APPRAISAL OF GLOSS AND SLIPPERINESS OF RESILIENT FLOOR COVERING MATERIALS

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by

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CHAPTER I

INTRODUCTION

Perhaps man has always been attracted to surfaces which have a high degree of gloss. Within recent years, the resilient floor covering industry has capitalized on this by producing materials which possess a high shine, along with such features as durability, color clarity, and ease of care. The wax manufacturers have made it possible to increase the glossiness of these resilient floor covering materials with polishes especially made to enhance their appearance.

A generally known fact is that more accidents occur in the home than any other place, and falls are responsible for a large percentage of these accidents. Today, when resilient floor covering materials are being used in every room of the house, the question has been raised as to whether the high gloss of these floor covering materials is an indication that they are also slippery. The present study sought to determine the relationship which exists between gloss and slipperiness. At a meeting of the Chemical Specialties Manufacturers Association in May, 1961, Dr. Steinle reported the following observations:

> I have proved by experiment that the manner in which people walk and slip is affected by what they see. To most people gloss means slipperiness. I have conducted an experiment where I had 100 people walk over two surfaces, one glossy, the other not. They did this twice, once blindfolded and once not. When they saw the floors there was an almost unanimous agreement that the glossy floor was the more slippery. When they were blindfolded this was not the case. About half of the walkers thought the duller floor was the more slippery.[1]

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[1]J. Vernon Steinle, "Waxed Floors Are Safe," Soap and Chemical Specialties, XXXVII (September, 1961), p. 82.

This same psychological concept was presented in an article which appeared in Institutions Magazine.

> The fourth reason [why people slip], and a frequently underrated and even forgotten one, is the mental condition of the individual doing the walking. This usually is most evident in the user's psychological reaction to seeing a shine on a floor. By long mental association of shine with slipperiness, it is too often assumed that a high gloss on a floor indicates a dangerously slippery condition. Illogical as it may seem, people slip more often on a floor that they think is slippery than on a floor that they do not think is slippery---although the two floors may have equal coefficients of friction.[2]

Thus, the relationship between gloss and slipperiness was presented as a psychological matter in these two articles. However, neither article presented any concrete evidence that a dull floor is less slippery than a shiny floor, only that people assume that shine also indicates slipperiness.

Mrs. Bush, Consumer Education Director, Johnson's Wax, presented this approach to the question of gloss and slipperiness:

> Never assume that a highly polished floor is not a safe floor. It happens to be a fact that the brighter the polish on a floor, the safer it is. The more you buff a polishing wax, the harder and drier the finish becomes. And the brighter the shine on a self-polishing wax, the more perfect the application and, therefore, the harder and drier it is. A hard, dry finish on a floor is a safe surface.[3]

According to Mrs. Bush, then, the belief that gloss is indicative of slipperiness is a fallacious one. However, as was true of the previous material quoted, no direct data supporting her statement was presented.

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[2] "Floor Safety is No Accident," Institutions Magazine, XLII (June, 1958), p. 56.

[3] Lucille Bush, "The Safe Home...in 1959," Speech given at 29th Annual Safety Convention of the Greater New York Safety Council, New York City, (April, 1959), p. 2. (Mimeographed.)

In a treatise on gloss, Harrison made the following suggestions for research: "The work which most urgently needs to be done is the correlation of measurements made according to different methods with one another and with visual estimations."[4] It was of interest to the investigator to determine how closely subjective evaluations of gloss and skid resistance would agree with instrumental values.

The present study was the third in a series of studies contributing to a state project entitled "Testing of Smooth Floor Surfaces and Finishes from the Standpoint of Safety,"[5] which is sponsored by the North Carolina Agricultural Experiment Station and contributes to the Southern Regional Housing Project, S-8. Two experiments have been carried to completion. In the first, the skid resistance of various combinations of resilient floor covering materials and shoe heel materials was tested.[6] In the second investigation the same floor covering materials were tested with four sizes of rubber and leather heels with the application of various weight loads to the heels.[7]

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[4]V. G. W. Harrison, Definition and Measurement of Gloss (Cambridge, England: W. Heffer & Sons Ltd., 1945), p. 133.

[5]Savannah S. Day, "Testing of Smooth Floor Surfaces and Finishes from the Standpoint of Safety." Research in progress.

[6]Jean Webb Trogdon, "Skid Resistance of Waxed and Unwaxed Smooth Floor Surfaces" (unpublished Master's thesis, The Woman's College of the University of North Carolina, Greensboro, 1962).

[7]Fern Tuten, "Testing of Skid Resistance of Smooth Floor Surfaces Using Various Sizes of Rubber and Leather Shoe Heels" (unpublished Master's thesis, The Woman's College of the University of North Carolina, Greensboro, 1963).

I. THE PROBLEM

<u>Statement of the problem</u>. It was the purpose of this study (1) to determine through the use of a glossmeter the gloss measurements of resilient floor covering materials in a new condition and when waxed with three different types of water-emulsion polishes, (2) to relate the gloss measurements determined with the glossmeter to the coefficients of friction previously determined with a friction-testing machine, (3) to secure gloss rankings of resilient floor covering materials in a new condition and in waxed conditions as rated by selected individuals, (4) to secure rankings of skid resistance of resilient floor covering materials in a new condition by employing the same individuals, and (5) to relate rankings of gloss and skid resistance of resilient floor covering materials and to relate each set of rankings to the instrument measurements.

<u>Importance of the study</u>. Judging from the literature which has been cited, the relationship between gloss and slipperiness has not been determined, and no known investigation exploring this relationship has been conducted. The need for this information led the writer to conduct such an investigation. Also considered worthwhile was the enlargement of the scope of the investigation to include a "touch" method whereby an individual could appraise the slipperiness of resilient floor covering materials and to compare this method with mechanical measurements.

In accordance with Harrison's suggestion, it was deemed important to correlate visual judgments and mechanical measurements of gloss to see whether or not these were in agreement. As an additional step, the experiment was extended to determine the effect of different types of polishes on the resilient floor covering materials as judged by individuals and mechanically recorded.

II. DEFINITIONS OF TERMS USED

Gloss. A property of surfaces which causes them to have a shiny or mirrorlike appearance as dependent upon the nature of the surface, such as type of material, texture, color, and finish.

Friction-testing machine. An apparatus used to determine the frictional force present when one surface slides over another.

Specular reflection. That reflection which occurs when the angle between the incident ray and the normal to the surface at the point of incidence equals the angle between the reflected ray and the normal.

Coefficient of friction. The ratio of the force of friction to the normal force holding two surfaces together.

Resilient floor covering. A smooth-surfaced material which has some capacity to compress when weight is applied and to gradually return to its original state when the weight is removed.

Water-emulsion polish. An aqueous dispersion of wax particles and other modifying ingredients in a solution.

Anti-skid ingredient. Colloidal silica or a latex constituent added to a polish to increase skid resistance.

CHAPTER II

REVIEW OF THE LITERATURE

Involved in this study were the measurement of gloss and of skid resistance of resilient floor covering materials when new and when waxed with water-emulsion polishes. The review of literature covers gloss in a general context, a brief history of water-emulsion polishes, studies concerned with the testing of the glossiness of floor polishes on resilient floor coverings, and studies of skid resistance in which actual coefficients of friction were derived.

MEASUREMENT OF GLOSS

In 1945, Harrison incorporated in a treatise summaries of all works of merit, as judged by the author, which had to do with gloss. His prime interest was in the field of paper and ink gloss testing; however, he attempted to uncover all pertinent research which had been conducted up to the date of publication of his book. He also made reference to research in progress at that time. In Part Four of his book, Mr. Harrison summed up the state of knowledge then existing, pointing out difficulties lying in the way of an exact specification of gloss and indicating lines along which progress might be made most rapidly.

Some of the points made by Mr. Harrison are that:

1. Gloss, smoothness and texture are not physical objects or quantities that can be measured in the same way as mass and length; they are sensations, or more correctly, sense

data: they are neither material nor purely mental; they are dependent on our own minds.[8]

2. The idea of surface finish can be analyzed into at least five different sets of sense data, three of which come to us through the sense of sight, and two through the sense of touch: these are---gloss (lustre), sharpness of mirror image, texture, smoothness, and frictional resistance. These qualities are independent of one another.[9]

3. Gloss is not a single sensation, but a complex of at least three simpler sensations - sharpness of mirror image, variations in the brightness of the surface when viewed at different angles, and the parallactic effect in which one sees one surface through, or behind, another.[10]

4. While measurements made with instruments are usually taken at fixed angles of incidence and viewing, in making a visual estimation of gloss, many angles of incidence and viewing are used, and final judgment is based, not on a single observation, but on a whole series of observations.[11]

5. Although gloss has a physical basis, it may have some GESTALT properties, in which case, if one is not careful, when one tries to analyze it, one may lose by the very process of analysis the property one is trying to study.[12]

In 1950, Hammond and Nimeroff were co-authors of a paper devoted to the topic of the measurement of 60° specular gloss. Their principle concern was the variables which affect glossmeter accuracy, these being the size of the receiver aperture, source aperture, and position of source image. These authors reiterated Mr. Harrison's statements concerning the variety of properties of a material which determine the

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[8]Harrison, op. cit., p. 6.

[9]Ibid., p. 117.

[10]Ibid.

[11]Ibid., p. 136.

[12]Ibid.

surface finish. Specifically, they said that "the appearance of an object depends upon several factors; the illuminant, the reflection characteristics of the material, the surface texture, the illuminating and viewing geometry, and the observer."[13]

Both color and gloss are attributes of reflection. Hammond and Nimeroff explained that color and glossiness of a specimen are determined by the spectral composition and geometric distribution of the incident light and upon the transformations that take place upon reflection from the specimen. A distinction was drawn between surface reflection and body reflection. Body reflection was described as reemission when the light penetrates the surface of the specimen and reemerges at the incident face.[14]

This concept of surface and body reflection corresponds to Hunter's explanation of specular and diffuse reflection.[15] He states that specular reflection occurs at the skin of the surface and diffuse reflection in the granular structure beneath the skin. Specular reflection gives rise to shininess or glossiness, diffuse reflection to whiteness and color.

Hammond and Nimeroff stated "that the reflected light received by the glossmeter may be considered to be composed of two parts, the specular

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[13]Harry K. Hammond, III, and Isadore Nimeroff, Measurement of Sixty Degree Specular Gloss, National Bureau of Standards, United States Department of Commerce, Research Paper RP2105 (Washington: Government Printing Office, 1950), p. 585.

[14]Ibid., p. 586.

[15]Richard Hunter, "Gloss Evaluation of Materials," ASTM Bulletin, No. 186 (December, 1952), p. 49.

reflection or true gloss contributed by the surface of the specimen and the diffuse reflection contributed by the body of the specimen. Thus we see that the light-scattering properties of the body of the specimen, or in a sense its body color, affects the measured gloss.[16] Upon these facts related to specular and diffuse reflection, the choice of a calibrating standard for glossmeters has been based. This standard is most commonly polished black glass because the light rays not reflected specularly are absorbed by the body of the material.

In addition to working with instrumental evaluation of gloss, Hunter has investigated visual criteria by which rankings of gloss are made. He concluded that there were at least six of these criteria and subsequently six types of gloss, which he defined as follows:

1. Specular gloss - shininess, brilliance of highlights (medium-gloss surfaces of paint, plastics, etc.).

2. Sheen - shininess at grazing angles (low-gloss surfaces of paint, paper, etc.).

3. Contrast gloss - contrast between specularly reflecting areas and other areas (low-gloss surfaces of paint, textile cloth, etc.).

4. Absence-of-bloom gloss - absence of haze, or milky appearance adjacent to reflected highlights (high- and semigloss surfaces in which reflected highlights may be seen).

5. Distinctness-of-image gloss - the distinctness and sharpness of mirror images (high-gloss surfaces in which mirror images may be seen).

6. Surface-uniformity gloss - surface uniformity, freedom from visible nonuniformities (medium-to-high-gloss surfaces of all types).[17]

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[16] Hammond and Nimeroff, op. cit., p. 593.

[17] Hunter, loc. cit.

Other important gloss features brought out by Mr. Hunter were that surface departures from planeness only one fourth the wave length of light are large enough to cause diminution and diversion of specularly reflected light. Dimension-wise, the smallest surface roughness which interferes with gloss is in the order of 0.1 micron.[18] The geometric distribution of reflected light varies with orientation as well as with direction of the incident light. When woven cloth is tested for gloss, the weave or pattern affects the readings obtained, and the direction of reflection is changed by brush marks on brushed paint panels. There are thus a variety of physical features which affect the geometric manner in which surfaces of objects reflect the light that is incident upon them.

One of the features which affects the reflection from a floor surface is the type of polish which is applied to it. Much of the research on floor polishes has been in relation to the development of synthetic ingredients and to the high gloss obtainable.

WATER-EMULSION FLOOR POLISHES

The beginning of the self-polishing, water-emulsion wax industry dates back to the late 1920's when it was discovered that Carnauba wax could be used on floors to impart a gloss without buffing.[19] This wax came from the Carnauba palm in Brazil. As the demand for Carnauba wax rose, its price steadily increased. For this reason, and because the

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[18] Ibid., p. 50.

[19] L. M. Prince and Dr. J. Zevallos, "Recent Trends in Aqueous Floor Polish," Soap and Chemical Specialties, XXXV (May, 1959), p. 135.

quality differed from shipment to shipment, manufacturers began looking for another source of wax. Many materials were tried separately and in combinations, some with a reasonable degree of desirable performance. As soon as it was found that a certain material was suitable, its price rose just as that of Carnauba wax had. What evolved was a search for a completely synthetic product which would be free of supply problems.

Extensive research has gone into the quest for synthetic ingredients for water-emulsion polishes of the self-polishing type. Synthetic polymer resins have been blended with emulsified wax and a solution of an alkali-soluble resin to produce high-gloss polymer emulsions of satisfactory quality.[20] Each constituent contributes some important property.

Low molecular weight emulsifiable polyethylene was experimentally added to emulsion floor polishes and improved buffability, water resistance, and slip resistance in some cases.[21] A subsequent investigation involved the addition of high molecular weight emulsifiable polyethylene. Great emphasis was placed on gloss and leveling in the series of tests involving this ingredient. It was concluded that gloss was relatively unaffected except at very high concentration; buffability, leveling, and water-spot

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[20] L. Chalmers, "Formulation of Emulsion Polishes," Reprint from Paint Manufacture (April, 1962) for Eastman Chemical Products, Inc.

[21] Robert Rosenbaum, Ralph Bock, and Robert E. Clark, "Property Changes of Emulsion Floor Polishes," Soap and Chemical Specialties, XXXIII (August, 1957), p. 83.

and slip resistance properties decreased as the concentration of polyethylene increased.[22]

One of the latest developments has been a new type of polymerized resin emulsion which forms a film which is resistant to washing by normal light detergents, water, or mild alkalis. It may be removed by washing with weak acid solutions.[23]

The emphasis upon high gloss in floor polish research is easily discernible. However, recently attention has been toward increasing the safety of floor polishes. One way this has been made possible is by the addition of colloidal silica. Although colloidal silica had been used for the past ten or twelve years, it was not compatible with the newer polymer polishes. A new form of colloidal silica was developed by the addition of aluminum to the silica molecule. The polymer polishes modified with colloidal silica for slip resistance have demonstrated constant anti-slip performance throughout the life of the polish in floor service tests. It has also been found to improve removability and enhance buffability.[24]

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[22]Walter J. Hackett, B. Berkeley, and R. E. Clark, "Polyethylene Latex in Floor Polishes," Soap and Chemical Specialties, XXXVIII (April, 1962), p. 73.

[23]Chalmers, op. cit., p. 6.

[24]F. A. Simko, "Modified Antislip Polish Additive," Soap and Chemical Specialties, XXXIX (January, 1963), p. 99.

TESTING THE EFFECT OF POLISHES ON RESILIENT FLOOR COVERING MATERIALS

When the newer vinyl floor covering materials came into production, the question arose as to whether or not these materials needed polish. An extensive study of resilient materials involved several brands of vinyl flooring. The study was initiated and authorized by the Wax and Floor Finishes Division of the Chemical Specialties Manufacturers Association. In laboratory evaluation studies, the following results had been obtained:

> 1. The appearance of the tile, as judged by gloss measurement, is greatly improved by waxing.
>
> 2. The use of wax does not significantly change the coefficient of friction or slip properties of tile.
>
> 3. The soiling tendency of vinyl tile may be substantially decreased by waxing.
>
> 4. Soil removal by scrubbing is greatly facilitated when vinyl tile has been previously waxed.
>
> 5. Pronounced protection against marring of the surface results from waxing.
>
> 6. Some difficulty may be encountered in waxing brand new tile flooring with emulsion type waxes because of poor wetting and spreading. However, our experience with vinyl floor installations indicates that after a period of use this condition disappears.[25]

Two types of test floors were constructed for field tests of these laboratory findings, one of which was subjected to moderate traffic and

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[25]Cyril S. Kimball, Dan Schoenholz, and George D. Burns, _The Effect of the Use of Floor Wax on Vinyl Flooring_. A Report to the Waxes and Floor Finishes Division, Chemical Specialties Manufacturers Association, Inc., (December, 1953), p. [illegible].

the other to heavy traffic. Three waxes were used, a conventional high wax content self-polishing wax, a high shellac content self-polishing wax, and a buffing type liquid solvent wax. The Gardner 60° Glossmeter was used for obtaining the gloss measurements.

In all instances, the field tests demonstrated the value of waxing and confirmed the laboratory evaluation results. The final conclusions were that waxing will: (1) provide a great improvement in the gloss of vinyl tile, (2) aid in maintaining a good gloss, (3) help to preserve and protect the tile surface, (4) reduce soiling and soil embeddment during use.[26]

Kimball and Hackett made a somewhat similar report to the Chemical Specialties Manufacturers Association in 1960. In this latter study the value of waxing resilient smooth surface floor covering materials involved eleven different types: asphalt tile, vinyl asbestos tile, backed vinyl sheet, vinyl (homogeneous) tile, roto vinyl sheet, rubber tile, and linoleum sheet.[27]

The three waxes employed were a non-buffable emulsion type, a buffable emulsion type, and a solvent base liquid wax. Test panels were installed on eight floors of Snell Laboratories in New York City. The panels were swept daily, damp mopped weekly, scrubbed and stripped of wax every two weeks, and then re-waxed again for a period of sixteen weeks. Both a Gardner 60° Glossmeter and a 45° Reflectance Meter were used.

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[26]<u>Ibid</u>., p. 8.

[27]Walter J. Hackett and Cyril S. Kimball, <u>The Value of Waxing Resilient Smooth Surface Floor Coverings</u>. Research Sponsored by the Wax and Floor Finishes Division of the Chemical Specialties Manufacturers Association, Inc., (May, 1960), p. 4.

From the data collected and observations made during the sixteen weeks, the following conclusions were reached:

> 1. The regular waxing of resilient smooth surface floor coverings . . . will provide a gloss of 3 to 16 times greater than if no wax were used.
>
> 2. Differences in gloss and brightness of floor coverings maintained by waxing and those on which no wax is used, become more pronounced with longer service on the floor.
>
> 3. Some types of floor coverings unless treated with wax are dull in appearance. Waxing enhances the floor beauty by increasing the gloss during service by 300 per cent to 400 per cent.
>
> 4. Waxing of all floor coverings produces a dramatic superiority in brightness and prevents the ingraining of dirt to which certain types of coverings are quite susceptible.
>
> 5. The regular use of floor wax affords substantial protection for all floor coverings against scratching and dulling. The greatest degree of protection is afforded to the dense and very smooth surfaced materials such as rubber tile and homogeneous vinyl. With these coverings waxing shows a definite advantage, as measured by gloss readings after removal of all wax and dirt from the surface, of 100 per cent to 250 per cent.
>
> 6. Soil removal by scrubbing is greatly facilitated by the regular use of floor wax. Equal effort in scrubbing shows a marked superiority in brightness or reflectance for the floor coverings maintained by regular waxing.
>
> 7. The application of a fresh coating of floor wax to a cleaned floor covering, following a substantial period of use on the floor, restores the gloss and appearance to almost its original condition. When no wax is used there is an average loss of more than 50 per cent in original cleaned store-new gloss.[28]

MEASUREMENT OF SKID RESISTANCE

Many methods have been used in the evaluation of skid resistance from simply sliding one foot along a surface to attempting reproduction

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[28] *Ibid.*, p. 3.

of the human walking motion mechanically. However, only those research projects which resulted in actual coefficients of friction will be presented here.

One such investigation was a joint research project conducted by the National Safety Council and the National Bureau of Standards. This project was undertaken in 1947 for the purpose of developing a suitable instrument and method of measuring slipperiness and securing data that could be used in the preparation of a code for safe walkway surfaces. The National Safety Council conducted a statistical survey of accidents from falls, and the National Bureau of Standards engaged in an engineering study of both walkways and footwear materials which were involved in slipping.

To secure information leading to the development of the testing apparatus, a study of the mechanics of the human gait was conducted by means of concealed, slow-motion cameras. In the development of the slipperiness tester, it was desirable that it be designed for use on floors in actual service. The design was based on the premise that, in the process of ordinary walking, slipping is most likely to occur when the rear edge of the heel contacts the walkway surface. The machine consisted for the main part of a pendulum, by means of which a heel material was impacted and swept over the walkway surface to be tested.

Rubber and leather heels were tested in both dry and wet conditions. All walkway surfaces gave relatively high anti-slip coefficients with dry rubber heels. A total of twenty-three tests were run on the following walkway materials: concrete slab, cement-mortar, paving brick, terrazzo, quarry tile, soap-stone stair tread, metal plate coated with phenolic resin and No. 46 alundum, yellow pine, white oak, pressed fiberboard, linoleum, rubber tile, asphalt tile, rubber and cotton matting, and vinyl resin flooring. Solvent-type wax was applied to white oak, pressed fiberboard, linoleum and rubber tile; water-emulsion wax was applied to yellow pine, linoleum, rubber tile, and asphalt tile. With all materials on which both waxes were tested, the water-emulsion wax yielded a higher anti-slip coefficient; in addition, it was found that polishing the water-emulsion wax brought about a slight increase in anti-slip coefficient.[29]

> The results of these tests, considered in relation to slipperiness as actually experienced, indicate that a slippery condition does or does not exist according to whether the measured coefficient is less or greater than 0.4.[30]

In a dry condition the anti-slip coefficients of all materials were greater than 0.4 when tested with a rubber heel. Only quarry tile, metal plate, soapstone stair tread, linoleum, rubber and asphalt tiles maintained with water-emulsion wax (polished), rubber-and-cotton matting, and vinyl resin flooring worn rough had coefficients higher than 0.4 for leather heels.

The materials which had anti-slip coefficients greater than 0.4 were the same for both rubber and leather heels when tested in a wet condition. They were concrete slab, soapstone stair tread, and metal plate.

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[29] Percy A. Sigler, Martin N. Geib, and Thomas H. Boone, "Measurement of the Slipperiness of Walkway Surfaces," Journal of Research of the National Bureau of Standards XL (May, 1948), p. 345.

[30] Ibid., p. 346.

The testing instrument was then used on untreated and waxed (water-emulsion wax) asphalt-tile corridors in a large government building in Washington.

> Higher anti-slip coefficients were obtained for the waxed asphalt tiles than for the untreated tiles when tested with a rubber heel under dry conditions. With a leather heel the opposite was found except for one wax. Under wet conditions all of the corridors would be considered hazardous for both rubber and leather footwear and especially so when waxed.[31]

The next extensive investigation was conducted at Michigan State University in the Agricultural Engineering Department. At the onset of the study one hundred persons who had sustained a fall on a stairway were interviewed. "Slipped" accounted for 38 per cent of all falls (more than twice as many as any other cause).[32] The tread on the stairways on which slipping occurred was then studied. Varnish was found to be more than twice as conducive to slipping as was paint. Rubber mats also were almost twice as likely to slip as was paint.

The study of slipperiness characteristics of stairway tread and shoe sole materials was begun with the development of a friction measuring machine and recording instrument. Six types of tread covering materials and six shoe sole materials were tested under four conditions: (1) a new sole material on a new tread material, (2) a new sole material on a worn tread material, (3) a worn sole material on a new tread material, and (4) a worn sole material on a worn tread material.[33]

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[31] Ibid.

[32] Agricultural Engineering Department of Michigan State University, "The Cause and Nature of Stairway Falls," Michigan Contributing Project Report for 1959, p. 2. (Mimeographed.)

[33] Ibid., p. 8.

The tread materials tested were an abrasive strip, varnish, rubber mat, paint, wood, and linoleum. The abrasive strip had the highest over-all average coefficient of friction (0.75) and linoleum had the lowest (0.56). Wood and paint decreased slightly with use, and linoleum and rubber mat showed some increase.[34]

The six shoe sole materials tested were ripple, neoprene, neolite, crepe, Goodrich, and leather. Ripple had the highest over-all average coefficient of friction (1.02), and leather had the lowest (0.42). The coefficients of friction of all the sole materials except crepe increased some with use.

With the increased use of resilient floor covering materials in homes, the choice of a safe material necessitated further study of anti-slip coefficients. In 1961, a project entitled "Testing of Smooth Floor Surfaces and Finishes from the Standpoint of Safety" was begun at the Woman's College of the University of North Carolina.[35] The laboratory machine used in this investigation consists chiefly of a movable circular table, an electric motor, and a mechanical recorder. Nine different types of resilient floor covering materials were selected for testing - asphalt, greaseproof asphalt, vinyl asbestos, solid vinyl opaque, solid vinyl translucent, rubber, battleship linoleum, plain cork, and vinyl cork.

The resilient floor covering materials were first tested with one heel size, a woman's Cuban heel.[36] The heel materials tested were leather,

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[34]*Ibid*.

[35]Day, *op. cit*.

[36]Trogdon, *op. cit*.

hard rubber, nylon, Neolite, rubber crepe, Adiprene, and Neoprene-cord. An analysis of variance of the skid resistance of the floor covering materials in new, worn, and waxed conditions revealed a highly significant difference beyond the .1 per cent level of significance among heel materials and among floor covering materials in each of the three conditions. The coefficients of friction for all types of floor covering materials in all conditions were lowest with the leather heel and highest with Neoprene-cord. The floor covering material having the lowest coefficient of friction in all three conditions was linoleum, while rubber consistently had the highest. The other materials varied from one condition to another in rank.

The floor covering materials were next tested with different sizes of leather and rubber shoe heels with the application of different weight loads.[37] Five sizes of rubber and leather heels, a spike heel, a stacked heel, a Cuban heel, a child's or woman's flat heel, and a man's heel, were used. Weight loads of 7, 15, 25, 35, and 45 pounds per square inch were selected.

Analysis of variance revealed highly significant differences in the mean force of friction measurements between leather and rubber heel materials and among resilient smooth floor surface materials. The rubber heel materials consistently indicated a higher force of friction measurement than leather heel material when tested with the floor surface materials in a dry, worn condition. In the over-all results, plain cork and grease-proof asphalt indicated the highest force of friction measurements while linoleum had the lowest. No significant differences in the mean force of

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[37]Tuten, op. cit.

friction measurements were found among the five heel sizes. However, force of friction measurements for the floor surface materials tended to increase as the size of the leather heel increased but to decrease with an increase in the size of the rubber heel.

Significant differences were found in the mean coefficients of friction among the five different weight loads applied to the heels. The coefficients of friction increased when the heavier weight loads were applied to the heels.

SUMMARY

In reviewing the literature, several research projects were found dealing with the gloss of floor polishes and the skid resistance of floor covering materials. However, no studies correlating gloss and skid resistance of floor coverings were found, nor was any mention located of a manner in which gloss measured by an instrument could be correlated with visual judgments of individuals.

CHAPTER III

EXPERIMENTAL PROCEDURE

Both instrumental measurements and individual judgments of gloss and of skid resistance were dealt with in this study. The skid resistance measurements used were those determined with a friction testing machine in the experiments on skid resistance cited earlier.[38]

Discussed in this chapter will be the selection of the materials, instrument, and subjects and the procedure for preparation and testing of the untreated and polished floor covering materials.

I. SELECTION OF TEST MATERIALS

Floor covering materials. The materials used in the present study were the same kinds as those tested in the two studies carried out by Trogdon and Tuten.[39] Nine different floor covering materials were tested. The Federal specification numbers and manufacturers of these materials are given in Table I. In the preparation for the skid resistance studies, samples of each of the nine different materials had been obtained through donation by the manufacturers or purchased from a local supplier. The samples to be used in the experiment were limited to the products of two manufacturers for each kind of floor covering material since there were only two manufacturers of vinyl cork. The two manufacturers to be represented for each material had been randomly determined. From the eighteen

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[38] See pp. 19-21.

[39] Ibid.

TABLE I

MANUFACTURERS AND FEDERAL SPECIFICATION NUMBERS
OF RESILIENT FLOOR COVERING MATERIALS TESTED

Floor Covering Material	Manufacturer	Federal Specifications
SET A		
Battleship Linoleum	Armstrong	LLL-L-351 b (COM-NBS)
Greaseproof Asphalt	Flintkote	SS-T-307
Plain Cork	Armstrong	LL-T-00431 a
Asphalt	Armstrong	SS-T-306 b
Vinyl Asbestos	Kentile	L-T-00345 (COM-NBS)
Solid Vinyl Opaque	Kentile	L-F-00450 (COM-NBS)
Vinyl Cork	Armstrong	LL-T-00431 a (COM-NBS)
Solid Vinyl Trans.	Bolta	L-F-00450 (COM-NBS)
Rubber	Goodrich	ZZ-T-301 a
SET B		
Plain Cork	Kentile	FS-LL-T-431 B
Battleship Linoleum	Congoleum-Nair	LLL-L-351 b
Vinyl Asbestos	Flintkote	L-T-00345 (COM-NBS)
Asphalt	Flintkote	SS-T-306 b
Greaseproof Asphalt	Kentile	SS-T-307
Vinyl Cork	Dodge	LLL-T-00431 a (C-M-NBS)
Solid Vinyl Opaque	Robbins	L-F-00450 (COM-NBS)
Rubber	Kentile	ZZ-T-301 a
Solid Vinyl Trans.	Amtico	L-F-00450

so chosen manufacturers, four samples of each material were then selected. Since these four samples came from the same box, they were assumed to be from the same lot. Three of these had been used in the earlier skid resistance studies; the fourth sample was reserved for use in the present study. The majority of the samples tested were neutrals; however, no particular effort had been made to select similar patterns or colors from among the floor covering materials.

Polishes. Hackett and Kimball reported that: "Solvent base liquid and paste wax are said to account for approximately one-fifth of the total sales with water base or bright drying waxes making up the remaining four-fifths."[40] In addition, this investigator made a survey of six chain grocery stores in Greensboro, North Carolina, to determine which types of floor polishes were most frequently bought by the consumer. The manager in each of the following stores was interviewed: Colonial, Bi-Rite, Kroger, A & P, Big Bear, and Winn-Dixie. The findings reported by Hackett and Kimball were substantiated by the local survey. Following the survey, three polishes were selected for testing: (1) the polish which was reportedly sold in greatest quantity, (2) a polish highly recommended by the managers of several stores as one which is especially made to prevent yellowing of light-colored floors, and (3) an additional polish, one containing an anti-skid ingredient, purchased from a commercial janitorial supply company. The order of testing these was randomized in the following order:

Polish A - anti-skid ingredient polish
Polish B - most widely sold polish
Polish C - polish recommended for light-colored floors

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[40]Hackett and Kimball, op. cit., p. 3.

II. SELECTION OF THE GLOSSMETER

The Gardner 60° Portable Glossmeter, Model No. GG 9042, was the instrument used for measuring specular gloss.[41] The geometric angle of 60° was the one most frequently used by other researchers in the measurement of gloss of resilient floor covering materials and of floor polishes. The American Society of Testing Materials has a tentative method for testing 60° specular gloss of emulsion floor polishes, and this method was used as a guide.[42]

III. SELECTION OF SUBJECTS

The individuals who participated in this study were students in the School of Home Economics at the Woman's College of the University of North Carolina. They were selected on the basis of their availability, and no attempt was made at random selection of subjects. Their classifications ranged from sophomore to graduate level with the greatest proportion of subjects being seniors.

IV. PREPARATION FOR TESTING

Preparation of test panels. The floor covering samples were first cut into the trapezoid shape of the panels as used on the plywood rings of the friction-testing machine. They were next mounted on $\frac{1}{4}$ inch Masonite board with contact cement; the Masonite projected beyond the

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[41]Gardner Laboratories, Bethesda, Maryland.

[42]"Tentative Method of Test for 60-Deg Specular Gloss of Emulsion Floor Polish," American Society for Testing Materials (ASTM Designation: D 1455-56 T).

smallest edge of the trapezoid for handling purposes. Each test panel was washed with a mild soap flakes solution to remove any surface soil. The panels were divided into sets designated as Set A and Set B, with one sample of each kind of floor covering material in each set. The panels were coded and the order of testing within these two sets was determined by using a table of random numbers.

Application of polishes. The polishes were applied according to a method recommended in ASTM Designation No. 3 1436.[43] In this method, No. 50 grade cheesecloth was cut into two-inch strips weighing 0.60 grams each. The amount of polish, 2 ml. per eighty-one square inches, was converted to 1.7 ml. for the area of the trapezoid test panels. The correct amount of polish was measured with a pipette, deposited in the center of the test panel and distributed with the cheesecloth applicator. The cheesecloth applicators were weighed individually in an air-tight weighing jar. Any applicator which varied more than 0.15 gram from all other applicators necessitated that the panel on which that applicator was used be cleaned and again polished.

Stripping the test panels. After test panels were subjected to testing, they were cleaned, or stripped, of the polish by using a solution of one part detergent and one part ammonia to six parts of water. This solution was applied with a sponge, after which the panels were rinsed and then thoroughly dried.

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[43] "Tentative Methods for Application of Emulsion Floor Polishes to Substrates for Testing Purposes," American Society for Testing Materials, ASTM Designation: D 1436-56T (Reprinted from Copyrighted 1956 Supplement to Book of ASTM Standards, Part 4), p. 112.

V. TESTING PROCEDURE

Gloss testing. Gloss measurements were obtained first from untreated test panels. Ten glossmeter readings were taken, five in the lengthwise plane and five in the crosswise plane, that is, on each corner and in the center. This same procedure was followed after the application of each of the three polishes. In addition, glossmeter readings were obtained after each polish was removed to ascertain whether or not the test panels had returned to their original values.

Gloss evaluation by individuals. The test panels were divided into Set A and Set B, each set containing one sample of the nine floor covering materials being tested. Each set was presented independently and was arranged in random order along a counter surface above which was a fluorescent wall bracket that provided even lighting. The same random order was repeated for each subject. The subjects were asked to rearrange the panels according to their glossiness. They were instructed to have the least glossy panel to their left and the most glossy panel to their right with the intermediate panels in ascending order accordingly. They were told that they could start at either end of the scale, that they could tilt the panels and view them from any angle; the only restriction was that they could touch only the projecting Masonite. These instructions applied to the gloss evaluation of test panels in an untreated condition or when treated with the polishes.

Skid resistance evaluation. The test panels were arranged in the same fashion as they were for gloss evaluation. Again, the two sets were presented separately. The subjects were asked to rearrange the test panels by placing the least slippery one on their left and the other panels in ascending order. This time the subjects were instructed to apply pressure with the index finger and to push this finger across the floor covering sample. They were asked to try to apply a relatively heavy amount of pressure and the same amount of pressure to each panel, as a difference in the pressure applied might affect their evaluation.

VI. TREATMENT OF THE DATA

The values for gloss of resilient floor covering materials in treated conditions were subjected to an analysis of variance. Both the differences in gloss among treatments and among materials were analyzed.

Correlation coefficients were computed between the glossmeter readings and coefficients of friction determined with the friction-testing machine, between gloss rankings and skid resistance rankings, and between all rankings of gloss or skid resistance and the corresponding instrumental values.

An analysis of this data is given in the following chapter.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

The purposes of the study were to determine the gloss of new and of polished resilient floor covering materials with a glossmeter, to relate these gloss measurements to coefficients of friction, to determine rank orders of gloss and of skid resistance of resilient floor covering materials as judged by individuals, and to relate the rank orders to instrument measurements.

The hypotheses tested in this investigation were that:

(1) There are differences in gloss among the three types of water-emulsion polishes tested on resilient floor covering materials.

(2) There is a positive correlation between gloss of resilient floor covering materials as determined with a glossmeter and the order in which they are ranked by individuals.

(3) There is a negative correlation between gloss and coefficients of friction of resilient floor covering materials in a new and in a polished condition.

(4) There is a positive correlation between individuals' rankings of slipperiness of resilient floor covering materials and the coefficients of friction of these materials.

(5) There are differences among the gloss measurements of different types of resilient floor covering materials.

I. GLOSS VALUES OF RESILIENT FLOOR COVERINGS

Ten glossmeter readings were taken from each of eighteen test panels in an untreated condition and when polished with three water-emulsion polishes. The effects of pattern and surface texture were noted on these gloss values. Several materials were lower in gloss in one plane than in the other. This was especially true of solid vinyl translucent, which was considerably more shiny in the crosswise plane than in the lengthwise plane. The averages of the ten gloss values for each material are given in Table II.

Set A Floor Covering Materials. In an untreated condition, the gloss values of materials in Set A ranged from 4.90 for battleship linoleum to 71.65 for rubber. The order in Set A according to increasing gloss average in an untreated condition was battleship linoleum, greaseproof asphalt, plain cork, asphalt, vinyl asbestos, solid vinyl opaque, vinyl cork, solid vinyl translucent, and rubber. Gloss values of the polished materials ranged from 8.05 for battleship linoleum to 89.15 for rubber. The average gloss for the test panels in Set A was 29.17, untreated; 43.99, Polish A; 50.71, Polish B; and 46.14, Polish C.

In Table III the percentages showing gloss increase when polishes were applied to Set A materials reveal that the solid vinyl opaque test panel excelled in increase of gloss, in one instance demonstrating a 266% increase. Other materials which showed a 200% increase in gloss with one or more polishes were battleship linoleum and vinyl cork. The material which showed the least increase upon polishing was rubber, which, however, was still highest in gloss. The mean percentage of increase for all polished materials ranged from 116.3% to 232.6%. These increases are shown graphically in Figure I according to gloss values for each condition.

Set B Floor Covering Materials. As shown in Table II, the gloss values of the materials in Set B in an untreated condition ranged from 5.90 for plain cork to 63.70 for solid vinyl translucent. The order of materials according to increasing gloss average in the untreated condition

TABLE II

GLOSS VALUES OF UNTREATED AND POLISHED RESILIENT FLOOR COVERINGS

Floor Coverings	Untreated	Polish A	Polish B	Polish C
SET A				
Battleship Linoleum	4.90	8.05	8.65	11.65
Greaseproof Asphalt	11.30	18.45	21.30	20.20
Plain Cork	16.10	27.35	31.55	29.30
Asphalt	22.35	31.65	35.55	32.00
Vinyl Asbestos	27.45	37.50	40.25	38.20
Solid Vinyl Opaque	29.40	60.75	78.20	66.25
Vinyl Cork	36.80	68.30	77.20	69.95
Solid Vinyl Translucent	42.60	63.95	74.50	66.75
Rubber	71.65	79.95	89.15	80.95
Mean	29.17	43.99	50.71	46.14
SET B				
Plain Cork	5.90	9.10	10.20	9.85
Battleship Linoleum	10.65	22.60	26.65	24.00
Vinyl Asbestos	11.50	18.00	21.40	20.75
Asphalt	16.85	26.40	31.30	28.90
Greaseproof Asphalt	24.70	36.10	42.30	38.50
Vinyl Cork	34.15	53.45	61.70	56.00
Solid Vinyl Opaque	37.15	59.60	74.25	63.40
Rubber	60.85	74.50	85.85	76.85
Solid Vinyl Translucent	63.70	81.15	93.90	84.60
Mean	29.49	42.32	49.73	44.76

TABLE III

PERCENTAGES OF GLOSS INCREASE OF RESILIENT FLOOR COVERINGS AFTER APPLICATION OF POLISHES

Floor Coverings	Polish A	Polish B	Polish C	Mean
SET A				
Rubber	111.6	124.4	113.0	116.3
Vinyl Asbestos	136.6	146.6	139.2	140.8
Asphalt	141.6	159.1	143.2	148.0
Solid Vinyl Translucent	150.1	174.9	156.7	160.6
Greaseproof Asphalt	163.3	188.5	178.8	176.9
Plain Cork	169.9	196.0	182.0	182.6
Battleship Linoleum	164.3	176.5	237.8	192.9
Vinyl Cork	185.6	209.8	190.1	195.2
Solid Vinyl Opaque	206.6	266.0	225.3	232.6
SET B				
Rubber	122.4	141.1	126.3	129.9
Solid Vinyl Translucent	127.4	147.4	132.8	135.9
Greaseproof Asphalt	146.2	171.3	155.9	157.8
Plain Cork	154.2	172.9	166.9	164.7
Vinyl Cork	156.5	180.7	164.0	167.1
Asphalt	156.7	185.8	171.5	171.3
Vinyl Asbestos	156.5	186.1	180.4	174.3
Solid Vinyl Opaque	160.4	199.9	170.7	177.0
Battleship Linoleum	212.2	250.2	225.4	229.3

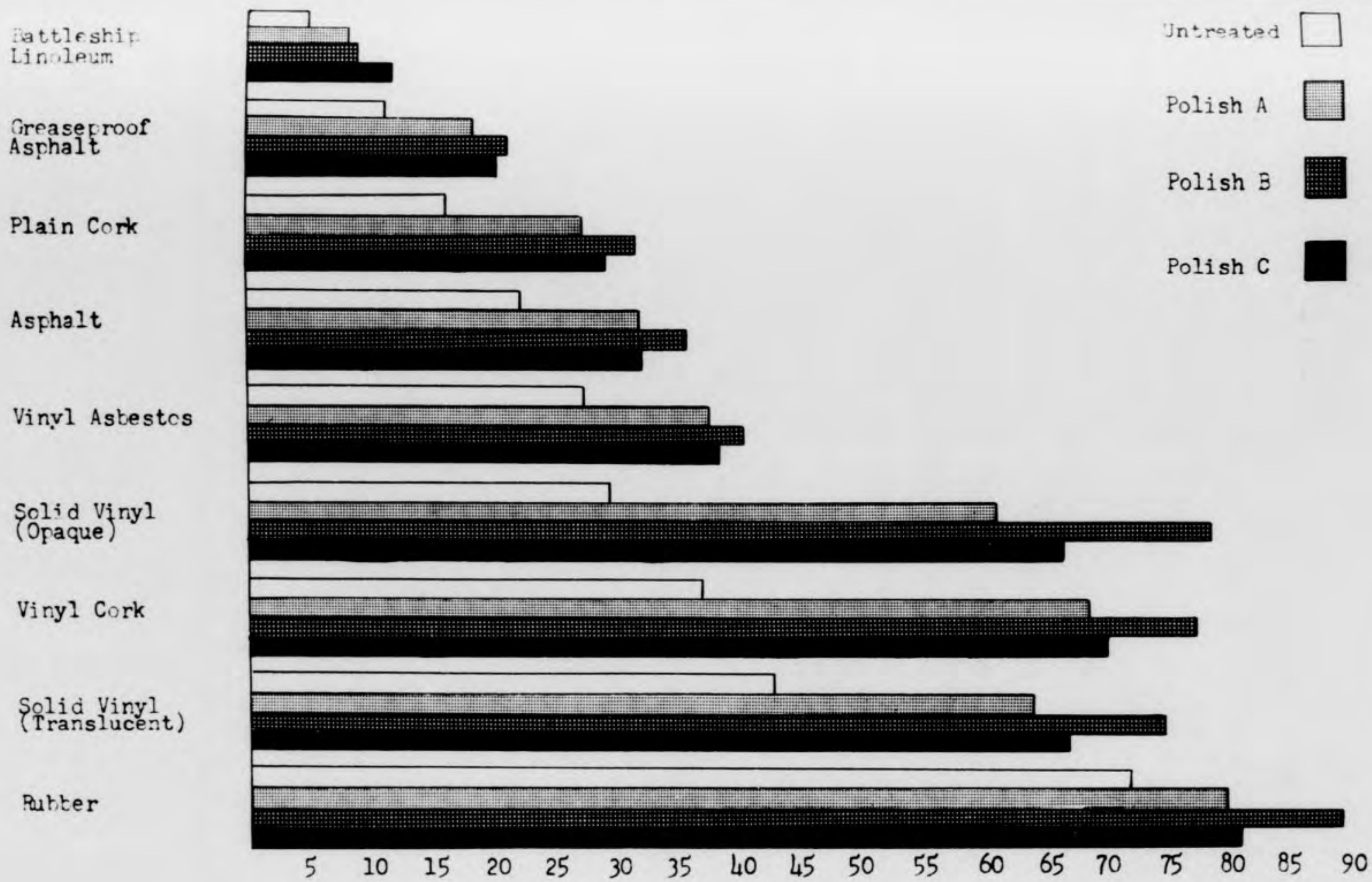

FIGURE I

GLOSS VALUES OF UNTREATED AND POLISHED RESILIENT FLOOR COVERINGS SET A was plain cork, battleship linoleum, vinyl asbestos, asphalt, greaseproof asphalt, vinyl cork, solid vinyl opaque, rubber, and solid vinyl translucent. Means of gloss values for Set B were 29.49, untreated; 42.32, Polish A; 49.73, Polish B; and 44.76, Polish C.

As shown in Table III, battleship linoleum had gloss increases of 212%, 250% and 225%. There was no other material which had an increase in gloss of 200%, although solid vinyl opaque showed an increase of 199.9%. The material which displayed the least increase in gloss (122.4%) was rubber, as was true in Set A. The polish which brought about the greatest increase in gloss was Polish B. Mean percentages of gloss increase for all polished materials ranged from 129.9% to 229.3%. The gloss values for each condition are shown graphically in Figure II.

Analysis of Variance. The gloss readings obtained from the polished materials were treated to an analysis of variance. This analysis is given in Table IV. There was a highly significant difference in gloss at the one per cent level among polishes and an even greater difference in gloss among materials. These differences were greater in Set B than in Set A, suggesting the possibility that there is heterogeneity among the same types of materials made by different manufacturers. Also, the material to which it is applied apparently affects the degree of shine which a floor polish assumes. The hypotheses that there are differences in gloss among the three water-emulsion polishes tested and that there are differences in gloss measurements of different types of resilient floor covering materials were retained.

FIGURE II

GLOSS VALUES OF UNTREATED AND POLISHED RESILIENT FLOOR COVERINGS SET B

TABLE IV

ANALYSIS OF VARIANCE OF GLOSS VALUES OF RESILIENT FLOOR COVERING MATERIALS TREATED WITH DIFFERENT FLOOR POLISHES

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
SET A				
Treatments	2	211.4763	105.7382	12.35*
Materials	8	16699.8197	2087.4775	243.72*
Error	16	137.0387	8.5650	
Total	26	17048.3347		
SET B				
Treatments	2	256.3747	128.1874	20.34*
Materials	8	18141.6013	2267.7002	359.83*
Error	16	100.8337	6.3021	
Total	26	18498.8097		

* Significant at the one per cent level.

II. COEFFICIENTS OF FRICTION OF RESILIENT FLOOR COVERINGS

The gloss value for each untreated material was paired with its respective coefficient of friction, which was previously determined with the friction-testing machine. These coefficients of friction are shown in Table V. Each coefficient was an average of three determinations with each of seven different heel materials tested on six samples of each material. The coefficients of friction which were determined when Polish B was previously tested with the friction-testing machine were also paired with the gloss values recorded when Polish B was applied to the test panels.

In Set A the order of materials in an untreated condition according to increasing coefficient of friction was battleship linoleum, vinyl cork, greaseproof asphalt, vinyl asbestos, solid vinyl opaque, solid vinyl translucent, asphalt, plain cork, and rubber. In Set B the order of materials in an untreated condition according to increasing coefficient of friction was vinyl cork, asphalt, battleship linoleum, solid vinyl translucent, solid vinyl opaque, vinyl asbestos, greaseproof asphalt, rubber, and plain cork. All materials in both sets were lower in coef-fient of friction when polished than when unpolished.

III. RELATIONSHIP BETWEEN GLOSS AND SKID RESISTANCE OF RESILIENT FLOOR COVERINGS

Correlation coefficients showing the relationship between gloss and skid resistance are given in Table VI. Correlated were instrumental values of gloss and coefficients of friction in an untreated condition and in one treated condition, instrumental values and rankings of gloss and of skid resistance, and rankings of gloss and rankings of skid resistance.

TABLE V

COEFFICIENTS OF FRICTION OF UNTREATED AND POLISHED RESILIENT FLOOR COVERINGS

Floor Coverings	Coefficient of Friction	Floor Coverings	Coefficient of Friction
SET A UNTREATED		SET B UNTREATED	
Battleship Linoleum	.516	Battleship Linoleum	.564
Vinyl Cork	.588	Vinyl Asbestos	.572
Greaseproof Asphalt	.593	Plain Cork	.592
Vinyl Asbestos	.627	Asphalt	.641
Solid Vinyl Opaque	.639	Greaseproof Asphalt	.655
Solid Vinyl Translucent	.645	Solid Vinyl Opaque	.679
Asphalt	.659	Vinyl Cork	.683
Plain Cork	.732	Solid Vinyl Translucent	.715
Rubber	.790	Rubber	.798
SET A POLISHED*		SET B POLISHED*	
Vinyl Cork	.319	Vinyl Asbestos	.314
Asphalt	.345	Greaseproof Asphalt	.314
Battleship Linoleum	.355	Plain Cork	.315
Solid Vinyl Translucent	.356	Battleship Linoleum	.330
Solid Vinyl Opaque	.369	Asphalt	.400
Vinyl Asbestos	.391	Solid Vinyl Translucent	.427
Greaseproof Asphalt	.408	Vinyl Cork	.433
Rubber	.408	Rubber	.492
Plain Cork	.427	Solid Vinyl Opaque	.494

* Polish B

TABLE VI

CORRELATIONS AMONG GLOSS VALUES AND RANKINGS AND COEFFICIENT OF FRICTION VALUES AND RANKINGS

Untreated Materials	Set A	Set B
Gloss Values and Coefficients of Friction	.669	.917
Gloss Rankings and Coefficients of Friction	.588	.897
Skid Rankings and Coefficients of Friction	-.012	.420
Gloss Rankings and Skid Rankings	.708	.712
Gloss Values and Skid Rankings	.618	.591
Gloss Values and Gloss Rankings	.906	.952
Treated Materials		
Gloss Values and Gloss Rankings		
Polish A	.978	.979
Polish B	.975	.984
Polish C	.977	.951
Gloss Values and Coefficients of Friction		
Polish B	-.202	.840

<u>Gloss Values and Coefficients of Friction</u>. Correlation coefficients were computed for the paired gloss values determined with the glossmeter and the coefficients of friction determined with the friction-testing machine. Correlation coefficients of .669 for Set A and .917 for Set B were obtained, indicating a high relation between gloss of unpolished materials and the skid resistance of these materials. As the gloss increased, so did the coefficients of friction. This was true to a greater extent with Set B than with Set A. This was counter to what was expected and to the common assumption that floor coverings which are shiny are also slippery.

When the gloss values for the materials polished with Polish B were paired with the coefficients of friction obtained when this polish was tested with the friction-testing machine, correlation coefficients of -.202 for Set A and .840 for Set B were obtained. The positive relationship between gloss and coefficients of friction was maintained with Set B, but this was not true with Set A. There was almost no relationship between the gloss values of the polished test panels for Set A and their respective coefficients of friction. The writer can only surmise that this is a possible result of differences in the behavior of materials made by different manufacturers. The hypothesis that there is a negative correlation between gloss and coefficients of friction of resilient floor covering materials in a new and in a polished condition was rejected.

<u>Gloss Rankings and Coefficients of Friction</u>. Gloss rankings of untreated materials by twenty-nine individuals were paired with the coefficients of friction. In ranking the panels on gloss, the panels exhibiting the most gloss were given the highest ranks. The mean ranks of gloss of the floor covering materials by the subjects can be seen in Table VII.

TABLE VII

MEAN RANKS OF GLOSS AND SKID RESISTANCE OF FLOOR COVERINGS AS JUDGED BY SUBJECTS

Floor Coverings	Untreated Materials		Treated Materials		
	Gloss (29 subjects)	Skid Resistance (27 subjects)	Polish A (26 subjects)	Polish B Gloss (25 subjects)	Polish C (25 subjects)
SET A*					
Battleship Linoleum	1.21	3.26	1.00	1.08	1.00
Greaseproof Asphalt	2.45	3.59	2.35	2.36	2.24
Plain Cork	3.24	1.26	3.96	3.88	4.16
Asphalt	5.52	3.85	3.89	3.96	3.84
Vinyl Asbestos	4.38	5.04	3.85	3.80	3.76
Solid Vinyl Opaque	6.38	7.82	6.85	7.08	6.72
Vinyl Cork	7.24	6.93	8.46	8.44	8.36
Solid Vinyl Translucent	5.66	7.19	6.35	6.24	6.76
Rubber	8.93	6.07	8.31	8.16	8.16
SET B*					
Plain Cork	2.21	3.07	1.54	1.40	1.60
Battleship Linoleum	1.93	4.11	3.00	3.20	2.64
Vinyl Asbestos	2.00	4.44	1.77	1.88	1.96
Asphalt	3.86	3.22	3.69	3.56	3.80
Greaseproof Asphalt	5.03	5.52	5.08	4.96	5.08
Vinyl Cork	6.41	5.78	6.39	6.28	6.16
Solid Vinyl Opaque	6.93	7.74	7.23	7.48	7.32
Rubber	7.62	4.52	7.35	7.28	7.64
Solid Vinyl Translucent	9.00	6.59	8.96	8.96	8.80

* Materials are listed in order of increasing gloss in an untreated condition as determined by the glossmeter.

Correlation coefficients of .588 for Set A and .897 for Set B were computed. These correlations reveal that the subjects' rankings of the materials followed the same trend as the coefficients computed between the gloss instrument and the coefficients of friction. High gloss rankings of the materials corresponded to high coefficients of friction.

Skid Rankings and Coefficients of Friction. When the rankings of skid resistance by twenty-seven subjects were correlated with the coefficients of friction, correlation coefficients of -.012 for Set A and .420 for Set B were obtained, neither of which was a significant prediction of the relationship existing between individuals' judgments of slipperiness and mechanically determined coefficients of friction. In the case of Set A materials, there was no relation between these two ways of evaluating the skid resistance of resilient floor coverings.

The hypothesis that there is a positive correlation between individuals' rankings of slipperiness of resilient floor covering materials and the coefficients of friction of these materials was rejected. However, several uncontrolled factors may have affected the results obtained from the ranking procedure. When the subjects were performing this ranking procedure, many of them moved the shiny materials to the top positions, where those which were slippery were to be located, before they had even tested all the materials with their fingers. The amount of pressure which they applied possibly affected the manner in which they ranked the materials. If they changed fingers during the process, this also may have affected their judgments. In addition, several subjects seemed to the writer to be influenced by the pitch of the sound made by their fingers rubbing across the materials. If the procedure had been different, perhaps different results would have been obtained.

<u>Gloss Rankings and Skid Rankings</u>. Correlation coefficients of .708 for Set A and .712 for Set B were computed. The subjects ranked the materials from least glossy to most glossy and from least slippery to most slippery. The rank orders can be seen in Table VII. The correlation coefficients indicate that the subjects chose generally the same materials as being both slippery and glossy. This is in keeping with the assumption that people spontaneously associate gloss with slipperiness.

<u>Gloss Values and Gloss Rankings</u>. In an untreated condition, the correlation coefficients for the gloss values determined with the glossmeter and the gloss rankings were .906 for Set A and .952 for Set B. When the three water-emulsion polishes were tested with the glossmeter and ranked by either 25 or 26 subjects, the following correlation coefficients were obtained:

Polish A - .978, Set A; .979, Set B
Polish B - .975, Set A; .984, Set B
Polish C - .977, Set A; .951, Set B

These correlation coefficients evidence the ability of the subjects to distinguish the glossiness of the materials and to rank them accordingly. This ability appeared to increase when the panels were higher in gloss after application of the polishes. Except in the case of Polish C, there was a higher degree of correlation with Set B than with Set A. The hypothesis that there is a positive correlation between gloss of resilient floor covering materials as determined with a glossmeter and the order in which they are ranked by individuals was retained.

<u>Gloss Values and Skid Rankings</u>. Correlation coefficients of .618 for Set A and .591 for Set B were determined. These values were to be expected considering the high correlations between gloss rankings and skid

rankings and between gloss values and gloss rankings. These values apparently substantiated the assumption that the subjects were influenced by gloss in making their skid rankings.

IV. AGREEMENT AMONG SUBJECTS

Coefficients of concordance were computed for each set of rankings of gloss and skid resistance. These coefficients of concordance are presented in Table VIII. These coefficients ranged from .319 to .945. The lowest coefficient of concordance was computed for the rankings of skid resistance for Set B, upon which the subjects showed little agreement although there was initial agreement (.631) on Set A. All other coefficients of concordance revealed a high degree of agreement among the subjects.

TABLE VIII

COEFFICIENTS OF CONCORDANCE FOR GLOSS RANKINGS AND SKID RANKINGS

Rankings	Set A	Set B
Gloss - Untreated Materials	.791	.935
Skid Resistance - Untreated Materials	.631	.319
Gloss - Polish A	.914	.937
Gloss - Polish B	.897	.945
Gloss - Polish C	.909	.933

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

The present study was an investigation of the relationship existing between gloss and slipperiness using mechanical measurements and rankings by individuals. In reviewing the literature, references were found to the psychological effect of gloss, this effect being that people attribute slipperiness to surfaces which possess a high degree of shine. However, no study which correlated gloss and slipperiness was found.

The materials appraised in this study of gloss and slipperiness were nine different types of resilient floor coverings. Two samples of each material were used and in each case were representative of two manufacturers. The nine materials were battleship linoleum, greaseproof asphalt, vinyl cork, solid vinyl translucent, plain cork, vinyl asbestos, solid vinyl opaque, asphalt, and rubber.

The nine resilient floor covering materials were cut into trapezoid shapes and mounted to $\frac{1}{4}$ inch Masonite board. A Gardner Portable 60° Glossmeter was used for securing specular gloss measurements. The order of testing the eighteen untreated test panels was randomized. Ten measurements, five lengthwise of the panel and five crosswise, were obtained for each test panel and averaged.

Students in the School of Home Economics at the Woman's College of the University of North Carolina were selected for participation in this study. Originally there were twenty-nine subjects who participated by ranking the floor covering materials as to gloss. In subsequent tests the number ranged from twenty-five to twenty-seven subjects.

For the ranking procedure, the test panels were divided into two sets, each set containing one sample of each of the nine different materials. These were designated as Set A and Set B. Each set was separately arranged in random order along a counter surface, above which there was a fluorescent wall bracket for even lighting. The test panels were arranged in the same order for each subject, who then ranked the materials according to the amount of gloss observed on each material.

Secondly, the subjects ranked the floor covering materials as to slipperiness. They did this by applying pressure with the index finger and pushing the index finger across the test panels. Mechanical measurements of slipperiness had previously been determined with a friction-testing machine. These coefficient of friction measurements for the materials in a new and in a polished condition were used in the present study.

Three polishes were selected for testing their effect on the floor coverings, a polish containing an anti-skid ingredient, a polish reported as most frequently purchased in the Greensboro, North Carolina, area, and a polish especially recommended for light-colored floors. The order of testing the polishes was randomized. These polishes were applied according to a method recommended by the American Society of Testing Materials. Using the same procedure as had been used with the untreated materials, gloss measurements were obtained after each of the polishes was applied to the floor covering materials, and the materials were again ranked according to gloss by the subjects. After the materials were ranked, the polish was removed with a solution of ammonia and detergent, and gloss measurements were taken to ascertain whether or not the materials had returned to their untreated condition.

The hypotheses tested in this investigation were that:

(1) There are differences in gloss among the three types of water-emulsion polishes tested on resilient floor covering materials.

(2) There is a positive correlation between gloss of resilient floor covering materials as determined with a glossmeter and the order in which they are ranked by individuals.

(3) There is a negative correlation between gloss and coefficients of friction of resilient floor covering materials in a new and in a polished condition.

(4) There is a positive correlation between individuals' rankings of slipperiness of resilient floor covering materials and the coefficients of friction of these materials.

(5) There are differences among the gloss measurements of different types of resilient floor covering materials.

The gloss values for the polished materials were treated to an analysis of variance. Correlation coefficients were computed between instrumental values of gloss and skid resistance, between instrumental values and individuals' rankings of gloss and of skid resistance, and between rankings of gloss and rankings of skid resistance.

Highly significant differences in gloss were found among the three polishes tested and among the nine floor covering materials. Generally, battleship linoleum and plain cork were found to be low in gloss; solid vinyl translucent and rubber were found to be high in gloss. Polish B, the most frequently purchased polish, brought about the greatest increase in the gloss of the floor covering materials.

When gloss values and coefficients of friction were correlated, a positive relationship was found, high gloss corresponding to high skid resistance, among untreated floor covering materials. When polish was applied, there remained a high positive relationship between gloss and skid resistance with the materials designated as Set B; however, with the other materials designated as Set A, there was no relationship between gloss and skid resistance. This suggests that possibly the same types of materials made by two different manufacturers behave differently. The hypothesis that there is a negative correlation between gloss and skid resistance was rejected.

Correlation coefficients between gloss values and rankings of gloss by individuals were consistently high for both the untreated and polished floor covering materials, indicating that these individuals possessed the ability to judge the glossiness of the materials and to rank them accordingly.

The relationship between coefficients of friction and rankings of skid resistance was essentially negative for one set of materials and so low as to be insignificant for the other set of materials. The procedure followed by the subjects in evaluating skid resistance in this study was, therefore, not considered to be valid.

A high correlation was found between gloss rankings and skid rankings. This indicated that perhaps the subjects were inclined to select the same materials as being both glossy and slippery.

II. CONCLUSIONS

From the data collected in this investigation of the gloss and slipperiness of nine resilient floor covering materials - battleship linoleum, greaseproof asphalt, plain cork, asphalt, vinyl asbestos, vinyl cork, solid vinyl opaque, solid vinyl translucent, and rubber - by both mechanical and subjective means, the following conclusions are drawn:

(1) There is a highly significant difference in gloss among different types of resilient floor covering materials when water-emulsion polishes are applied to them.

(2) In an untreated condition and in treated conditions, the materials which are generally low in gloss are battleship linoleum and plain cork; high in gloss are solid vinyl translucent and rubber.

(3) In an untreated condition, those materials which are high in gloss are also high in coefficient of friction. In a polished condition, the relationship between the coefficients of friction and gloss values does not follow a set pattern.

(4) The coefficients of friction and gloss values may be different for the same type of material produced by different manufacturers.

(5) One polish may increase the glossiness of a floor covering material more than another polish. However, the gloss of all floor covering materials is enhanced by the application of polish.

(6) The method of evaluating slipperiness whereby an individual applies pressure with the index finger and pushes it across resilient floor covering materials does not correlate with a mechanical measure of slipperiness.

(7) It is possible for individuals to effectively evaluate the glossiness of resilient floor covering materials and to rank them in relation to glossmeter measurements.

(8) Apparently there is a psychological association between gloss and slipperiness.

III. RECOMMENDATIONS FOR FURTHER STUDY

Further investigation of the relationship between gloss and slipperiness would be desirable for more conclusive evidence bearing upon this relationship. In future investigations it is suggested that:

(1) A wider variety of polishes be tested with the glossmeter and with the friction-testing machine and that the glossmeter values and coefficients of friction be correlated.

(2) Multiple coats of polish be tested with the glossmeter and with the friction-testing machine in order to determine the effects of polish build-up on the measurements obtainable.

(3) Other methods of subjectively evaluating slipperiness be formulated and tested.

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