determination.

The determinations in which the results were decreasing were regarded as conditioning swings for the flooring samples. The values obtained following the conditioning swings were recorded as valid test results. Six determinations were made on each flooring sample, in the machine direction and at right angles to it (cross machine).

5.2.2.2 Tests of Wet Surfaces

The wet test procedure for testing the flooring was the same as that for the dry test procedure, except that the sliders and the flooring samples were wetted thoroughly with distilled water before each determination.

5.2.3 Horizontal Pull Slipperiness Test

This test method is designed for measuring the slip index of floor surfaces by means of the Horizontal Pull Slipmeter. The slip index, according to the manufacturer's literature, is approximately ten times the coefficient of friction. The Slipmeter is able to measure both static and dynamic coefficients of friction, but not necessarily both for all types of surfaces.

This device measures the frictional properties of a flat surface as a function of the effort required to pull a weighted meter fitted with shoes of a specific sole or heel material across the surface at a fixed rate of speed. The stress placed on the spring of the meter is indicated on the meter dial as the slip index of the surface under test.

The Tester is a portable instrument which utilizes a weighted meter resting on three feet 1/2 in (1.27 cm) in diameter and 3/16 in (0.47 cm) to 1/4 in (0.64 cm) thick, and a battery-operated power unit with a cord which is used to pull the meter at a fixed rate of 3.93 in 9.98 cm) per minute across the surface being tested. Figure 3 shows the apparatus assembled and figure 4 shows the underside with the three round leather shoes installed.

The shoe sole and heel materials were the same as those used for the James and British Portable Tests.

5.2.3.1 Tests of Dry Surfaces

Preparation of Sliders (Shoes). Pieces of leather and rubber, 1/2 in (1.27 cm) in diameter, were bonded to the feet of the Tester. The leather shoes were sanded with carborundum paper No. 400A with four strokes in two directions at right angles to one another before each determination. The shoes were wiped free of dust with tissue.

The rubber shoes were dusted free of any loose material before each determination.

Test Procedure. The flooring sample to be tested was placed on a table against a retaining bar to prevent it from moving during the test. The slipmeter was then placed on the flooring sample facing the retaining bar. The power unit was placed on the other side of the retaining bar from the flooring sample with the pulley in line with the slipmeter hook. The cord was attached to the hook.

The meter-control switch was released, and the meter zeroed by moving the rim of the meter. The meter switch was then pushed to the rear position for registering the static slip index, which is the highest reading attained just as the slipmeter starts forward.

The cord was held taut at the center of the pulley, and pushing down on the power unit to keep it from moving, the power switch was depressed. As soon as the slipmeter moved, the power was shut off. The static slip index was then read from the dial and the needle released to return to zero by moving the control switch to the middle position. The control switch did not always function properly, so that the true maximum reading was not always retained.

In order to determine the dynamic slip index, the control switch was left in the middle position, and the slipmeter was pulled forward by the power unit.

If the movement of the slipmeter was steady, the slip index recorded on the dial was dynamic. Occassionally the slipmeter moved in a jerky or "stick-slip" manner indicating that both static and dynamic friction were being displayed.

Five slip index determinations were made for each flooring sample with the slipmeter in different starting positions.

5.2.3.2 Tests of Wet Surfaces

The leather and rubber sliders which were used for the dry tests were used for the wet tests. The leather slider was soaked in distilled water for one half hour before use and was wetted before each determination. The leather slider was not sanded after wetting. The rubber sliders were wetted before each determination using distilled water.

The wet test procedure for testing the flooring was the same as that used for the dry procedure, except that the sliders and the flooring samples were thoroughly wetted prior to the wet determinations.

6.0 Results

6.1 James Static Friction Test

The data obtained with the James Static Friction Tester for vinyl asbestos tile, vinyl tile and linoleum are presented in tables 2, 3, and 4, respectively. Each table includes five recorded values of coefficient of static friction using both leather and rubber shoes in wet and dry conditions for each of five samples tested, the average and standard deviation of those five values, and the total average and standard deviation of all recorded values for each type of flooring. The data in tables 2, 3 and 4 were obtained in the machine direction of the flooring. Table 5 contains a summary of the data from tables 2, 3 and 4.

The total averages and standard deviations, which represent a total of 25 coefficient of static friction values, for the samples tested dry using leather shoes were 0.42 ± 0.02 for vinyl asbestos tile, 0.60 ± 0.04 for vinyl tile and 0.57 ± 0.02 for linoleum. The values obtained for the wet tests were 0.41 ± 0.02 for vinyl asbestos tile, 0.35 ± 0.02 for vinyl tile and 0.45 ± 0.02 for linoleum.

The results indicate that wetting the surfaces of vinyl tile and linoleum lowers the coefficient of static friction substantially, but that wetting has little if any effect on the values obtained for vinyl asbestos tile. The results also indicate that coefficients of static friction determined with the James Static Friction Tester yield reasonably good reproducibility.

The friction between all three types of resilient flooring and the rubber shoes was so high in both the wet and dry tests that no slippage occurred in any of the determinations. Thus, the coefficient of friction could not be determined for any of the three types of flooring in contact with the rubber shoes.

6.2 British Portable Skid Resistance Test

The data obtained with the British Portable Skid Resistance Tester for vinyl asbestos tile, vinyl tile and linoleum tested in the machine direction of the flooring are presented in tables 6, 7 and 8, respectively. Tables 10 and 11 contain the data obtained for vinyl asbestos tile and vinyl tile, respectively when tested in the across machine direction of the flooring.

Each of these tables includes six recorded British Portable Test Number values using both leather and rubber shoes in wet and dry conditions for each of five samples tested, the average and standard deviation of those six values, and the total average and standard deviation for all recorded values for each type of flooring. Table 9 is a summary of the averages presented in tables 6, 7 and 8 while table 12 contains a summary of the data presented in tables 10 and 11.

The total averages and standard deviations for the samples tested in the machine direction (table 9) with leather shoes were: 36.9 ± 2.4 for vinyl asbestos tile tested dry and 10.2 ± 0.4 for vinyl asbestos tile tested wet, 19.4 ± 2.0 for vinyl tile tested dry and 10.4 ± 0.5 for vinyl tile tested wet and 57.8 ± 4.9 for linoleum tested dry and 26.3 ± 3.1 for linoleum tested wet. Comparable values for samples tested in the machine direction (table 9) with rubber shoes were 101.4 ± 5.2 for vinyl asbestos tile tested dry and 24.6 ± 1.3 for vinyl asbestos tile tested wet, 91.1 ± 1.9 for vinyl tile tested dry and 14.2 ± 0.4 for vinyl tile tested wet, and 117.2 ± 3.5 for linoleum tested dry and 41.3 ± 2.3 for linoleum tested wet.

The total averages and standard deviations for the samples tested in the across machine direction (table 12) with leather shoes were: 37.4 ± 2.5 for vinyl asbestos tile tested dry and 10.4 ± 0.5 for vinyl asbestos tile tested wet and 19.6 ± 1.4 for vinyl tile tested dry and 11.0 ± 0.6 for vinyl tile tested wet. Comparable values for samples tested in the across machine direction (table 12) with rubber shoes were: 99.7 ± 5.3 for vinyl asbestos tile tested dry and 25.3 ± 1.1 for vinyl asbestos tile tested wet and 93.6 ± 2.6 for vinyl tile tested dry and 14.0 ± 0.2 for vinyl tile tested wet. Linoleum samples were not tested in the across machine direction because the samples were too narrow to obtain measurements in that direction.

As can be seen the direction of test with respect to the direction of manufacture, had little effect in the British Portable Tester results. This was also the case for the other two testers.

The values obtained in the wet test condition were considerably lower in each case than those obtained in the dry condition. Wetting lowered the values for vinyl asbestos tested in the machine direction from 36.9 to 10.2 (72.4 percent) with leather shoes and 101.4 to 24.6 (75.7 percent) with rubber shoes. With vinyl tile, tested in the machine direction, wetting lowered the values from 19.4 to 10.4 (46.4 percent) with leather shoes, and from 91.1 to 14.2 (84.4 percent) with rubber shoes. Wetting lowered the values for linoleum tested in the machine direction from 57.8 to 26.3 (54.5 percent) with leather shoes and from 117.2 to 41.3 (64.8 percent) with rubber shoes. Thus, the precentage change of the British Portable Test Number due to wetting varies substantially depending on the shoe material. The lower friction values in the wet test may be due to hydroplanning of the slider as it passes over the flooring material.

Comparisons between values obtained in the two directions (tables 9 and 12) machine and across machine, show that there is little if any effect from the test direction for both vinyl asbestos and vinyl tile tested with both leather and rubber shoes and tested in both wet and dry conditions.

The results also indicate that values obtained using the British Portable Skid Resistance Tester yield reasonably good reproducibility.

The manufacturer's literature states that the British Portable Test measures dynamic (or kinetic) friction. It did this in all the tests except the dry rubber slider determinations on the vinyl asbestos tile, in which "stick-slip" (jerky, instead of smooth motion) occurred. Where "stick-slip" occurs, the friction is a mixture of static and dynamic.

6.3 Horizontal Pull Slipperiness Test

The data obtained with the Horizontal Pull Slipperiness Tester for vinyl asbestos tile, vinyl tile and linoleum tested in the machine direction of the flooring are presented in tables 13, 14 and 15, respectively. Each of these tables includes five recorded values of coefficient of friction using both leather and rubber shoes in wet and dry conditions for each of the five samples tested and the average and standard deviation for all recorded values for each type of flooring. Table 16 contains a summary of the data presented in tables 13, 14 and 15.

The total averages and standard deviations for the samples tested with leather shoes were: 0.44 ± 0.02 for vinyl asbestos tile tested dry and 0.66 ± 0.02 for vinyl asbestos tile tested wet, 0.60 ± 0.04 for vinyl tile tested dry and 0.60 ± 0.05 for vinyl tile tested wet, and 0.64 ± 0.02 for linoleum tested dry and 0.88 ± 0.02 for linoleum tested wet. The values obtained for the three types of flooring tested with rubber shoes were 0.82 ± 0.03 for vinyl asbestos tested dry and 0.81 ± 0.02 for vinyl asbestos tested wet, 0.94 ± 0.03 for vinyl tile tested dry and 0.96 ± 0.02 for vinyl tile tested wet, and 0.80 ± 0.03 for linoleum tested dry and 0.87 ± 0.02 for linoleum tested wet.

This test method indicates the frictional properties for two surfaces in contact as a "Slip Index". The Slip Index is reported by the manufacturer to be about ten times the coefficient of friction. Using this factor the data as reported in the tables were converted to coefficients of friction.

The Horizontal Pull Slipmeter is capable of determining both static and dynamic friction. However, in these tests, it measured only one or the other type for each type of sliding material used. For example, for all the tests, both dry and wet, involving the leather shoes, the slipmeter motion was jerky. This motion is called "stick-slip", and the type of friction is static. The slipmeter moved smoothly throughout the tests with the rubber shoes, both dry and wet, the friction being dynamic. Thus, the results in the tables for leather shoes are termed static and those with rubber shoes are termed dynamic. If the motion was smooth throughout a test, including the start, the static and dynamic coefficients would be equal. Significant jerk indicates that static and dynamic coefficients are not equal and that there is too much capability for the storage of elastic energy in the test device, probably in the string.

The coefficient of friction results from the Horizontal Pull Slipmeter from all wet tests were equal to or higher than those from the dry tests except for the vinyl asbestos tile tested with rubber shoes. This was in direct contrast to the results from the British Portable Test, and the James Test with a leather foot (no slippage occurred with the rubber foot in the James Test). In these two tests the dry test results were higher than those from the wet tests.

The data indicate that values obtained using the Horizontal Pull Slipmeter yield reasonably good reproducibility. However, according to the manufacturer, the reliability of coefficients of friction above 0.8 is rather doubtful because interpolation is required above that point.

7.0 Discussion of Results

Table 17 contains a summary of all test data obtained in this preliminary study.

The static coefficients of friction obtained with the James Static Friction Tester and the Horizontal Pull Slipmeter using leather shoes and dry test conditions show reasonably good agreement for all three types of flooring tested. However, the results of these two methods using leather shoes and wet conditions show no agreement for any of the three types of flooring.

The difference between the values in dry and wet tests show no consistent trend when comparing the results obtained using the three test methods. For example, the dry and wet results of vinyl asbestos tile using leather shoes were: 0.42 ± 0.02 and 0.41 ± 0.02 using the James Tester, 36.9 ± 2.4 and 10.2 ± 0.4 using the British Portable Tester and 0.44 ± 0.02 and 0.66 ± 0.02 using the Horizontal Pull Slipmeter.

As mentioned in Section 6.2, and as is evident in table 17, the wet values obtained with the British Portable Tester were considerably lower than the dry values for both leather and rubber shoes and for all three types of flooring. The lower values in the wet tests may be due to hydroplanning of the strider as it passes over the flooring material. The other two test methods did not show a consistent trend for the three types of flooring.

With the James Tester and leather shoes, the vinyl tile had the highest coefficient of friction in the dry test. However, with the British Portable Tester and the Horizontal Pull Slipmeter and leather shoes, the linoleum had the highest value in the dry test. In the wet tests with leather shoes, all three methods showed linoleum to have the highest value.

8.0 Discussion of Possible Equipment Improvements

We believe that the apparatus used in all three tests could be improved by redesign or modification. This was especially true of the Horizontal Pull Slipmeter.

Our suggestions for improvements in the test apparatus are as follows:

<u>James Tester</u>

a) The recording pencil should be replaced by a pen with a much stronger release spring. The lines drawn by the pencil are very faint towards the end of the curves.

b) The springs of the chart clamps are weak, and easily bent. Unless the charts are fixed by other means, such as adhesive tape, they frequently come loose during the test. Thus, improved chart clamps are needed.

c) Lock nuts are needed for some of the bolts of the Tester. The impact of the 80 lb. weight on the shoe falling at the end of the test gradually loosens some of the bolts of the Tester and frequent tightening is necessary.

d) The Tester needs leveling bolts, and indicators. Shims under the legs are the best way of leveling the Tester at present. This method of leveling the Tester is unsatisfactory because the Tester is free to slide on them during the tests.

e) The Tester utilizes an 80 lb. (3.63 kg) weight and a relatively large shoe contact area. Studies are needed to determine if the shoe contact area and the weight could be reduced substantially. Reducing the weight of the Tester could make it portable, and therefore, suitable for field studies.

f) The shock absorber currently used is a rubber biscuit. This is not sufficient to prevent shaking due to the large weight applied to the shoe. It is not practicable to increase the thickness of the biscuit because that would restrict even further the slide path of the shoe. If an 80 lb. (36.3 kg) weight is necessary, a spring shock absorber may be a better alternative. If the weight can be reduced, a smaller absorber may be an appropriate alternate.

<u>British Portable Tester</u>

A method for conversion of the British Portable Test Numbers to coefficients of friction should be developed. This may not be possible, since this machine measures line contact between the shoe on the pendulum and the flooring surface and the pressure on the shoe during the pendulum swing is not constant over the path of contact. It is also highly receptive to hydroplanning of the slider in wet surfaces. This test method, therefore, has inherent weaknesses resulting from the basic design of the equipment which, we believe, may make it less acceptable for standard methods than the other two studied.

Horizontal Pull Slipmeter

The Horizontal Pull Slipmeter, in our opinion, would be more accurate and versatile if the following modifications were made:

a) The pull cord presently used is made of cotton string. It is fairly elastic, and during the test, can introduce variations in test results. Consideration should be given to replacing the cotton string with a polymeric cord or wire so that stretching can be minimized. The cord, however, must be very flexible.

b) The power unit has only one speed, which is very slow. If the speed could be varied, the apparatus would be more versatile for frictional characteristics studies.

c) The present recording meter should be replaced by one which is more accurate. For example, the indicator occasionally was observed to slip from the maximum reading to a lower reading. Also, the accuracy of the recorder, as indicated by the manufacturer, is poor in the higher slip index range. The results above a slip index of 8.0 (coefficient of friction of 0.80) must be obtained by extrapolation.

d) The Slipmeter was observed to "stick-slip" frequently during the tests. Design changes are needed to minimize this effect.

9.0 Conclusions

1. The reproducibility of the James Static Friction Test fitted with the leather shoe was very good. The friction between the styrene butadiene rubber shoe and all resilient flooring samples both dry and wet was too high to be determined by the James Tester.

2. The reproducibility of the British Portable Test was good, and it was capable of evaluating the frictional properties between styrene butadiene rubber and all three types of resilient flooring, dry and wet.

3. The Horizontal Pull Slipmeter Test had good reproducibility for leather in contact with all three types of resilient flooring, both dry and wet. However, this test is not accurate for measuring coefficients of friction higher than 0.8, which is the region in which rubber and resilient flooring friction falls.

4. There was some correlation between results from the James Test and the Horizontal Pull Slipmeter Test as discussed in Section 7, but there was little correlation between the results from the British Portable Test and those of the other tests. However, this is understandable because the tests do not necessarily measure the same frictional properties, largely because of the differences in speed and inter-surface pressures at which the tests are conducted.

5. To obtain a fuller understanding of the significance of the results of these tests and the capabilities of the apparatus used in performing them, a much larger range of flooring samples than that used in our preliminary study should be investigated. A wider range of sole and heel materials should also be used in these tests. This is discussed in the Project Proposal entitled "Safety Criteria for Slipperiness of Flooring", in the Appendix.

6. There is a need for additional studies to improve existing floor slipperiness test methods or develop new methods to adequately reflect human perambulation factors.

7. From the work done in the preliminary study, it is obvious that with some design modifications, the apparatus used in the three test methods evaluated could be improved. This is particularly true for the Horizontal Pull Slipmeter and the James Tester.

Acknowledgement

Acknowledgement is hereby given to Mr. Jack Lee and Mr. Edward Embree for their substantial efforts in obtaining the test data presented in this report.

Acknowledgement is also given to Dr. Robert J. Brungraber, Intergovernmental Personnel Act appointee to the Building Safety Section, National Bureau of Standards, for his assistance in editing this report.

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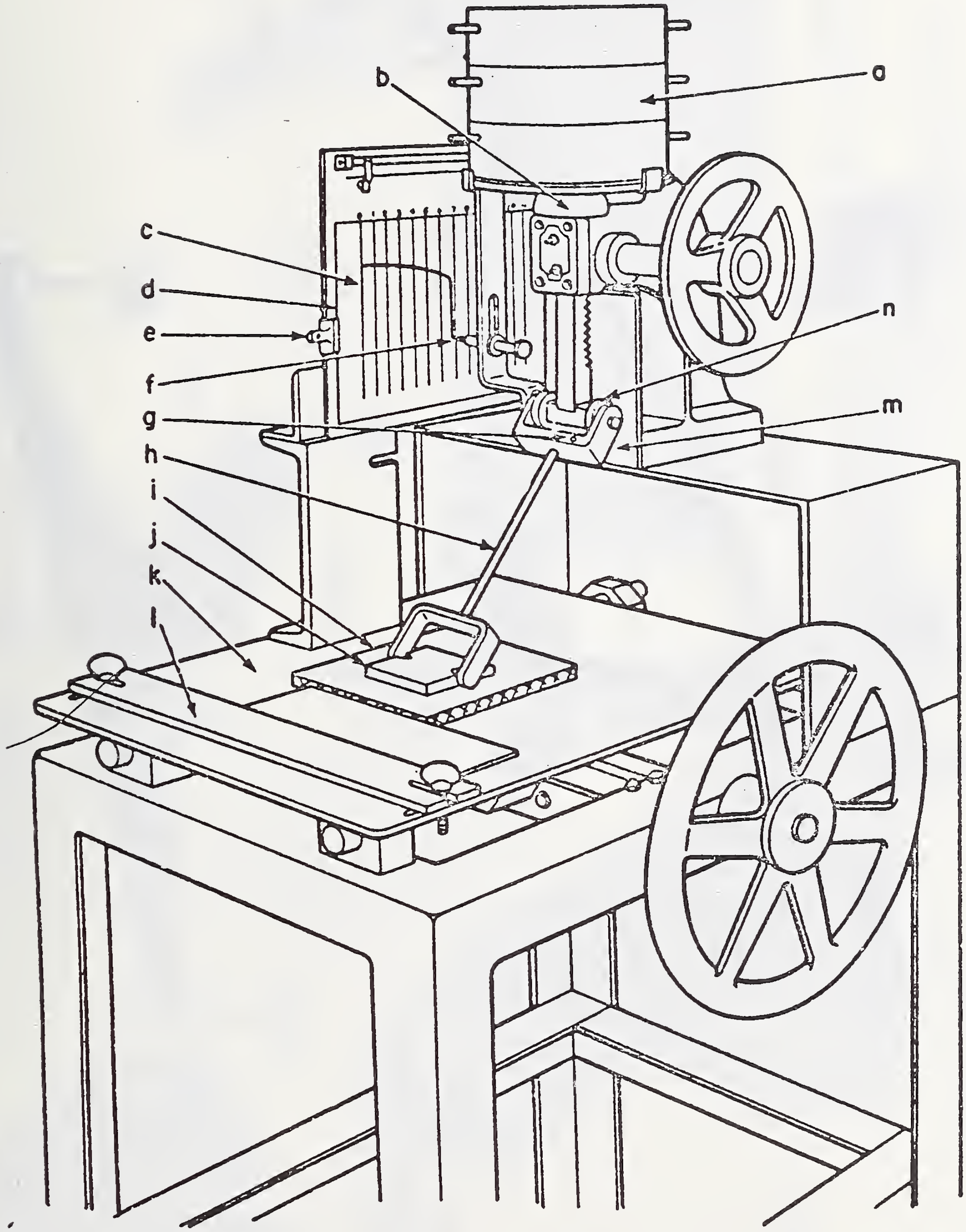
Figure 1

JAMES STATIC FRICTION TESTER



a—Weights	h—Strut
b—Cushion	i—Specimen
c—Chart	j—Shoe
d—Chart Board	k—Test Table
e—Spring Clip	l—Retaining Bar
f—Recording Pencil	m—Back Plate
g—Set Screw	n—Ball Bearing Rollers

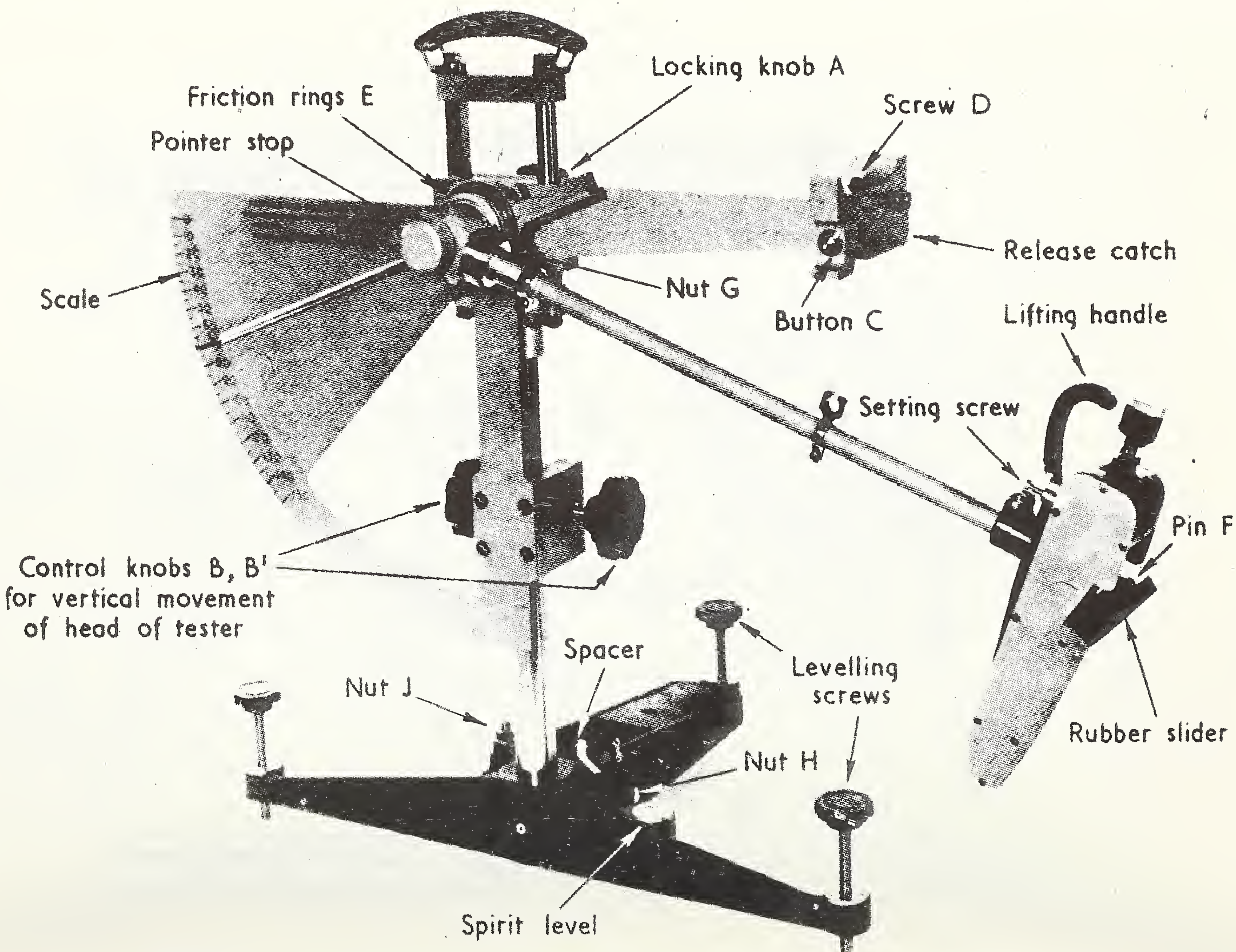


Figure 2.

BRITISH PORTABLE SKID-RESISTANCE TESTER

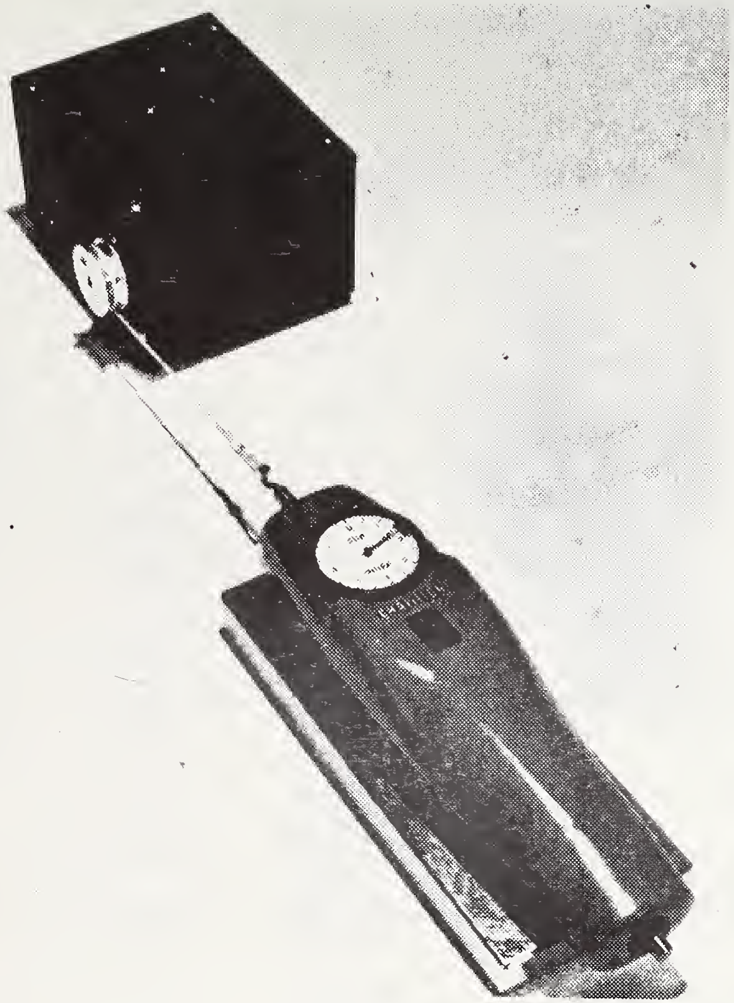


Figure 3.

HORIZONTAL PULL SLIPMETER

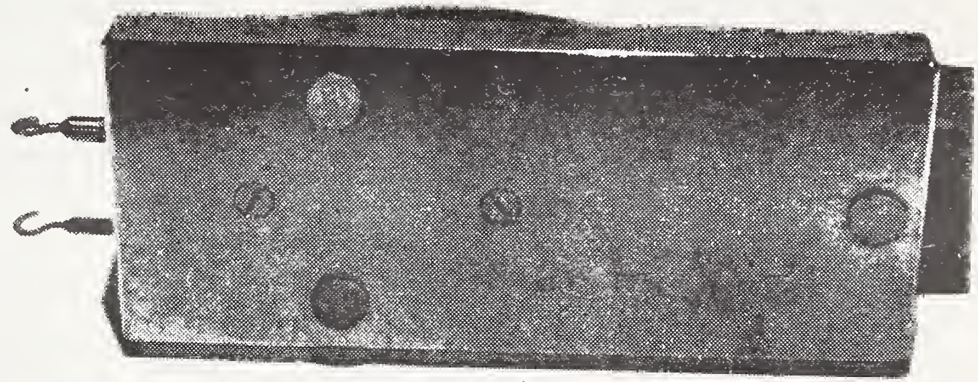


Figure 4.

BOTTOM OF HORIZONTAL PULL SLIPMETER
SHOWING LEATHER FEET

Table I
APPARATUS FOR MEASURING SLIP-RESISTANCE*

Designation	Type	Friction Measured	Method of	Versatility	Common Use	Developer and/or User	Remarks
Weighted Bag	Horizontal Track	Static and Dynamic	Horizontal Force	Field and Laboratory	Treated Flooring	Hospital Bureau, Inc.; Post Office Department	Results depend on operation technique.
Egan	Horizontal Track	Static and Dyanmic	Horizontal Force	Laboratory only		Thwing-Albert Instrument Company	Little work apparently done so far on flooring materials.
Polishing Brush	Horizontal Track	Dynamic	Force in Energy (Electrical)	Field and Laboratory	Treated Flooring	Bell Laboratories (AT&T) Public Buildings Administration	Good machine, justifies more research.
Hunter	Horizontal Track	Static	Angle of Force	Laboratory only	Flooring	National Bureau of Standards	Replaced by James and Dura machines.
James	Horizontal Track	Static	Angle of Force	Laboratory only	Treated Flooring	Underwriters' Laboratories, Inc.	Limited measurements, static only.
Dura	Horizontal Track	Static	Angle of Force	Laboratory only	Flooring	Dura Commodities Corporation, Germany and New York	Limited measurements, static only
Horizontal Pull Slipmeter	Horizontal Track	Static and Dynamic	Horizontal Force	Field and Laboratory	Flooring	Olson Medical Products, Inc.	Good machine, could easily be made more versatile.
Sigler	Pendulum	Decelerating Dynamic	Loss in Energy	Field and Laboratory	Flooring	National Bureau of Standards	Good principle; too fragile.
Leroux	Pendulum	Decelerating Dynamic	Loss in Energy	Field and Laboratory	Roadways	M. Leroux, Netherlands	
British	Pendulum	Decelerating Dynamic	Loss in Energy	Field and Laboratory	Roadways	Road Research Laboratory Great Britain	Good machine needs more research on flooring materials.
NCSA Wheel	Flywheel	Decelerating Dynamic	Loss in Energy	Field and Laboratory	Roadways	National Crushed Stone Association	Bicycle tire should be standardized.
Travelers	Pendulum & Horizontal Track	Decelerating Dynamic	Distance of Travel	Field and Laboratory	Flooring	Travelers Insurance Company	

*Table taken from Federal Construction Council Technical Report No. 43, Publication 899, National Academy of Sciences, National Research Council, Washington, D.C., 1961.

Table 2. Static Coefficients of Friction of Vinyl Asbestos Tile Using the James Static Friction Tester

Test Constants: Ambient Temp. °F 74 ± 1 — Relative Humidity % 45 + 3

Weight on Shoe, Total, Lbs. 80 — Platform Speed, inches per minute 100.

Slip Direction Machine

TYPE OF FLOORING	COEFFICIENT OF STATIC FRICTION					
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	100% Leather 1/4 in thick Wet	Sample No.	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Wet
Vinyl Asbestos Tile	1	0.41, 0.40, 0.46 0.45, 0.43	0.41, 0.41, 0.42 0.43, 0.43	1	No slip (NS)	NS
Average & std. dev.		0.43 ± 0.03	0.42 ± 0.01			
	2	0.43, 0.39, 0.41 0.41, 0.41	0.43, 0.44, 0.40 0.40, 0.41	2	NS	NS
Average & std. dev.		0.41 ± 0.01	0.42 ± 0.02			
	3	0.43, 0.41, 0.40 0.41, 0.41	0.43, 0.43, 0.40 0.39, 0.39	3	NS	NS
Average & std. dev.		0.41 ± 0.01	0.41 ± 0.02			
	4	0.42, 0.43, 0.43 0.41, 0.41	0.39, 0.40, 0.40 0.39, 0.41	4	NS	NS
Average & std. dev.		0.42 ± 0.01	0.40 ± 0.01			
	5	0.43, 0.44, 0.43 0.41, 0.42	0.39, 0.40, 0.42 0.41, 0.41	5	NS	NS
Average & std. dev.		0.43 ± 0.01	0.41 ± 0.01			
Total average & std. dev.		0.42 ± 0.02	0.41 ± 0.02			

Table 3. Static Coefficients of Friction of Vinyl Tile Using the James Static Friction Tester

Test Constants: Ambient Temp. °F 74 ± 1 Relative Humidity % 45 ± 3

Weight on Shoe, Total, Lbs. 80 Platform Speed, inches per minute 100.

Slip Direction Machine

TYPE OF FLOORING	COEFFICIENT OF STATIC FRICTION					
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	100% Leather 1/4 in thick Wet	Sample No.	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Wet
Vinyl Tile	1	0.63, 0.59, 0.62 0.54, 0.53	0.33, 0.34, 0.33 0.32, 0.33	1	No slip (NS)	NS
Average & std. dev.		0.58 ± 0.05	0.33 ± 0.01			
	2	0.60, 0.64, 0.65 0.65, 0.64	0.37, 0.36, 0.35 0.37, 0.35	2	NS	NS
Average & std. dev.		0.64 ± 0.02	0.36 ± 0.01			
	3	0.62, 0.63, 0.64 0.65, 0.66	0.36, 0.37, 0.37 0.37, 0.36	3	NS	NS
Average & std. dev.		0.64 ± 0.02	0.37± 0.01			
	4	0.56, 0.56, 0.57 0.60, 0.61	0.34, 0.35, 0.37 0.35, 0.37	4	NS	NS
Average & std. dev.		0.58 ± 0.02	0.36 ± 0.01			
	5	0.55, 0.58, 0.58 0.60, 0.60	0.33, 0.34, 0.33 0.32, 0.33	5	NS	NS
Average & std. dev.		0.58 ± 0.02	0.33 ± 0.01			
Total average & std. dev.		0.60 ± 0.04	0.35 ± 0.02			

Table 4. Static Coefficients of Friction of Linoleum Using the James Static Friction Tester

Test Constants: Ambient Temp. °F 74 ± 1 Relative Humidity % 45 ± 3

Weight on Shoe, Total, Lbs. 80 Platform Speed, inches per minute 100.

Slip Direction Machine

TYPE OF FLOORING	COEFFICIENT OF STATIC FRICTION					
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	100% Leather 1/4 in thick Wet	Sample No.	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Wet
Linoleum	1	0.55, 0.60, 0.57 0.57, 0.56	0.46, 0.42, 0.43 0.43, 0.43	1	No Slip (NS)	NS
Average & std. dev.		0.57 ± 0.02	0.43 ± 0.02			
	2	0.55, 0.55, 0.55 0.58, 0.55	0.43, 0.44, 0.44 0.43, 0.45	2	NS	NS
Average & std. dev.		0.56 ± 0.01	0.44 ± 0.01			
	3	0.62, 0.58, 0.58 0.55, 0.56	0.47, 0.47, 0.44 0.46, 0.47	3	NS	NS
Average & std. dev.		0.58 ± 0.03	0.46 ± 0.01			
	4	0.55, 0.57, 0.60 0.55, 0.56	0.45, 0.45, 0.45 0.44, 0.43	4	NS	NS
Average & std. dev.		0.57 ± 0.02	0.44 ± 0.01			
	5	0.55, 0.55, 0.54 0.57, 0.56	0.45, 0.47, 0.48 0.46, 0.47	5	NS	NS
Average & std. dev.		0.55 ± 0.01	0.47 ± 0.01			
Total average & std. dev.		0.57 ± 0.02	0.45 ± 0.02			

Table 5. Static Coefficients of Friction of Resilient Flooring Using the James Static Friction Tester

Test Constants: Ambient Temp. °F 74 ± 1 — Relative Humidity % 45 ± 3

Weight on Shoe, Total, Lbs. 80 — Platform Speed, inches per minute 100.

Slip Direction Machine

TYPE OF FLOORING		COEFFICIENT OF STATIC FRICTION*				
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	100% Leather 1/4 in thick Wet	Sample No.	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Wet
Vinyl Asbestos Tile	1	0.43 ± 0.03	0.42 ± 0.01	1	No slip	No slip
	2	0.41 ± 0.01	0.42 ± 0.02	2	No slip	No slip
	3	0.41 ± 0.01	0.41 ± 0.02	3	No slip	No slip
	4	0.42 ± 0.01	0.40 ± 0.01	4	No slip	No slip
	5	0.43 ± 0.01	0.41 ± 0.01	5	No slip	No slip
Total average & std. dev.		0.42 ± 0.02	0.41 ± 0.02			
Vinyl Tile	1	0.58 ± 0.05	0.33 ± 0.01	1	No slip	No slip
	2	0.64 ± 0.02	0.36 ± 0.01	2	No slip	No slip
	3	0.64 ± 0.02	0.37 ± 0.01	3	No slip	No slip
	4	0.58 ± 0.02	0.36 ± 0.01	4	No slip	No slip
	5	0.58 ± 0.02	0.33 ± 0.01	5	No slip	No slip
Total average & std. dev.		0.60 ± 0.04	0.35 ± 0.02			
Linoleum	1	0.57 ± 0.02	0.43 ± 0.02	1	No slip	No slip
	2	0.56 ± 0.01	0.44 ± 0.01	2	No slip	No slip
	3	0.58 ± 0.03	0.46 ± 0.01	3	No slip	No slip
	4	0.57 ± 0.02	0.44 ± 0.01	4	No slip	No slip
	5	0.55 ± 0.01	0.47 ± 0.01	5	No slip	No slip
Total average & std. dev.		0.57 ± 0.02	0.45 ± 0.02			

*Values for each sample number represent the average and standard deviation of five determinations.

Table 6. British Portable Test Number of Vinyl Asbestos Tile Using the British Portable Skid Resistance Tester

Test Constants: Ambient Temp. °F 74 ± 1 Relative Humidity % 45 ± 3

Slip direction: Machine

TYPE OF FLOORING	BRITISH PORTABLE TEST NUMBER					
Shoe Material:		100% Leather 1/4 in thick			Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630)	
Moisture Condition of Shoe & Sample	Sample No.	Dry	Wet	Sample	Dry	Wet
Vinyl Asbestos Tile	1	34, 34, 34 32, 33, 33	11, 11, 11 11, 11, 11	1	105, 106, 107 109, 107, 108	25, 24, 24, 24, 24, 25
Average & std. dev.		33.3 ± 0.8	11.0 ± 0.0		107.0 ± 1.4	24.3 ± 0.5
	2	34, 34, 36 36, 36, 36	10, 10, 10 10, 10, 10	2	100, 98, 102 105, 102, 102	25, 24, 25 26, 25, 24
Average & std. dev.		35.3 ± 1.0	10.0 ± 0.0		101.5 ± 2.3	24.8 ± 0.8
	3	38, 38, 38 38, 38, 38	10, 10, 10 10, 10, 10	3	107, 107, 105 105, 107, 105	27, 27, 26 26, 27, 27
Average & std. dev.		38.0 ± 0.0	10.0 ± 0.0		106.0 ± 1.1	26.7 ± 0.5
	4	38, 38, 38 38, 38, 38	10, 10, 10 10, 10, 10	4	96, 102, 104, 94, 97, 96	24, 24, 23 23, 24, 23
Average & std. dev.		38.0 ± 0.0	10.0 ± 0.0		98.2 ± 3.9	23.6 ± 0.6
	5	40, 40, 40 40, 40, 40	10, 10, 10 10, 10, 10	5	94, 93, 96 95, 95, 94	25, 25, 23 24, 23, 23
Average & std. dev.		40.0 ± 0.0	10.0 ± 0.0		94.5 ± 1.1	23.8 ± 1.0
Total average & std. dev.		36.9 ± 2.4	10.2 ± 0.4		101.4 ± 5.2	24.6 ± 1.3

Table 7. British Portable Test Number of Vinyl Tile Using the British Portable Skid Resistance Tester

Test Constants: Ambient Temp. °F 74 ± 1 Relative Humidity % 45 ± 3

Slip direction: Machine

TYPE OF FLOORING	BRITISH PORTABLE TEST NUMBER					
Shoe Material: Moisture Condition of Shoe Sample	Sample No.	100% Leather 1/4 in thick Dry	100% Leather 1/4 in thick Wet	Sample	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Wet
Vinyl Tile	1	19, 19, 19 19, 19, 19	10, 10, 10 10, 10, 10	1	93, 92, 94 93, 94, 90	14, 14, 14 14, 14, 14
Average & std. dev.		19.0 ± 0.0	10.0 ± 0.0		92.7 ± 1.5	14.0 ± 0.0
	2	22, 22, 22 22, 22, 22	10, 10, 10 10, 10, 10	2	90, 91, 92 92, 92, 93	15, 14, 15 14, 14, 14
Average & std. dev.		22.0 ± 0.0	10.0 ± 0.0		91.7 ± 1.0	14.3 ± 0.5
	3	20, 20, 20 20, 20, 20	11, 11, 11 11, 11, 11	3	93, 95, 88 91, 90, 88	14, 14, 14 14, 14, 14
Average & std. dev.		20.0 ± 0.0	11.0 ± 0.0		90.8 ± 2.8	14.0 ± 0.0
	4	20, 20, 20 20, 20, 20	11, 11, 11 11, 11, 11	4	89, 90, 90 86, 90, 92	15, 15, 15 14, 14, 15
Average & std. dev.		20.0 ± 0.0	11.0 ± 0.0		89.5 ± 2.0	14.7 ± 0.5
	5	16, 16, 16 16, 16, 16	10, 10, 10 10, 10, 10	5	91, 91, 91 91, 90, 92	14, 14, 14 14, 14, 14
Average & std. dev.		16.0 ± 0.0	10.0 ± 0.0		91.0 ± 0.6	14.0 ± 0.0
Total average & std. dev.		19.4 ± 2.0	10.4 ± 0.5		91.1 ± 1.9	14.2 ± 0.4

Table 8. British Portable Test Number of Linoleum
Using the British Portable Skid Resistance Tester

Test Constants: Ambient Temp. °F 74 ± 1 Relative Humidity % 45 ± 3

Slip direction: Machine

TYPE OF FLOORING	BRITISH PORTABLE TEST NUMBER					
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	100% Leather 1/4 in thick Wet	Sample	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Wet
Linoleum	1	50, 50, 50 50, 50, 50	30, 30, 30 30, 30, 30	1	117, 114, 113 113, 118, 118	43, 43, 43 43, 42, 42
Average & std. dev.		50.0 ± 0.0	30.0 ± 0.0		115.5 ± 2.4	42.7 ± 0.5
	2	55, 55, 55 55, 55, 55	25, 25, 25 25, 25, 25	2	123, 122, 122 123, 122, 122	40, 39, 39 39, 39, 38
Average & std. dev.		55.0 ± 0.0	25.0 ± 0.0		122.3 ± 0.5	39.0 ± 0.6
	3	60, 60, 60 60, 60, 60	24, 24, 24 24, 23, 23	3	117, 117, 116 118, 118, 116	40, 40, 40 40, 40, 40
Average & std. dev.		60.0 ± 0.0	23.7 ± 0.5		117.0 ± 0.9	40.0 ± 0.0
	4	60, 60, 60 60, 60, 60	23, 23, 23 23, 23, 23	4	119, 118, 120 117, 118, 119	40, 40, 40 40, 40, 40
Average & std. dev.		60.0 ± 0.0	23.0 ± 0.0		118.5 ± 1.1	40.0 ± 0.0
	5	64, 64, 64 64, 64, 64	30, 30, 30 30, 30, 30	5	113, 110, 114 115, 111, 114	45, 45, 45 45, 45, 45
Average & std. dev.		64.0 ± 0.0	30.0 ± 0.0		112.8 ± 1.9	45.0 ± 0.0
Total average & std. dev.		57.8 ± 4.9	26.3 ± 3.1		117.2 ± 3.5	41.3 ± 2.3

Table 9. British Portable Test Number of Resilient Flooring Using the British Portable Skid Resistance Tester

Test Constants: Ambient Temp. °F 74 ± 1 Relative Humidity % 45 ± 3

Slip direction: Machine

TYPE OF FLOORING	BRITISH PORTABLE TEST NUMBER					
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	100% Leather 1/4 in thick Wet	Sample	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Wet
Vinyl Asbestos Tile	1	33.3 ± 0.8	11.0 ± 0.0	1	107.0 ± 1.4	24.3 ± 0.5
	2	35.3 ± 1.0	10.0 ± 0.0	2	101.5 ± 2.3	24.8 ± 0.8
	3	38.0 ± 0.0	10.0 ± 0.0	3	106.0 ± 1.1	26.7 ± 0.5
	4	38.0 ± 0.0	10.0 ± 0.0	4	98.2 ± 3.9	23.6 ± 0.6
	5	40.0 ± 0.0	10.0 ± 0.0	5	94.5 ± 1.1	23.8 ± 1.0
Average & std. dev.		36.9 ± 2.4	10.2 ± 0.4		101.4 ± 5.2	24.6 ± 1.3
Vinyl Tile	1	19.0 ± 0.0	10.0 ± 0.0	1	92.7 ± 1.5	14.0 ± 0.0
	2	22.0 ± 0.0	10.0 ± 0.0	2	91.7 ± 1.0	14.3 ± 0.5
	3	20.0 ± 0.0	11.0 ± 0.0	3	90.8 ± 2.8	14.0 ± 0.0
	4	20.0 ± 0.0	11.0 ± 0.0	4	89.5 ± 2.0	14.7 ± 0.5
	5	16.0 ± 0.0	10.0 ± 0.0	5	91.0 ± 0.6	14.0 ± 0.0
Average & std. dev.		19.4 ± 2.0	10.4 ± 0.5		91.1 ± 1.9	14.2 ± 0.4
Linoleum	1	50.0 ± 0.0	30.0 ± 0.0	1	115.5 ± 2.4	42.7 ± 0.5
	2	55.0 ± 0.0	25.0 ± 0.0	2	122.3 ± 0.5	39.0 ± 0.6
	3	60.0 ± 0.0	23.7 ± 0.5	3	117.0 ± 0.9	40.0 ± 0.0
	4	60.0 ± 0.0	23.0 ± 0.0	4	118.5 ± 1.1	40.0 ± 0.0
	5	64.0 ± 0.0	30.0 ± 0.0	5	112.8 ± 1.9	45.0 ± 0.0
Average & std. dev.		57.8 ± 4.9	26.3 ± 3.1		117.2 ± 3.5	41.3 ± 2.3

Table 10 British Portable Test Number of Vinyl Asbestos Tile Using the British Portable Skid Resistance Tester

Test Constants: Ambient Temp. °F 74 ± 1 Relative Humidity % 45 ± 3

Slip direction: Across Machine

TYPE OF FLOORING	BRITISH PORTABLE TEST NUMBER					
Shoe Material:		100% Leather 1/4 in thick			Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630)	
Moisture Condition of Shoe & Sample	Sample No.	Dry	Wet	Sample	Dry	Wet
Vinyl Asbestos Tile	1	34, 34, 34 34, 34, 34	11, 11, 11 11, 11, 11	1	100, 100, 98 101, 101, 100	26, 26, 25 24, 27, 25
Average & std. dev.		34.0 ± 0.0	11.0 ± 0.0		100.0 ± 1.1	25.5 ± 1.1
	2	35, 35, 35 35, 35, 35	11, 11, 11 11, 11, 11	2	100, 101, 101 101, 101, 100	25, 25, 24 24, 24, 24
Average & std. dev.		35.0 ± 0.0	11.0 ± 0.0		100.7 ± 0.5	24.3 ± 0.5
	3	38, 38, 38 38, 38, 38	10, 10, 10 10, 10, 10	3	107, 107, 107 107, 107, 106	26, 27, 27 26, 25, 27
Average & std. dev.		38.0 ± 0.0	10.0 ± 0.0		106.8 ± 0.4	26.3 ± 0.8
	4	40, 40, 40 40, 40, 40	10, 10, 10 10, 10, 10	4	96, 93, 95 99, 97, 110	25, 24, 24 24, 25, 25
Average & std. dev.		40.0 ± 0.0	10.0 ± 0.0		98.3 ± 6.1	24.5 ± 0.6
	5	40, 40, 40 40, 40, 40	10, 10, 10 10, 10, 10	5	93, 93, 93 93, 93, 92	27, 27, 26 26, 26, 25
Average & std. dev.		40.0 ± 0.0	10.0 ± 0.0		92.8 ± 0.4	26.2 ± 0.8
Total average & std. dev.		37.4 ± 2.5	10.4 ± 0.5		99.7 ± 5.3	25.3 ± 1.1

Table 11. British Portable Test Number of Vinyl Tile Using the British Portable Skid Resistance Tester

Test Constants: Ambient Temp. °F 74 ± 1 Relative Humidity % 45 ± 3

Slip direction: Across Machine

TYPE OF FLOORING	BRITISH PORTABLE TEST NUMBER					
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	100% Leather 1/4 in thick Wet	Sample	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Wet
Vinyl Tile	1	20, 20, 20 20, 20, 20	10, 10, 10 10, 10, 10	1	95, 95, 95 95, 96, 96	14, 14, 14 14, 14, 14
Average & std. dev.		20.0 ± 0.0	10.0 ± 0.0		95.3 ± 0.5	14.0 ± 0.0
	2	21, 21, 21 21, 21, 21	11, 11, 11 11, 11, 11	2	94, 94, 95 95, 95, 95	14, 14, 14 14, 14, 14
Average & std. dev.		21.0 ± 0.0	11.0 ± 0.0		94.7 ± 0.5	14.0 ± 0.0
	3	20, 20, 20 20, 20, 20	11, 11, 11 11, 11, 11	3	93, 95, 85 96, 86, 95	14, 14, 14 14, 14, 14
Average & std. dev.		20.0 ± 0.0	11.0 ± 0.0		91.7 ± 4.9	14.0 ± 0.0
	4	20, 20, 20 20, 20, 20	11, 11, 11 11, 11, 11	4	91, 91, 92 92, 93, 92	15, 14, 14 14, 14, 14
Average & std. dev.		20.0 ± 0.0	11.0 ± 0.0		91.8 ± 0.8	14.2 ± 0.4
	5	17, 17, 17 17, 17, 17	12, 12, 12 12, 12, 12	5	95, 95, 94 95, 93, 95	14, 14, 14 14, 14, 14
Average & std. dev.		17.0 ± 0.0	12.0 ± 0.0		94.5 ± 0.8	14.0 ± 0.0
Total average & std. dev.		19.6 ± 1.4	11.0 ± 0.6		93.6 ± 2.6	14.0 ± 0.2

Table 12. British Portable Test Number of Vinyl Asbestos and Vinyl Tile Using the British Portable Skid Resistance Tester

Test Constants: Ambient Temp. °F 74 ± 1 Relative Humidity % 45 ± 3

Slip direction: Across Machine

TYPE OF FLOORING	BRITISH PORTABLE TEST NUMBER					
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	Wet	Sample	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Wet
Vinyl Asbestos Tile	1	34.0 ± 0.0	11.0 ± 0.0	1	100.0 ± 1.1	25.5 ± 1.1
	2	35.0 ± 0.0	11.0 ± 0.0	2	100.7 ± 0.5	24.3 ± 0.5
	3	38.0 ± 0.0	10.0 ± 0.0	3	106.8 ± 0.4	26.3 ± 0.8
	4	40.0 ± 0.0	10.0 ± 0.0	4	98.3 ± 6.1	24.5 ± 0.6
	5	40.0 ± 0.0	10.0 ± 0.0	5	92.8 ± 0.4	26.2 ± 0.8
Average & std. dev.		37.4 ± 2.5	10.4 ± 0.5		99.7 ± 5.3	25.3 ± 1.1
Vinyl Tile	1	20.0 ± 0.0	10.0 ± 0.0	1	95.3 ± 0.5	14.0 ± 0.0
	2	21.0 ± 0.0	11.0 ± 0.0	2	94.7 ± 0.5	14.0 ± 0.0
	3	20.0 ± 0.0	11.0 ± 0.0	3	91.7 ± 4.9	14.0 ± 0.0
	4	20.0 ± 0.0	11.0 ± 0.0	4	91.8 ± 0.8	14.2 ± 0.4
	5	17.0 ± 0.0	12.0 ± 0.0	5	94.5 ± 0.8	14.0 ± 0.0
Average & std. dev.		19.6 ± 1.4	11.0 ± 0.6		93.6 ± 2.6	14.0 ± 0.2
Linoleum*	1			1		
	2			2		
	3			3		
	4			4		
	5			5		
Average & std. dev.						

*Linoleum samples not wide enough to measure slipperiness in transverse direction.

Table 13. COEFFICIENT OF FRICTION OF VINYL ASBESTOS TILE USING THE HORIZONTAL PULL SLIPMETER.

Test Constants: **Ambient Temperature °F** 74 ± 1 **Relative Humidity %** 45 ± 3

Slip Direction Machine

TYPE OF FLOORING		COEFFICIENT OF FRICTION				
Shoe Material:		100% Leather 1/4 in thick			Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630)	
Moisture Condition of Shoe & Sample	Sample No.	Dry	Wet	Sample No.	Dry	Wet
TYPE OF FRICTION		Static	Static		Dynamic	Dynamic
Vinyl Asbestos Tile	1	0.47, 0.47, 0.48, 0.48 0.48	0.66, 0.67 0.67, 0.69 0.70	1	0.80, 0.80, 0.80 0.82, 0.80	0.82, 0.83, 0.83, 0.80, 0.82
Average & std. dev.		0.48 ± 0.01	0.68 ± 0.02		0.80 ± 0.01	0.82 ± 0.01
	2	0.45, 0.46 0.46, 0.45 0.45	0.64, 0.66 0.67, 0.67 0.67	2	0.80, 0.82 0.80, 0.77 0.75	0.80, 0.83 0.83, 0.83 0.81
Average & std. dev.		0.45 ± 0.01	0.66 ± 0.01		0.79 ± 0.03	0.82 ± 0.01
	3	0.42, 0.42 0.43, 0.45 0.45	0.66, 0.64 0.68, 0.66 0.68	3	0.83, 0.83 0.83, 0.83 0.81	0.81, 0.82 0.77, 0.76 0.79
Average & std. dev.		0.43 ± 0.02	0.66 ± 0.02		0.83 ± 0.01	0.79 ± 0.03
	4	0.43, 0.43 0.42, 0.44 0.44	0.64, 0.65 0.66, 0.64 0.65	4	0.88, 0.85 0.85, 0.85 0.85	0.82, 0.81 0.82, 0.80 0.81
Average & std. dev.		0.43 ± 0.01	0.65 ± 0.01		0.86 ± 0.01	0.81 ± 0.01
	5	0.43, 0.43 0.42, 0.44 0.43	0.63, 0.64 0.64, 0.63 0.64	5	0.81, 0.80 0.82, 0.82 0.83	0.80, 0.81 0.81, 0.80 0.81
Average & std. dev.		0.43 ± 0.01	0.64 ± 0.01		0.82 ± 0.01	0.81 ± 0.01
Total average & std. dev.		0.44 ± 0.02	0.66 ± 0.02		0.82 ± 0.03	0.81 ± 0.02

Table 14. COEFFICIENT OF FRICTION OF VINYL TILE USING THE HORIZONTAL PULL SLIPMETER

Test Constants: Ambient Temperature °F 74 ± 1 Relative Humidity % 45 ± 3

Slip Direction Machine

TYPE OF FLOORING	COEFFICIENT OF FRICTION					
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	100% Leather 1/4 in thick Wet	Sample No.	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Wet
TYPE OF FRICTION		Static	Static		Dynamic	Dynamic
Vinyl Tile	1	0.57, 0.60 0.62, 0.50 0.58	0.68, 0.66 0.61, 0.65 0.67	1	0.96, 0.87 0.97, 0.97 0.98	0.95, 0.95 0.97, 0.96 0.92
Average & std. dev.		0.58 ± 0.02	0.65 ± 0.03		0.95 ± 0.05	0.95 ± 0.02
	2	0.65, 0.63 0.67, 0.68 0.65	0.53, 0.62 0.57, 0.54 0.58	2	0.91, 0.93 0.88, 0.86 0.90	0.94, 0.95 0.99, 1.0 0.99
Average & std. dev.		0.66 ± 0.02	0.57 ± 0.04		0.90 ± 0.03	0.97 ± 0.03
	3	0.59, 0.60 0.57, 0.57 0.56	0.68, 0.59 0.66, 0.64 0.62	3	0.92, 0.95 0.95, 0.92 0.96	0.96, 0.94 0.99, 0.99 0.94
Average & std. dev.		0.57 ± 0.02	0.64 ± 0.04		0.94 ± 0.02	0.96 ± 0.03
	4	0.63, 0.60 0.58, 0.58 0.55	0.58, 0.58 0.58, 0.58 0.60	4	0.97, 0.97 0.95, 0.94 0.96	0.99, 0.93 0.98, 0.92 0.97
Average & std. dev.		0.59 ± 0.03	0.58 ± 0.01		0.96 ± 0.01	0.96 ± 0.03
	5	0.52, 0.59 0.60, 0.60 0.58	0.56, 0.52 0.59, 0.53 0.60	5	0.99, 0.95 0.94, 0.95 0.97	0.95, 0.94 0.95, 0.96 0.96
Average & std. dev.		0.58 ± 0.03	0.56 ± 0.04		0.96 ± 0.02	0.95 ± 0.01
Total average & std. dev.		0.60 ± 0.04	0.60 ± 0.05		0.94 ± 0.03	0.96 ± 0.02

Table 15. COEFFICIENT OF FRICTION OF LINOLEUM USING THE HORIZONTAL PULL SLIPMETER.

Test Constants: Ambient Temperature °F 74 ± 1 Relative Humidity % 45 ± 3

Slip Direction Machine

TYPE OF FLOORING	COEFFICIENT OF FRICTION					
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	100% Leather 1/4 in thick Wet	Sample No.	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Wet
TYPE OF FRICTION		Static	Static		Dynamic	Dynamic
Linoleum	1	0.63, 0.65 0.64, 0.60 0.65	0.81, 0.87 0.86, 0.85 0.88	1	0.75, 0.80 0.80, 0.82	0.89, 0.85 0.86, 0.87 0.87
Average & std. dev.		0.63 ± 0.02	0.85 ± 0.03		0.78 ± 0.03	0.87 ± 0.02
	2	0.59, 0.62 0.66, 0.66 0.66	0.89, 0.86 0.88, 0.86 0.86	2	0.86, 0.85 0.85, 0.80 0.80	0.88, 0.90 0.86, 0.84 0.86
Average & std. dev.		0.64 ± 0.03	0.87 ± 0.01		0.83 ± 0.03	0.87 ± 0.02
	3	0.65, 0.66 0.66, 0.65 0.68	0.89, 0.90 0.87, 0.88 0.86	3	0.82, 0.82 0.82, 0.80 0.80	0.88, 0.87 0.85, 0.88 0.87
Average & std. dev.		0.66 ± 0.01	0.88 ± 0.02		0.81 ± 0.01	0.87 ± 0.01
	4	0.65, 0.64 0.64, 0.63 0.63	0.89, 0.90 0.89, 0.89 0.86	4	0.75, 0.75 0.80, 0.75 0.77	0.86, 0.89 0.86, 0.85 0.86
Average & std. dev.		0.64 ± 0.02	0.89 ± 0.01		0.76 ± 0.02	0.86 ± 0.02
	5	0.61, 0.62 0.60, 0.62 0.61	0.89, 0.89 0.89, 0.88 0.89	5	0.75, 0.80 0.80, 0.80 0.80	0.84, 0.88 0.88, 0.86 0.87
Average & std. dev.		0.61 ± 0.01	0.89 ± 0.01		0.79 ± 0.02	0.87 ± 0.02
Total average & std. dev.		0.64 ± 0.02	0.88 ± 0.02		0.80 ± 0.03	0.87 ± 0.02

Table 16. COEFFICIENT OF FRICTION OF RESILIENT FLOORING USING THE HORIZONTAL PULL SLIPMETER

Test Constants: Ambient Temperature °F 74 ± 1 Relative Humidity % 45 ± 3

Slip Direction Machine

TYPE OF FLOORING	*COEFFICIENT OF FRICTION					
Shoe Material: Moisture Condition of Shoe & Sample	Sample No.	100% Leather 1/4 in thick Dry	 Wet	Sample No.	Styrene Butadiene Rubber 1/4 in thick (Meets ASTM D 1630) Dry	 Wet
TYPE OF FRICTION		Static	Static		Dynamic	Dynamic
Vinyl Asbestos Tile	1	0.48 ± 0.01	0.68 ± 0.02		0.80 ± 0.01	0.82 ± 0.01
	2	0.45 ± 0.01	0.66 ± 0.01		0.79 ± 0.03	0.82 ± 0.01
	3	0.43 ± 0.02	0.66 ± 0.02		0.83 ± 0.01	0.79 ± 0.03
	4	0.43 ± 0.01	0.65 ± 0.01		0.86 ± 0.01	0.81 ± 0.01
	5	0.43 ± 0.01	0.64 ± 0.01		0.82 ± 0.01	0.81 ± 0.01
Total average & std. dev.		0.44 ± 0.02	0.66 ± 0.02		0.82 ± 0.03	0.81 ± 0.02
Vinyl Tile	1	0.58 ± 0.02	0.65 ± 0.03		0.95 ± 0.05	0.95 ± 0.02
	2	0.66 ± 0.02	0.57 ± 0.04		0.90 ± 0.03	0.97 ± 0.03
	3	0.57 ± 0.02	0.64 ± 0.04		0.94 ± 0.02	0.96 ± 0.03
	4	0.59 ± 0.03	0.58 ± 0.01		0.96 ± 0.01	0.96 ± 0.03
	5	0.58 ± 0.03	0.56 ± 0.04		0.96 ± 0.02	0.95 ± 0.01
Total average & std. dev.		0.60 ± 0.04	0.60 ± 0.05		0.94 ± 0.03	0.96 ± 0.02
Linoleum	1	0.63 ± 0.02	0.85 ± 0.03		0.78 ± 0.03	0.87 ± 0.02
	2	0.64 ± 0.03	0.87 ± 0.01		0.83 ± 0.03	0.87 ± 0.02
	3	0.66 ± 0.01	0.88 ± 0.02		0.81 ± 0.01	0.87 ± 0.01
	4	0.64 ± 0.02	0.89 ± 0.01		0.76 ± 0.02	0.86 ± 0.02
	5	0.61 ± 0.01	0.89 ± 0.01		0.79 ± 0.02	0.87 ± 0.02
Total average & std. dev.		0.64 ± 0.02	0.88 ± 0.02		0.80 ± 0.03	0.87 ± 0.02

*Values for each sample number represent the average and standard deviation of five determinations.

Table 17

COMPARISON OF FRICTIONAL PROPERTIES
OF RESILIENT FLOORING*

Test Method	Type of Flooring Tested		
	Vinyl Asbestos	Vinyl Tile	Linoleum
	(Average and standard deviations from 5 samples of each type of flooring.)		
James Static Friction Test	Static Coefficient of Friction		
Leather			
Dry	0.42 ± 0.02	0.60 ± 0.04	0.57 ± 0.02
Wet	0.41 ± 0.02	0.35 ± 0.02	0.45 ± 0.02
SB Rubber			
Dry	No Slip	No Slip	No Slip
Wet	No Slip	No Slip	No Slip
British Portable Skid Resistance Test (B.P.T. Number)	British Portable Test Number		
Leather			
Dry	36.9 ± 2.4	19.4 ± 2.0	57.8 ± 4.9
Wet	10.2 ± 0.4	10.4 ± 0.5	26.3 ± 3.1
SB Rubber			
Dry	101.4 ± 5.2	91.1 ± 1.9	117.2 ± 3.5
Wet	24.3 ± 1.3	14.2 ± 0.4	41.3 ± 2.3
Horizontal Pull Slipmeter			
Leather (Static coefficient of friction)			
Dry	0.44 ± 0.02	0.60 ± 0.04	0.64 ± 0.02
Wet	0.66 ± 0.02	0.60 ± 0.05	0.88 ± 0.02
Rubber (Dynamic coefficient of friction)			
Dry	0.82 ± 0.03	0.94 ± 0.03	0.80 ± 0.03
Wet	0.81 ± 0.02	0.96 ± 0.02	0.87 ± 0.02

*Slip in machine direction.

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NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS TR	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE Preliminary Study of the Slipperiness of Flooring			5. Publication Date 6. Performing Organization Code
7. AUTHOR(S) A. Philip Cramp - Larry W. Masters			8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			10. Project/Task/Work Unit No. 4615200 - 461.03 11. Contract/Grant No.
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* National Bureau of Standards Department of Commerce Washington, D. C. 20234			13. Type of Report & Period Covered Interim - July 1974 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

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

The National Commission on Product Safety reported in 1970, that falls in the home each year kill about 12,000 and injure 6,000,000 in the U.S.A. Slippery floors are listed as a large contributor to these very high casualty figures. Although there are some standardized test methods that are or might be suitable for such standards, there are no slipperiness standards for flooring. Thus, there is an immediate need for studies aimed at the development and establishment of such standards. Consequently, a preliminary study of floor slipperiness was sponsored by the Building Safety Section of the Center for Building Technology. The study included a state-of-the-art investigation on flooring slipperiness research and a laboratory evaluation of three existing test methods for measuring floor slipperiness. Samples of the three most commonly used resilient flooring materials, namely: vinyl asbestos, vinyl and linoleum were used in the study. The sliding material components for the frictional tests were leather and a commonly used styrene butadiene sole and heel rubber. The tests were performed both dry and wet. The results from this study were used in planning a large comprehensive study, which would lead to the development of accepted floor slipperiness standards. This report contains the results of the preliminary study.

Floor S

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)*

Floor Slipperiness; resilient flooring; slipperiness standards; frictional tests; slip tests; coefficient of friction; human perambulation.

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
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