safety sciences

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COLLECTION AND ANALYSIS OF WORK SURFACE ACCIDENT PROFILE DATA

Final Report

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ABSTRACT: Accident Circumstance Profiles were developed to describe the tasks, work surfaces, footwear, and industries that characterize frequent and serious work surface related injuries. Injury statistics from worker's compensation records were analyzed, and field visits to 50 sites were conducted to investigate slip and fall injuries, primarily on dry surfaces. A slip meter was used to measure the coefficient of friction (COF) at the field sites, and these measurements correlated well with subjective reports of slipperiness. The investigators found that most slips and falls occurred on wet surfaces, and that worker's compensation reports produced insufficient cause related data. An analysis of 3,270 first reports of injury related to work surfaces revealed that 50 percent were related to slips, but only 3.5 percent of these occurred on slippery surfaces. High risk accident circumstances regarding work surface problems were suggested, and these were discussed in terms of recurrent accident patterns. Training and housekeeping control measures were proposed.

KEYWORDS: NIOSH-Publication, NIOSH-Contract, Contract-210-76-0150, Accident-analysis, Accident-statistics, Working-surfaces, Surface-properties, Task-performance, Foot-protection, Personal-protective-equipment, Safety-shoes, Measurement-methods

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I. EXECUTIVE SUMMARY

The work reported here was directed towards developing Accident Circumstance Profiles which describe the various tasks, work surfaces, footwear and industries which characterize the frequent and serious work surface related injuries. The purpose was accomplished through two approaches:

- analysis of existing injury data, including worker's compensation (WC) agency tabulations, and First Reports of Injury
- field visits to 50 sites in nine organizations, each site having been associated with an injury from a slip or fall. No formal interviews or questionnaires were allowed under the terms of the contract. The emphasis, during field visits, was to be focused upon coefficient of friction (COF) as a primary factor, and an instrument to measure COF was furnished by NIOSH.

The field visits were made to ten types of work sites operated by the nine participating organizations. These work sites included:

- two hospitals
- two universities
- two local government organizations
- a major shipbuilder
- a chain of fast food restaurants
- a transportation vehicle manufacturer
- a telecommunications equipment manufacturer

The accident sites visited were selected to emphasize slips and falls that had occurred on dry surfaces. These proved to be a rather small fraction of the injuries at these work sites (even though the work sites themselves had been selected largely to maximize the number of such slips and falls). Slips and stumbles on all surfaces accounted for about 28%

of the total slips and falls. Slips and stumbles on dry surfaces accounted for only about 18% of the total slips and stumbles and about 5% of the total slips and falls (or about 1% of the total injuries).

Measurements of coefficient of friction with the instrument provided by NIOSH proved to be difficult, and a simpler "slip meter" unit was devised and used. With this unit, reproducible measurements of static COF could be made, using a variety of sole materials, and it was found that these measurements, for various sole and surface combinations, correlated well with the subjective "feel" of a dry floor surface in terms of slipperiness. Most slip meters do not provide consistent results on wet surfaces, or results that correlate with subjective slipperiness. However, it was found (near the end of the contract) that using water and a wetting agent rather than plain water may give COF readings that correlate with subjective slipperiness of wet surfaces.

The site observations related the measured COF to the work tasks and body positions (so far as they could be established) of the injured employee. Some general control measures are offered.

The analysis of injury data showed that WC agency tabulations are of little value in determining specific features of work surface related accidents. This is because of limitations in the coding method used, chiefly that most WC agencies use the "source of accident," which is defined as the "object, or substance that directly injured the employee." The floor is thus named for most falls, even if from a ladder, while some slips may not be coded with the floor as source, e.g., if the employee slips and touches a hot stove to save himself (in which case the "stove" is the source of the resulting burn).

FRASE coded First Reports of Injury are, however, a valuable resource for constructing accident profiles. Such profiles, presented in APPENDIX B, can be used to identify specific accident patterns in a manner suitable for countermeasure development, e.g., specification of housekeeping and safe work practices for use in training programs, specific work surface modifications, footwear usage, etc., as well as for calculating the proportion of accidents that are likely to be affected by specific countermeasures.

Analysis of 3,270 injury reports representing a cross-section of general industry revealed several high risk accident circumstances related to a variety of work surface

problems. These are discussed in terms of recurrent accident patterns which appear generally to require training and housekeeping type countermeasures, rather than specifications for materials. Areas are indicated where further research is needed.

II. BACKGROUND, CONCEPTS AND METHODS

Accidents related to work surfaces are responsible for a large fraction of U.S. occupational injuries. One of the more complete tabulations of occupational injuries, that for worker's compensation cases in New York State 1966-1970,[1] reported that 120,682 injuries with work surfaces as the agency of accident occurred during that period (20% of the total), with $219,152,000 awarded in worker's compensation (25.5% of the total). However, the tabulations of worker's compensation data do not permit the identification of what are the specific problems with work surfaces. Identification of these problems would provide guidance to NIOSH in focusing future research efforts and in developing criteria documents.

2.1 PROJECT DESCRIPTION, LIMITATIONS, SCOPE AND EMPHASIS

The work reported here was directed towards developing Accident Circumstance Profiles which describe the various tasks, work surfaces, footwear and industries which characterize the frequent and serious work surface related injuries. This purpose was to be accomplished through two approaches. The first approach was the analysis of existing injury data. The second was observations and measurements, comprising visits to 50 accident sites in at least six plants over the 18 month term of the contract, to observe work tasks and physical characteristics associated with injuries from slips and falls. The conduct of formal interviews, e.g., with the injured employee, or the administration of a questionnaire during the field visits was not allowed under the terms of the contract.

The emphasis, during field studies, was directed by the contract to focus on the friction coefficient as the primary factor associated with the work surface injuries. Coefficients of friction were to be measured in the vicinity of the sites where accidents occurred, and equipment for this purpose was furnished by NIOSH in the form of the Universal Friction Testing Machine (UFTM). The UFTM had previously been developed by NIOSH as an instrument capable of measuring both static and dynamic coefficients of friction.

Some difficulty was experienced in using the UFTM in the field and the contract was modified to permit the use of other appropriate instruments. At the same time, the requirement for a focus on coefficient of friction was deleted

from the contract. However, the sites for field measurements were selected to emphasize slips and stumbles that could be associated with coefficient of friction of the work surface-shoe combination, and, more particularly, slips and stumbles on dry rather than wet work surfaces. This was in order to study the feasibility of eventual incorporation of coefficient of friction requirements for dry floors in criteria documents. Prevention of slipperiness when wet is related to construction of the floor (e.g., use of expanded metal grids rather than solid floors) and to housekeeping (prevention, marking and clean up of spills) and other work practices as well as to coefficient of friction.

Study of tasks and biomechanics associated with slip accidents was approached by considering which body positions and activities are likely to result in slips, and by an analysis of the body positions and activities of the employees injured at the sites that were visited (to the extent feasible within the limitations imposed by the requirement for no interviewing, and by the lapse of time between accident occurrence and site visit). This study was not an experimental biomechanics study, using volunteers equipped with instrumentation to measure forces and vectors during simulated slip accidents, but a general analysis of the slip and fall problem into accident profiles, based upon injury analysis and 50 site measurements.

As an initial definition, a work surface was defined as follows:

- if employee's weight was supported mainly by feet at the start of accident sequence, the work surface is the surface which supported employee's footwear, e.g., floor, ground, platform, ladder rung, stair, step

- if employee's weight was supported other than mainly by feet at the start of accident sequence (e.g., employee sitting), surface on which employee was attempting to establish support for footwear during accident sequence, or surface which supported object which supported employee's weight at start of accident sequence

Work surface related (of an accident, injury or event) was defined as follows:

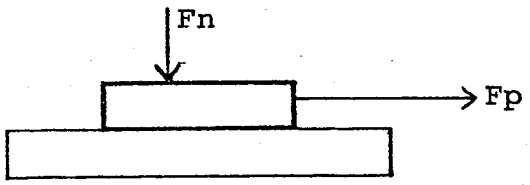
- accidents, injuries or events in which some property or behavior of the work surface was a contributing factor

- (more specifically) accidents, injuries or events in which the failure of the work surface to provide the expected support to the employee was a contributing factor

2.2 CONCEPTS ASSOCIATED WITH COEFFICIENT OF FRICTION

Friction represents the resistance of one surface to sliding over another. For simplicity, it is usual to consider the case of plane surfaces, for which the forces acting can be resolved into a force Fp parallel to the surface and a force, Fn, normal to the surface, as shown in FIGURE 2-1. The normal force tends to compress the surfaces together; the parallel force tends to make one surface slide relative to the other. Experimentally, it is found that for any given pair of surfaces and for a given normal force, as the parallel force is increased from zero, sliding does not occur until the parallel force reaches a critical value. This critical value of parallel force is found to be approximately proportional to the normal force, and the constant of proportionality is known as the coefficient of friction (COF).

FIGURE 2-1



That is, (critical parallel force) = (COF) x (normal force). The COF varies from one pair of surfaces to another, with a range generally between 0 and 1. Two regimes of sliding, and hence of COF, are generally recognized. One is the static case, in which one surface, initially stationary with respect to another, begins to slide over it when the critical value of parallel force is reached. The other regime is the dynamic case, in which the critical value of the parallel force is that required to maintain sliding at a specified velocity. The distinction is important because, in many cases, the dynamic COF is lower than the static COF, i.e., for a given pair of surfaces and a given normal force the parallel force required to maintain sliding is less than that required to initiate sliding.

Consider the case of a level floor surface and a person standing upright. The shoe and the floor form a pair of surfaces. If the person imposes a vertical force of 75 lbs. on one foot, and the static COF is 1, then an external parallel force of 75 lbs. force will be needed to just make his foot slip. If the COF is 0.3, then the minimum external force will be 25 lbs. force. If the leg is at an angle to the floor, any thrust imposed along the leg may be resolved into vertical and horizontal forces, that act as normal and parallel forces in relationship to slip. If the leg were at an angle of 45^{o} to the floor, any thrust along the leg would be resolved into equal normal and parallel forces, so that the foot would just slip with a COF of 1. For small angles, slip will occur when the tangent of the angle from the vertical equals the COF. For a COF of 0.5 this angle is 26.5^{o}: for a COF of 0.2 this angle is 11.5^{o}. This same relationship between angle and COF is used as the basis for an instrument used to measure COF (the articulated strut principle discussed in Section 2.4) and as the basis for elementary demonstrations in physics, in which COF is determined for a block on a surface by tilting the surface until the block just slides. The tangent of the angle of the surface from the horizontal is then equal to the COF between the block and the surface.

2.3 RELATIONSHIP BETWEEN BODY POSITIONS AND ACTIVITIES AND THE PROBABILITY OF SLIPS AND STUMBLES

For the purposes of this report, slip and fall type accidents are divided into several types, defined further in Section IV. The types used are:

- slip, due to loss of traction
- trip, e.g., trips over objects
- misstep, putting foot down wrongly, e.g., into hole or at abnormal angle to surface
- stumble, where foot is "caught" on surface such as carpet
- external force, i.e., pushed or pulled over
- postural overextension, e.g., lost balance while reaching

- loss of support, e.g., scaffold collapses
- medical, e.g., faint

The types related to COF are slips and stumbles, slips being related to a low COF and stumbles, possibly, to a high COF. A slip will occur if the parallel force Fp exceeds the product of the COF and the normal force Fn. For a constant COF, this situation will tend to arise under the following circumstances:

1. High horizontal forces. When the worker is pushing, pulling, accelerating in walking speed (including and especially when turning a corner or sidestepping), jumping, throwing or catching, high horizontal reaction forces must be imposed on the work surface.

2. Lowered vertical forces. These may occur if the worker "bobs down," i.e., rapidly bends the knees to unweight the feet, or if the work surface gives way beneath the worker's foot and accelerates downwards. Similarly, a worker who steps, unaware, onto a surface that is lower than the rest of his path can be in the situation where his walking motion will attempt to impose a normal horizontal force on the foot which has lower than normal vertical forces because his walking motion had attempted to place the foot at a higher level.

3. Angle between leg and a horizontal work surface. As described above, placing the leg at a larger angle to the vertical results in an increased component of the body weight in the parallel direction as well as a reduced component in the normal direction.

4. Angle between horizontal and work surface. If the work surface is not horizontal, the vertical forces associated with body or other weight will not be normal to the surface. Under these conditions, vertical forces will have substantial components parallel to the work surface. This situation may arise if the shoe is placed on a rounded object, and the ankle cannot keep

the foot level. The shoe then tilts, so that there is an angle between the horizontal and the normal to the surface, and the shoe "slides off" the object.

Combinations of the above circumstances may arise, e.g., in the case of a worker trying to push a cart up an inclined ramp.

Recovery from a slip will depend on the recovery of balance or on the termination of slipping for physical reasons, or both. Recovery of balance from a slip depends on the dynamic postural reflexes, through moving the center of gravity relative to the point of support (e.g., through flinging out an arm). This may involve injury through muscle strain. Slipping may also terminate for physical reasons, e.g., if there is a small patch with low COF on a high COF work surface. However, once slip starts the COF will have its dynamic (lower) value rather than its static value. In addition, the angle between leg and vertical is likely to be increasing rather than decreasing, and additional parallel forces would be needed to decelerate the moving foot to rest. Physical termination of a slip is thus unlikely except for very small low COF patches. The maximum size of such patches is not currently known.

Conversion from static to dynamic COF conditions may also occur in pivoting on a foot, where most of the shoe surface is made to move relative to the work surface.

Stumbles are possibly related to an unexpectedly high COF, so that a foot is "caught." The circumstances under which this can arise appear to be uncommon but may include:

1. Climbing stairs. Many persons, while climbing stairs, place their feet on the steps with a short controlled sliding motion. If the COF is unexpectedly high, control may be lost, with the foot being "caught" and delayed, typically followed by a trip over the next step.

2. Transition from smooth to rough surface. Many persons stumble when walking from a smooth surface onto a rougher surface such as a carpet. This may be due to a controlled glide type of walking on the smooth surface, in which the feet are elevated much less than usual and allowed to slip loosely over the surface

during the forward swing. If the same gait is attempted on a rough surface, the feet "catch" and loss of control results.

A review of data on the relationship between body position, task, and slip injuries is given in an article by Pfauth and Miller.(2) Additional information is available from references provided in the bibliography presented in APPENDIX A.

2.4 INSTRUMENTS FOR MEASURING COF

A number of instruments using a variety of principles have been developed for use in measuring COF. (See bibliography in APPENDIX A.) In this study, four instruments were used for measurement of COF at work surface related injury sites and for intercomparison purposes.

1. The Universal Friction Testing Machine (UFTM) was a motor driven rotary motion device supplied by the project officer. It rotated two 25/32 in. diameter footwear sole samples under a constant vertical pressure and provided both static and dynamic COF measurement capability. A range of motor speeds and a digital read-out of COF was also provided.

   Measurements obtained using the UFTM were found to have excessive scatter requiring a greatly increased number of replicates in order to obtain a desirable statistical level of confidence in the measured value of COF. One hundred measurements made with leather sole samples (surface restored after each measurement) on a formica table top with all parameters constant had a range of COF from .19 to .44 and a standard deviation of .064.

   Some problems associated with the design features of the UFTM were also encountered. The UFTM had trouble measuring "less-than-ideal" surface conditions which were found in the field. Examples of these conditions which limited the use of the UFTM were the

floor not being horizontal, the floor not uniform over the complete section swept over by the pads (for example, tiled surfaces with grooves and carpeted surfaces), the floor being wet, oily or dirty (the sweeping motion wipes these conditions clean changing the COF).

Other problems encountered in the field with the use of the UFTM were its lack of portability when measuring surfaces outside of the range of a power cord. Such locations required for power a battery supply and inverter which were both bulky and heavy. The size and shape of the machine precluded its use at a few tight-fit locations such as some stair treads, corners, etc.

Excessive "down time" due to intermittent electronic malfunctioning was experienced during the term of the contract. The UFTM also emitted too high levels of radio-frequency interference for use in a hospital or other sensitive environment.

2. The Olson Horizontal Pull Slip Meter was a commercially available device which employed a constant torque motor to drag a weighted scale with three one-half in. pads mounted with footwear sole samples across the test surface by means of an attached string so as to measure both static and dynamic COF.

This machine was portable with no outside power source required. It did, however, require approximately 18 inches of space on the horizontal plane for measurement which limited its use in several locations. The small sized pads, furthermore, interlock with less than uniform surfaces such as tiled or carpeted surfaces. Set up of this device requires careful parallel alignment of motor and scale so as to maintain a straight pull.

Some possibility of operator reading error exists with the use of this device, especially in the dynamic mode. Readings in

the dynamic mode vary with the influence of the stick-slip phenomenon which may be a function of the resiliency of the string.

3. BIGFOOT. The BIGFOOT device was a simple manually operated horizontal sliding device developed "in-house" by SAFETY SCIENCES, similar to the principle employed in the construction of many slipmeters built for practical application.

BIGFOOT consisted of a footwear sole sample holding bracket which allowed for the mounting of a 3 1/2" x 4 3/4" shoe sole sample. This large format minimized susceptibility to variations in readings due to irregular surface topography. A ten pound weight was mounted on top of the bracket and the whole unit was pulled horizontally by a 0-10 lb. spring balance (Chatillon gauge - R Cat 719-10) equipped with a peak reading device which gives the static COF measurement. Dynamic COF could also be measured and read by pulling the unit at a constant velocity and observing the scale readings.

The weight could also be removed from the bracket, placed in a shoe and, with a cord, pulled across the test surface. This enables measurements to be made with the actual shoe involved in an accident.

Despite a potential for operator error due to the variability in manual pulling speeds and pulling techniques possible, this device had the highest reproducibility of any of the four meters which were intercompared. For this reason, BIGFOOT was used for measurements at nearly all the field sites which were evaluated. Other devices were occasionally used in addition to or in the absence of BIGFOOT, but only the BIGFOOT values, where several testers were used, were reported so as to standardize the testing equipment parameter throughout the range of sites. One operator made all the measurements at the site evaluations.

4. NBS Brungraber Portable Slip-Resistance Tester. This is a non-powered device which was developed by the National Bureau of Standards. This device has a reasonably good correlation with the model of the James machine (accepted by A.S.T.M.) used by N.B.S.

This machine used the principle of the articulated strut, as does the James machine, and measures static COF only. A weight is attached to a shaft articulated at an angle approximately equal to a COF of .03. The weight is raised and released. The angle of articulation increases until the sole sample slips. The tangent of the angle between the articulated shaft and vertical is related to the COF.

This machine was borrowed from N.B.S. in order to intercompare with other meters and because it was stated to be promising for the measurement of wet surfaces at accident sites.

2.5 MEASUREMENTS OF COEFFICIENTS OF FRICTION

A number of measurements of COF were made other than at accident sites, in order to intercompare instruments, intercompare sole materials and to study distributions of COF over buildings or other areas.

2.5.1 Intercomparison of Four Measuring Instruments

The four COF measurement devices were intercompared in order to identify which device would yield the most reproducible data from the least number of measurements.

A test program was devised which called for a uniform surface, a clean formica lab table top, leather footwear sole samples sanded at regular consistent intervals and 100 static measurements made with each tester performed by one operator. The resulting measurements were then computer analyzed. TABLE 2-1 shows the means and standard deviations from this analysis.

TABLE 2-1

	UFTM	OLSON	BIGFOOT	BRUNGRABER
Mean	.31	.378	.335	.36
Std. Dev.	.064	.032	.023	.0388
Std. Dev./Mean	.206	.085	.069	.108

The mean of the mean COF values obtained was .345 and .34 was used as a central midpoint to plot histograms for each of the four distributions of data. FIGURE 2-2 shows these four distributions.

Analysis of the standard deviations indicates that the BIGFOOT device had the smallest standard deviation and would be expected to provide the most reproducible data. Further, its mean COF, .335, lay closest to the mean of all the mean COFs, .345.

2.5.2 Intercomparison of Different Sole Materials

The coefficient of friction is a property of two surfaces. It is not possible to characterize a single surface by a "partial" coefficient of friction such that when two surfaces are involved in slipping the COF is the sum of the two partial COFs. Nevertheless, it is a matter of common experience that the COF between a shoe sole material and a floor material depends on both materials such that if one sole material has a higher COF than another sole material when tested on one surface, it will generally have a higher COF when tested on another surface.

A series of measurements were made to intercompare COF with different sole materials, and to compare the results with subjective impressions of slipperiness of various surfaces. FIGURE 2-3 shows COF measured using six sole materials on six surfaces, selected to have widely different subjective degrees of slipperiness. The values for each surface are plotted against the average of all the COF measurements for that surface. The six sole materials were:

- leather
- Biltrite (a cork composition)

FIGURE 2-2

HISTOGRAMS SHOWING SCATTER IN MEASURED COF FOR FOUR INSTRUMENTS

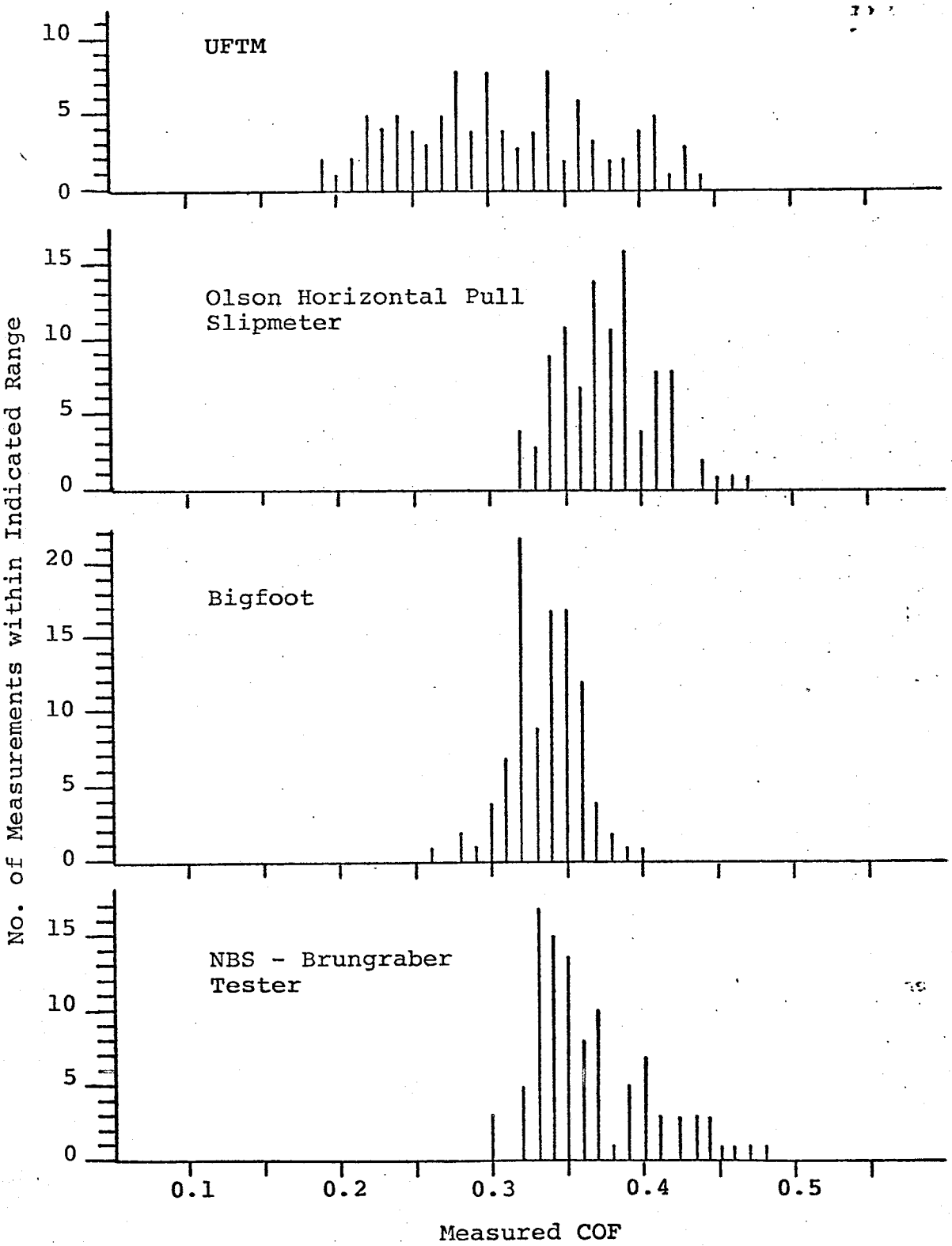
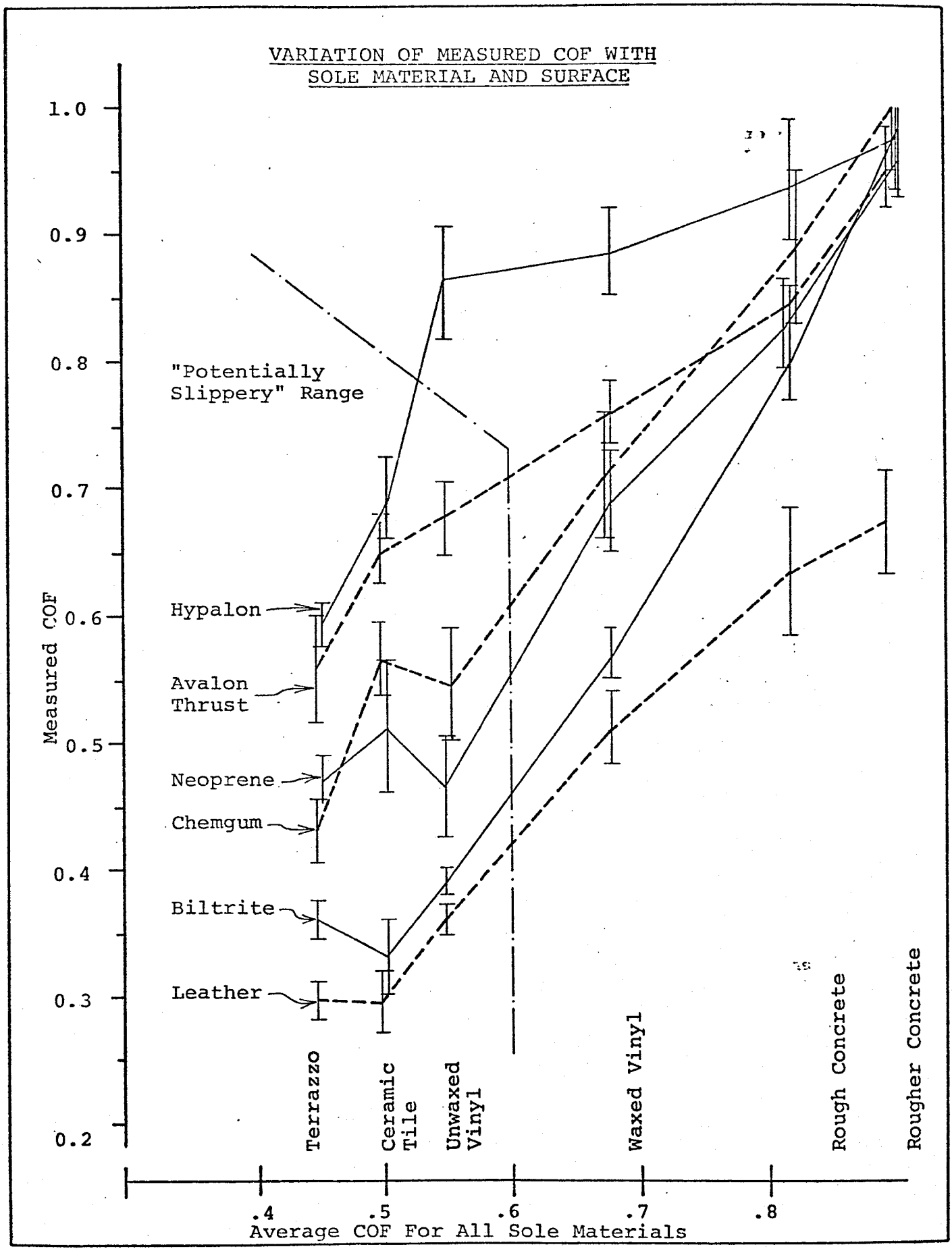


FIGURE 2-3


VARIATION OF MEASURED COF WITH SOLE MATERIAL AND SURFACE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Measured COF
"Potentially Slippery" Range
Hypalon
Avalon Thrust
Neoprene
Chemgum
Biltrite
Leather
Terrazzo
Ceramic Tile
Unwaxed Vinyl
Waxed Vinyl
Rough Concrete
Rougher Concrete
.4
.5
.6
.7
.8
Average COF For All Sole Materials

- Chemgum (a rubber-like material)
- Neoprene
- Avalon Thrust, an expanded material
- Hypalon Quabaug, a reinforced rubber material

The six surfaces were:

- terrazzo tile with brass edging
- ceramic floor tile
- unwaxed vinyl tile
- vinyl sheet, waxed and buffed
- concrete, walkway standard
- concrete, rough walkway standard

The first three of these surfaces felt subjectively slippery to a number of observers and the surfaces are arranged in order of decreasing slipperiness.

Examination of FIGURE 2-3 shows that the measured COF generally decreased as subjective slipperiness of the surface increased. The sole materials also show generally consistent COF behavior as the surface is varied. In this sense, some surfaces, and some sole materials can be described loosely as "high COF." An interesting observation is that the high COF sole materials appear to show a more rapid drop off in COF as the surface becomes more slippery than is shown by the lower COF materials. A line is drawn in FIGURE 2-3 to indicate the range considered to be "slippery." It should be noted that slipperiness may be related not only to the absolute value of the COF but to the difference in COF "felt" by a worker between one location and another. If the worker does not adjust his gait, a slip may occur even with a high absolute value of COF, while a worker habituated to working with a low shoe-floor COF may be able to avoid slips.

Floors were considered potentially slippery for COF readings below the following values:

- leather 4.35
- Biltrite 5.3

- Chemgum 5.8
- Neoprene 6.3
- Avalon Thrust 7.2
- Hypalon Quabaug 7.8

2.5.3 Measurements on Wet Surfaces

Wet spots on a floor such as vinyl tile or ceramic tile are well known to be more "slippery" than the dry floor, and are the cause of many slips and falls. It would be very desirable to be able to measure the degree to which water makes a flooring material more slippery. Unfortunately, most methods of COF measurement give inconsistent results on wet surfaces and often give results that are not in agreement with subjective experience. In many cases, the measured COF increases when a surface is wetted, even though the surface is known to be slippery when wet. It was found that, if measurements were made using water with a wetting agent added, rather than pure water, results more consistent with subjective experience were obtained. FIGURE 2-4 shows measurements using the same six sole materials as previously on a ceramic tile floor known to be "very slippery" when wet. The readings of COF using wetting agent were consistent with this subjective estimate. Further, the sole materials that had highest COF on high COF floor surfaces tended to have lowest COF on the wet ceramic tile, in conformity with experience where rubber soled shoes are "more slippery" than other materials.

FIGURE 2-5 shows similar measurements on a smooth concrete walkway, known to be "extremely slippery" when wet. The results using wetting agent are consistent with subjective experience. Leather appears to have a "high COF" when wet, as has been reported by other investigators.

FIGURE 2-6 shows measurements on a rough concrete surface, known to be "not especially" slippery when wet. Again, the COF measurements using wetting agent are in agreement with subjective experience.

The use of a wetting agent to improve the usefulness of COF measurements on wet surfaces should be investigated further.

FIGURE 2-4

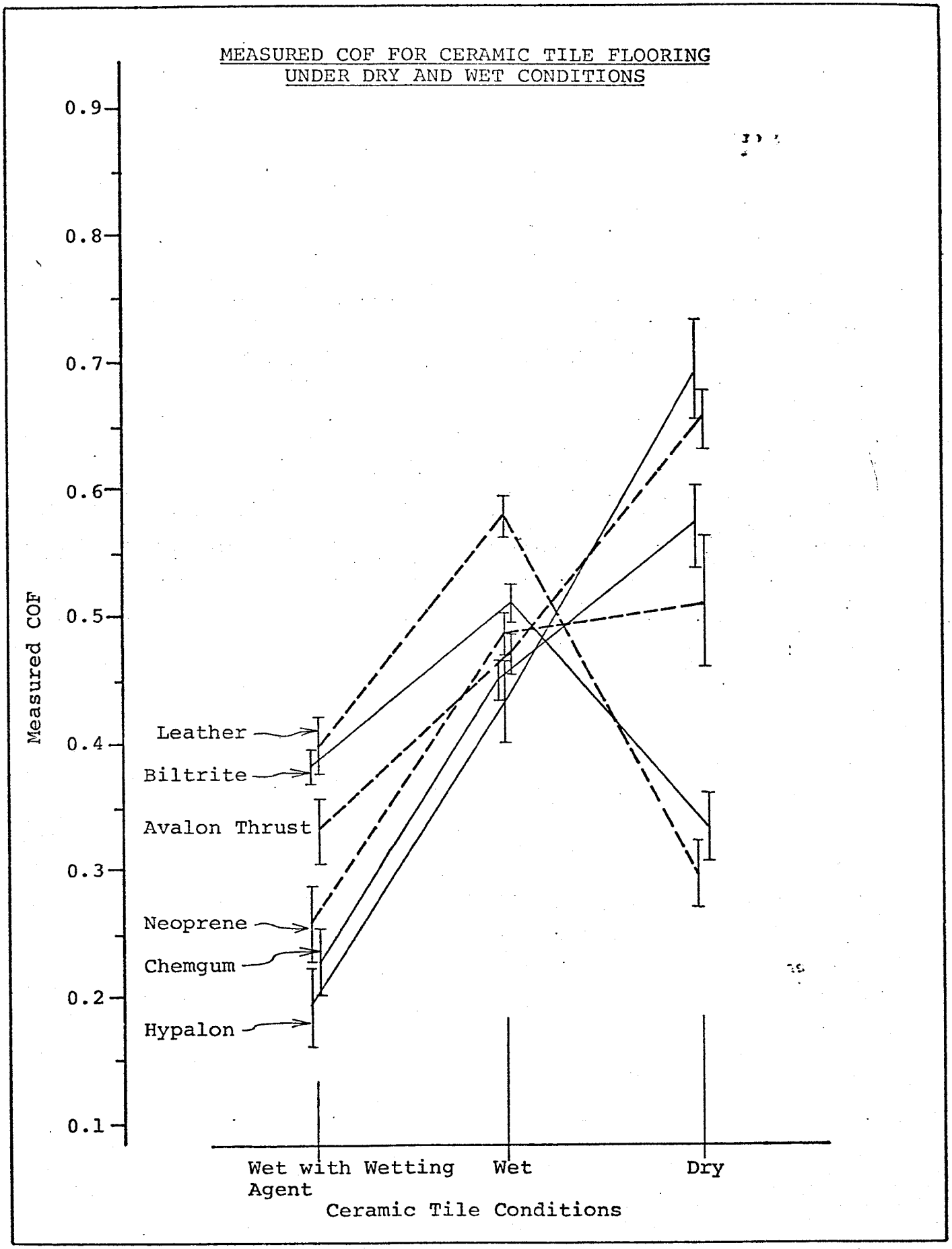

MEASURED COF FOR CERAMIC TILE FLOORING
UNDER DRY AND WET CONDITIONS
Measured COF
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Leather
Biltrite
Avalon Thrust
Neoprene
Chemgum
Hypalon
Wet with Wetting Agent
Wet
Dry
Ceramic Tile Conditions

FIGURE 2-5

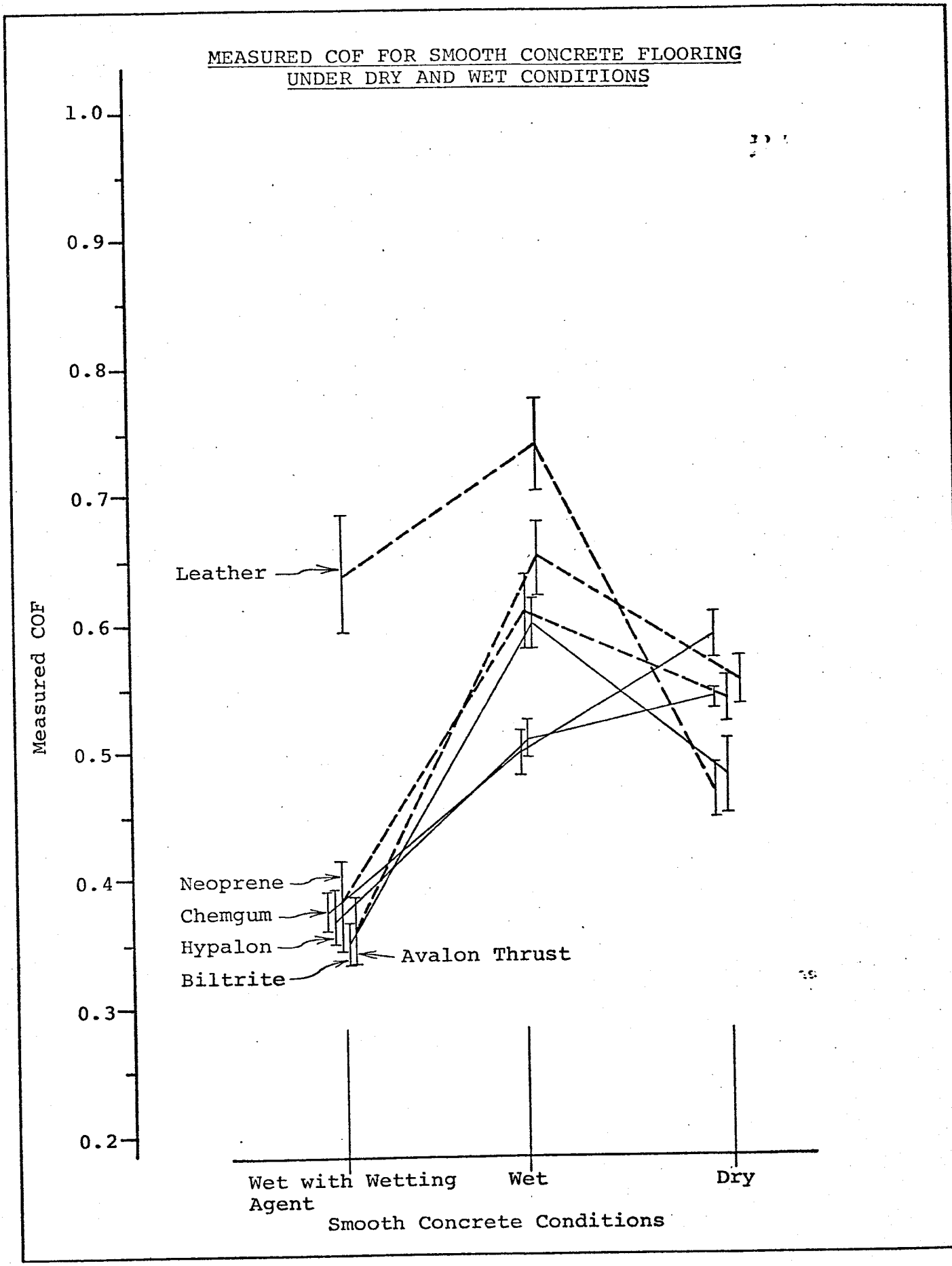
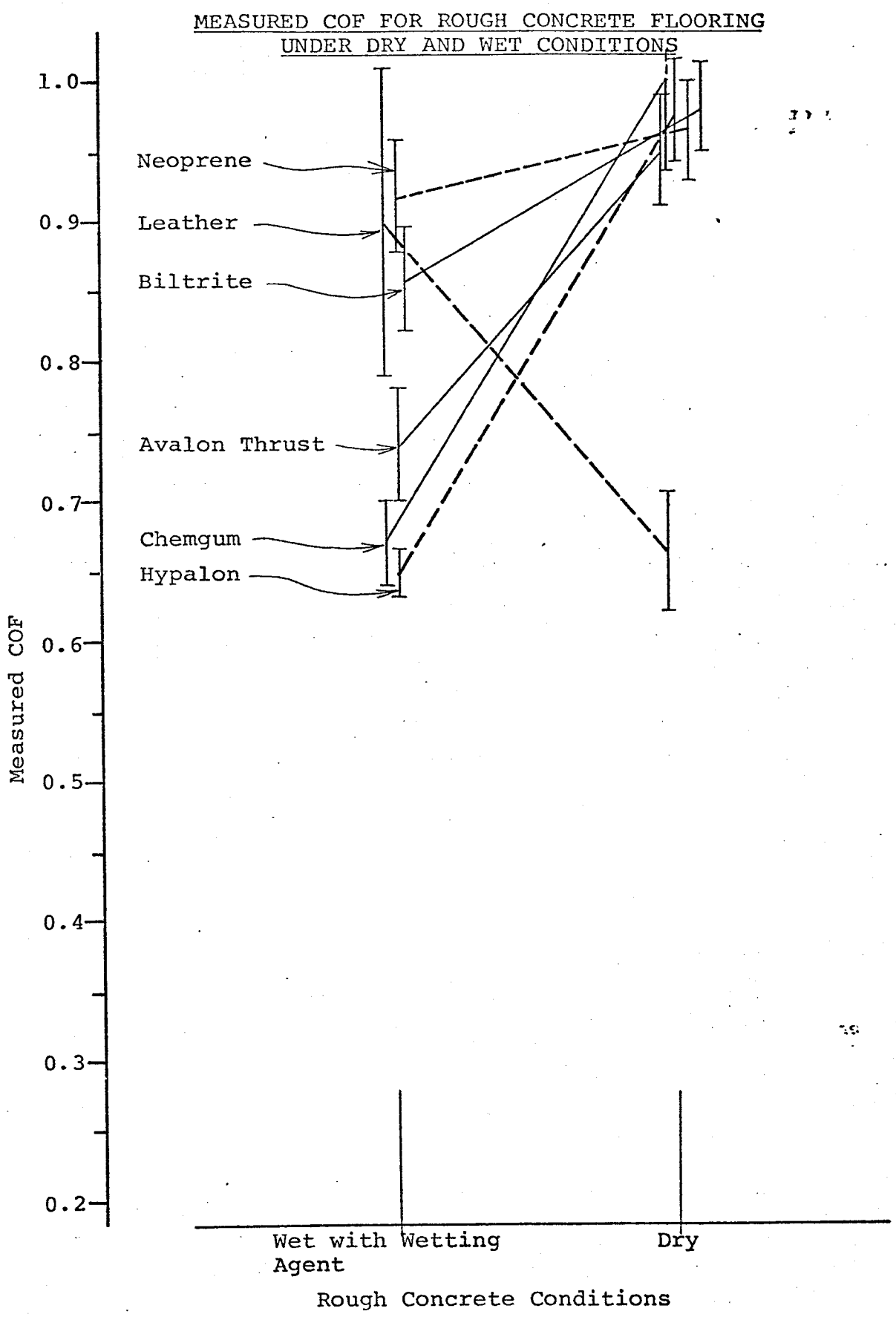

MEASURED COF FOR SMOOTH CONCRETE FLOORING
UNDER DRY AND WET CONDITIONS
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Measured COF
Leather
Neoprene
Chemgum
Hypalon
Biltrite
Avalon Thrust
Wet with Wetting Agent
Wet
Dry
Smooth Concrete Conditions

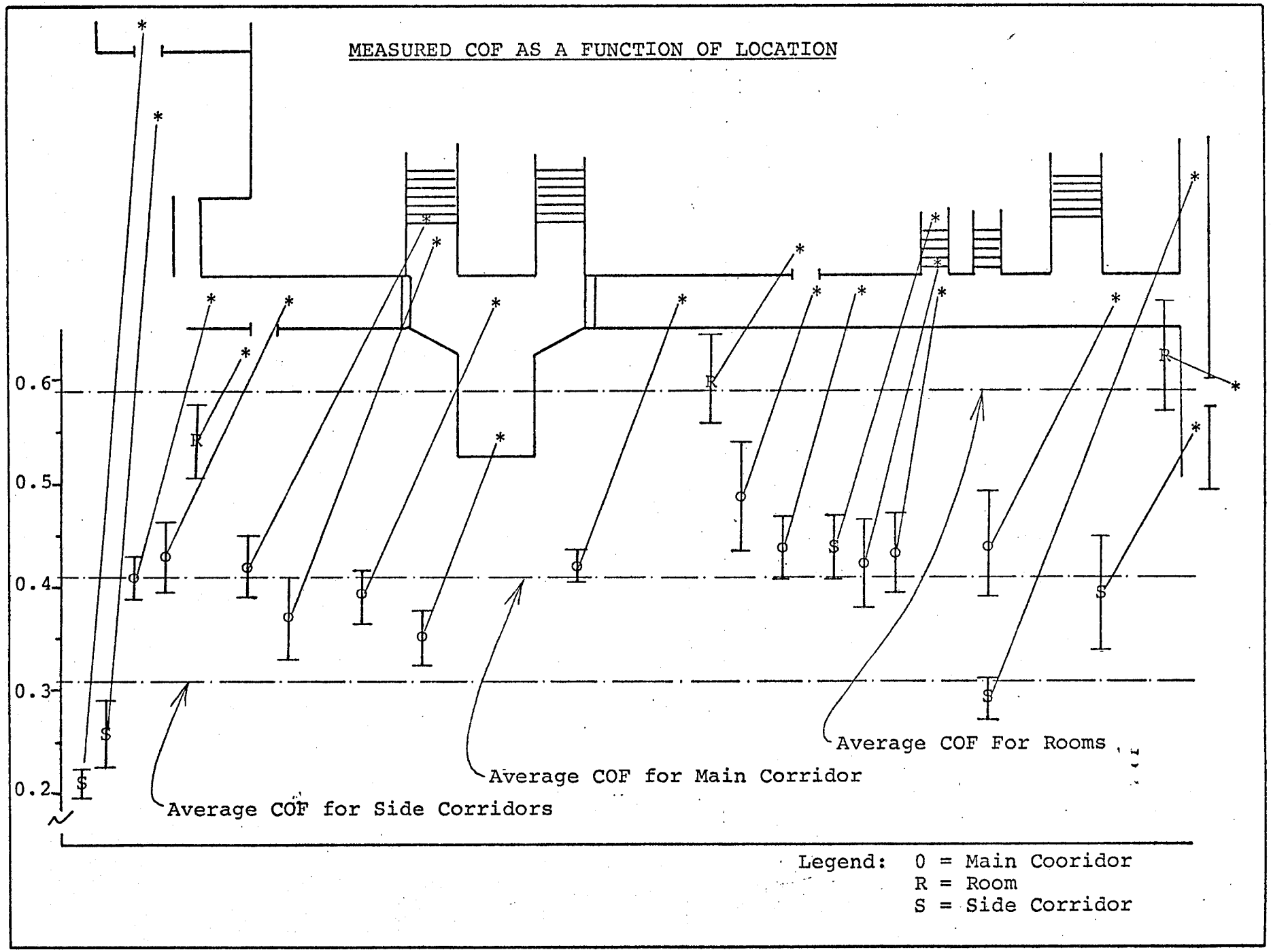
FIGURE 2-6


MEASURED COF FOR ROUGH CONCRETE FLOORING
UNDER DRY AND WET CONDITIONS
Neoprene
Leather
Biltrite
Avalon Thrust
Chemgum
Hypalon
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Measured COF
Wet with Wetting Agent
Dry
Rough Concrete Conditions

2.5.4 Measurement Over an Area of a Building

A number of series of measurements were made to compare different sites covering broad areas of selected buildings. An example of the results is shown in FIGURE 2-7 for a corridor and room system, all of which is floored with vinyl tile. As can be seen, the main corridor has values for COF that are approximately uniform. The rooms leading off this corridor tend to have significantly higher values of COF, while the side corridors have significantly lower values of COF. Non-uniformities of this kind impose a burden on walkers to adapt their gait to the circumstances.

FIGURE 2-7


MEASURED COF AS A FUNCTION OF LOCATION
Measured COF
0.6
0.5
0.4
0.3
0.2
Average COF for Side Corridors
Average COF for Main Corridor
Average COF For Rooms
Legend: 0 = Main Cooridor
R = Room
S = Side Corridor

III. OBSERVATIONS, EVALUATION AND DOCUMENTATION OF PHYSICAL PARAMETERS OF FIFTY SITES ASSOCIATED WITH WORK SURFACE RELATED INJURY SITES

In this section a description is given of the procedures used to collect, evaluate and document physical characteristics associated with 50 sites at which selected work surface related injuries had occurred.

3.1 SELECTION OF PARTICIPANTS

Selection of establishments in which to make site measurements was based upon the following criteria:

1. Nature of business:

   Representative of one of two classes of work establishment, those having a high incidence rate for slips and falls, or those having a high absolute number of slips and falls. Examples of the first class are shipbuilding, restaurants and manufacturing using machinery. Examples of the second are office workers, for whom falls form a major fraction of all injuries and who form a large population at risk.

2. A variety of sites.

3. Possibility of comparison of two establishments in the same industry to determine differences in methods and injury experience.

Where possible, establishments already participating in another concurrent NIOSH contract, No. 210-75-0018, "Investigation of Causal Factors in Selected Worker Accidents" were selected for the following reasons:

- Working relationships had been established with these establishments.

- An opportunity was provided to obtain certain critical data concerning key physical characteristics, such as footwear sole material and body position, through interviews which were disallowed under this contract but could be conducted in conjunction with the data collection procedures on the concurrent NIOSH contract.

Nine organizations agreed to participate in the study, make available their injury data and allow access to sites for observations. One organization (a university) also operated a hospital, which was separately identified in this study, giving ten establishments in all as listed in TABLE 3-1.

TABLE 3-1

DESCRIPTION OF PARTICIPANT ESTABLISHMENTS

Code #	SIC	Approximate Number of Employees	% of Work Surface Related Injury Sites Documented **	Operational Description
601	9199	9,000	18	local government
602	9199	6,000	4	local government
603	3731	6,160	4	ship construction, repair, conversion
604*	8062	1,885	2	medical and surgical hospital
605	8062	919	7	medical and surgical hospital
606	37	6,000	2	transportation vehicle manufacturer
607	8221	2,700	6	college, university
608	8221	5,000	2	college, university
609	3661	500	2	telecommunications apparatus manufacturer
610	2099	2,000	3	fast food restaurant chain

*Operated by the same organization as establishment #608.
**See Section 3.5.

3.2 INITIAL VISITS TO PARTICIPANTS

Initial visits were made to the participating establishments to explain the aims, specific requirements and possible benefits of the project to the establishment. A person (usually the safety director) was selected as a contact person for the project. At this initial visit, the project staff were familiarized with the characteristics of each establishment through discussions with the safety director or other contact person and tours of each of the establishments.

Discussions with the safety director or contact person covered the following topics:

1. Establishment Operations

   These discussions dealt with operational and organizational factors related to work related injuries. Types of data considered relevant were:

   - establishment job classifications and specific industrial or other operational processes
   - activities and tasks required to perform establishment operations
   - engineering features of the establishment such as equipment which may affect the work surfaces
   - specific types, materials and conditions of work surfaces
   - any footwear characteristics of the general employee population and any rules regarding footwear
   - employee characteristics such as size of work force, turnover rates, training
   - high, periodically high or other unusual foot traffic patterns discernible throughout the plant for later evaluation of actual sites studied
   - environmental features such as lighting, heating, noise and humidity

- housekeeping policies, problems and procedures

2. Establishment's Work Surface Related Injuries

These discussions dealt with the impressions, subjective or otherwise, held by the safety representative concerning the work surface related injury experience of the establishment. Discussion focused on the identification of:

- specific types of injury causing events, specifically types of slips and falls and types of circumstances considered to be problems
- specific sites found to have a high frequency of work surface related injuries
- types of work surfaces thought to be related to injuries
- discontinuities in types of work surfaces thought to be potential problems
- tasks and job classifications associated with work surface related injuries
- surface conditions such as substances, loose objects or insufficiency of work space associated with work surface related injuries

3. Plant Tours

A tour of each plant, conducted by the safety representative, was made in order to provide familiarization with each establishment. Particular features which had been emphasized during the discussions such as operations, jobs, surfaces and high frequency sites, were observed and documented.

3.3 ANALYSIS OF INJURY DATA AND SELECTION OF SITES

Injury data from First Reports of Injury, representing a period of approximately one year of experience, was analyzed in order to determine the extent to which the injuries were related to work surfaces and to make a preliminary selection of sites for possible observation and evaluation. Injury data was classified by accident circumstance profile patterns to determine activities and events associated with slips and falls and causes and results of those slips and falls. Task data was analyzed, to the extent data was available on the first reports of injury, to relate the role of task to the accident data. Task was evaluated in terms of specific job task performance, body, hands and feet positions and force vectors acting on the body during work.

The estimated role of the work surface/footwear interface in each work surface related injury was then evaluated. This evaluation was based upon the data provided by the accident reports, together with information supplied by the establishment safety officer or other contact person, including:

- exact location
- surface material
- surface conditions
- footwear sole material
- task

Selection of sites for observation was based on relevance to the project and feasibility of data collection. Selection was also based upon feasibility, for example whether the original work surface was still available for observation. In some cases where the work surface at a site had been modified as a result of an accident occurring at that site, a "surrogate" surface, similar to the surface as it had been at the time of the accident, was selected.

TABLE 3-2 shows, for each establishment, the number of recorded accidents of each of the following types occurring in a one-year period:

(a) all slips and falls

(b) slips and stumbles (excludes tripped over and missteps)

TABLE 3-2

SLIP AND FALL EXPERIENCE BY ESTABLISHMENT STUDIED

ONE YEAR PERIOD

Establishment No.	No. of Slips and Falls, Total	Incidence Rate, Total Falls	Slips and Stumbles, Total	Incidence Rate, Slips and Stumbles, Total	Slips and Stumbles, Dry Surface	Slips & Stumbles, Dry Surface As % of Slips & Stumbles
601	35	.38	13	.16	12	34
602	230	3.71	25	.40	0	0
603	172	2.71	26	.41	7	4
604	24	1.23	9	.45	1	4
605	23	2.43	15	1.58	1	4
606	126	2.03	45	.73	9	20
607	37	1.33	5	.18	1	2
608	41	.76	15	2.80	1	2
609	19	3.68	6	1.16	2	11
610	41	1.99	21	1.02	3	7
TOTAL	748		208		37	

(c) slips and stumbles on dry surfaces

For each accident type an incidence rate is given (events per 200,000 person hours worked).

It can be seen that, for all establishments combined, slips and stumbles accounted for about 28% of the total slips and falls. Slips and stumbles occurring on dry surfaces account for about 18% of the total slips and stumbles, and about 5% of the total slips and falls.

All the establishments taken together had 37 slips and stumbles occurring on dry surfaces in the one-year period. The 50 site observations were selected to include 35 sites at which "dry" slips had occurred, 15 sites at which slips had occurred on a wet surface and two sites at which stumbles had occurred. Obtaining this number of sites at which "dry" slips had occurred resulted in a need to make observations at sites at which accidents had occurred a year or more prior to the observation. Only two stumbles were identified during the study and the sites of both were included.

3.4 CONDUCT OF SITE OBSERVATIONS

An attempt was made in every site evaluation to acquire the most complete and detailed data possible regarding the condition and use of the site, the circumstances of the accident and the body tasks and positions of the injured employee.

The participating establishment safety director or contact person served a valuable role by supplementing First Report of Injury data on most of the selected injury sites. These persons had knowledge of the general characteristics of locations and operations. They had performed their own accident investigations on some of the selected sites and were intimately familiar with the details, or could provide investigation reports. If further data was required the contact person could often supply it by personally contacting either the employee, a witness or the employee's supervisor prior to the site visit. Some of the injury sites selected for observation had also been selected for in-depth accident investigation data collection on concurrent NIOSH contract No. 210-75-0017. In such cases ample data to sufficiently understand the accident sequence was generally obtainable. However, in only very few cases was it possible to establish exact body positions, or biomechanical parameters. This is

because the injured person usually had no exact recollection of foot placement or of how the slip occurred.

After all available data concerning the circumstances of the occurrence at a selected site had been gathered, a visit was made to the site to observe and document the physical parameters related to the event. The following items were covered:

Footwear Parameters

When possible, the actual footwear worn during the occurrence was closely examined. Shoe type, fastening type, sole and heel height, and proper fit were evaluated to determine if any of these could be factors. Sole and heel construction material and condition (extent of wear) were identified as closely as possible so as to evaluate the role of footwear in the coefficient of friction at the site. In most cases it was only possible to identify the type of material in the shoe sole and heel. In a few cases, the actual shoe was available and could be mounted on the BIGFOOT tester for coefficient of friction (COF) measurements.

In cases where footwear data was unavailable, a leather footwear sole sample was used for the purposes of testing. Much work had been done on the reproducibility of various COF testers, prior to the site evaluation phase, using leather as a standard medium and a large amount of data concerning its COF properties was therefore available.

Work Surface Characteristics

Floor surfaces at the accident site, approaches to that site and the location where an injured employee normally worked, if elsewhere, were observed. Surfaces at the approach and at locations at which the employee normally worked were considered important to observe in order to assess any differences in work surface properties between these locations and the accident site. Any such differences may have affected the behavior expected by the injured employee versus the actual behavior of the work surface.

Physical parameters of work surfaces which were routinely observed were:

- surface type and function: hall, walkway, stair, plant floor, scaffold, industrial truck, entrances, etc.

- surface construction: materials used, texture and visibility; design features such as incline, drainage, unusual topographical features

- surface treatment: acid-etched, waxed and buffed, non-skid material, etc.

- surface condition: maintenance features such as wear, scuffing, ill-repair; hazardous condition features such as water, oil, ice, dust, etc.

- layout: adequacy of floor space, traffic routes, work stations, adjoinments of two surfaces with widely different properties related to COF

- subjective estimates of slipperiness as determined by walking on the surface

Task Parameters

Observation of types of jobs performed in and about the site was made to determine relevancy to the accident occurrence. Generic types of tasks such as transit, materials handling, office work, etc. were identified. How these tasks were performed -- processes, procedures, and equipment used -- was also evaluated. Traffic volume and traffic patterns of persons working in the immediate area and of persons coming into the immediate area from other areas were observed.

From evaluation of all available data, attempts were made to reconstruct exactly what task the injured employee was performing at the time of the accident and exactly how it was being performed. This evaluation included the biomechanics of task performance and how the biomechanics was related to the occurrence of the accident.

Biomechanical considerations included determination of body postures and hand and foot tasks performed and the positions assumed by hands and feet. Areas of shoe sole contact with the work surface as associated with the performance of specific tasks, such as stair mounting and stair climbing, was investigated. An attempt to understand the forces and weight distributions imposed upon the body was made.

Housekeeping Parameters

General data on housekeeping practices, and problems that could be expected at various establishments was acquired from the safety representatives.

Specific housekeeping data relevant to actual sites observed was collected at the times of the visits. Some housekeeping issues that were determined relevant to work surface related injuries are:

- water, oil, etc. spills, and policies for reporting them and for immediate mopping; situations which may deter or postpone immediate mopping
- types of surface finishing treatments used and the criteria, if any, used for selection
- wax-stripping, waxing and buffing schedules and whether any workdays were allowed to elapse in between these two operations
- frequency of dust mopping and sweeping operations
- loose objects on the floor
- isolating in-progress stripping, waxing and mopping areas from foot traffic
- establishment operations (such as leaky machines) and procedures which contribute to housekeeping problems

Environmental Parameters

Characteristics of the environment that were considered relevant to causal factors of the work surface related injuries selected for study were noted at the site observations. The environmental factors considered most important to the study were:

- lighting type: indoor - fluorescent and incandescent; outdoor - sun, shade, overcast, glare; and lighting adequacy to properly illuminate work surfaces, especially at locations requiring the negotiation of changes in level

- heat and its possible effect on the properties of wax and other floor surface treatments. (The extent of any change, however, was insufficient to significantly affect COF readings made with current equipment.)

- humidity -- its possible effect on the properties of wax and other floor surface treatments, and on shoe soles

- ambient weather conditions such as precipitation and fog

- noise and other factors in the vicinity which may distract workers or in any other way destroy their attention to walking, etc.

Work Surface Coefficient of Friction Parameters

COF measurements using various meters were made at the 50 work surface related accident sites in order to determine the slipperiness of the work surface and better evaluate the role of the work surface in the occurrence of the event.

The COF is a function of the footwear/surface interface. Accordingly, when it was known what type of sole and heel material was being worn by the injured employee at the time of the accident, the same material type was employed for site COF measurements. In cases where the footwear sole material type was unknown (or no footwear was involved, e.g., in the case of a stool slipping), leather was employed as a material because it had been used extensively in reproducibility testing.

When complete data was available, the exact location and conditions obtaining on the work surface at the time of the accident were reproduced for testing purposes. Subjective estimates of slipperiness were made by walking over the site areas.

Some sites which involved non-level surfaces, such as edges of stairs and walkways, presented a problem for measurement. Measurements of COF were made at a level area of the same material as near to the accident site as possible.

At least five measurements of COF were made at each site. In some cases, more replications were made, depending

on the exact device used and the scatter found in the first five measurements.

COF measurements were made at a number of locations depending on the need to understand the circumstances of each accident:

- Measurements were made at the accident site. If some confusion existed as to the exact location, several locations, as could best be recalled, were measured.
- Measurements were made at approaches, where applicable, to the accident site that would have been in the immediate preceding path taken by the injured employee. Such measurements were considered valuable in determining any unexpected change in slipperiness of surface material or condition that may have contributed to the accident circumstances.
- Measurements were made at locations where the injured employee normally worked if it appeared that an unexpected change in COF may have been involved in the accident circumstances.

COF data are given as described in terms of:

- mean ($\bar{x}$)
- standard deviation (s)
- number of observations (n)

T-test statistics are used to test for the significance of differences between two sets of observations of COF.

3.5 WORK SURFACE RELATED INJURY SITE EVALUATION

Brief individual reports are given on the following pages for 50 sites investigated. Fifty-one accidents are included, because one site was associated with two accidents. In most measurements of COF, the BIGFOOT instrument described in Section 2.5 was used because of the lower scatter found in the measurements.

1. 12/8/76 - 9:30 p.m. 35 year old male senior systems analyst working in SIC 9199 with 7 years, 3 months experience with establishment #601 had been working overtime to resolve a computer program problem, was leaving area to go to parking lot, exited carpeted room, stepped on linoleum tile hallway, slipped and fell backwards. (The receptionist was able to relate that an event with similar circumstances had occurred that same week but had not resulted in injury. She could remember no exceptional conditions at the times of the events that could have been related to both events.) Multiple contusions. No lost workdays.

   a) footwear: unknown

   b) work surface: carpet dirty and matted at entry (high traffice area); vinyl tile hallway (site) waxed, moderate traffic.

   c) tasks performed at site: transit, materials handling route, moderate traffic volume area.

   d) employee task and biomechanics: unknown other than walking.

   e) housekeeping: no obstructions or hazardous conditions at time of field visit. Swept once daily, clean.

   f) environment: lighting fluorescent, temperature and humidity normal. Noise at moderate office level.

   g) COF: measured using BIGFOOT with leather sole:

      1) location 1: carpeted floor in EDP services, low traffic area.

         $\bar{x} = .551$
         $s = .026$
         $n = 5$

      2) location 2: carpeted floor at EDP entry -- high traffic, dirty and matted.

         $\bar{x} = .62$
         $s = .053$
         $n = 5$

3) location 3: vinyl tile hallway just outside doorway -- measurements taken approximately 1 step distance outside entry and slightly off center in direction of parking lot.

$\bar{x} = .39$
$s = .057$
$n = 5$

The difference in means between location 2 and location 3 is significant at the 0.05 level.

This case shows reasonable evidence for suspecting the work surface as a primary cause of the accident. The injured had worked on the carpeted surface for the most part of the over 12 hours he had been at work. On his first step onto the hallway at the end of the day, the work surface changed to one which (a) was in the slippery range and (b) had a lower COF than the carpet.

The juxtaposition of two surface types with very different COF properties (.2 or greater in this case) should be avoided or a transitional surface or marking could be introduced.

2. 1/18/77 - 9:06 a.m. 39 year old female data entry operator working in SIC 9199 with 2 years, 9 months experience with establishment #601 was on break, reporting back to work station walking around corner on waxed vinyl tile hallway carrying a cup of hot coffee, moved abruptly to avoid running into a woman coming around the corner from the opposite direction, slipped on "freshly waxed" floor and fell to same level striking floor with arm and wrist. Contusions to wrist and arm.

a) footwear: unknown

b) work surface: vinyl tile, waxed, clean, high traffic area, some scuffing, wear.

c) tasks performed at site: transit and materials handling route (high traffic volume): passage also used for storage of boxes.

d) employee task and biomechanics: uncertain which foot slipped -- the stepping foot or the pivoting foot; possible low vertical forces from sidestepping avoidance articulation; possible putting foot down at glancing angle.

e) housekeeping: no obstructions or hazardous conditions existing at time of field visit. Swept once daily. Clean.

f) environment: fluorescent lighting, adequate. Comfortable temperature and humidity. Noise at moderate office level. Blind corner in walking route.

g) COF: measured using BIGFOOT with a leather sole:

1) location 1: hallway straightaway -- approach to site.

$\bar{x} = .439$
$s = .05$
$n = 5$

2) location 2: turning point on track through hallway. Hallway users were observed in order to determine the typical path used for negotiating the corner from the direction taken by the injured employee.

$\bar{x} = .41$
$s = .054$
$n = 5$

The measurements taken are borderline slippery but without knowledge of the footwear involved in the accident circumstances, a definitive statement on COF cannot be made. Further, there was a five month time lapse between event and evaluation.

Some other circumstances in this event are noteworthy as potential factors. The event of suddenly encountering another person in the injured's path probably influenced walking behavior as she made a quick movement in an attempt to avoid a collision. The potential for misstepping, putting the foot down at a glancing angle or over-extending posture and losing balance is great when a sudden lateral movement is made. Carrying coffee is a task associated with a surprising number of work surface related injuries. Perhaps the injured was concentrating on not spilling the coffee to the degree that concentration on walking behavior suffered.

Installation of blind corner mirrors and work rules related to the carrying of coffee need to be considered as countermeasures in addition to proper maintenance of floor COF.

3. 3/22/76 - 2 p.m. 58 year old female secretary II, department clerk working in SIC 9199 with 3 1/2 yrs. experience within establishment #601 was on break, reporting back to work from the cafeteria, exited cafeteria and on first step into hallway slipped on a "slick" spot on the floor, skidded and fell sustaining contusion to unknown body part, requiring medical treatment.

a) footwear: unknown

b) work surface: vinyl tile in both hallway and cafeteria. Hallway high traffic area. No change in surface materials.

c) tasks performed at site: transit, high traffic area in cafeteria and hallway.

d) employee task and biomechanics: walking (exiting from cafeteria into hallway: returning to department would have involved turn to left in hallway).

e) housekeeping: no obstructions at time of field visit, hallway clean, cafeteria dusty. Both swept once daily.

f) environment: lighting, temperature, humidity, noise not obvious factors.

g) COF: no attempt was made to find the specific "slick" spot since 15 months had elapsed between injury and field visit. The BIGFOOT device was used with a leather sole sample.

1) location 1: in hallway just outside of exit and in direction and distance from cafeteria as dictated by the conditions "reporting back to (stated department)" and "first step in hallway."

$\bar{x} = .485$
$s = .052$
$n = 5$

2) location 2: just inside cafeteria - approach to accident site; prior to dust mopping.

$\bar{x} = .473$
$s = .034$
$n = 5$

3) location 3: just inside cafeteria, same site as location 2; immediately after dust mopping.

$\bar{x} = .601$
$s = .043$
$n = 5$

The measurements taken during the field visit at the accident site do not indicate an especially slippery floor condition. However, the significant change in measured COF produced by simple dust mopping suggests that the flooring and use conditions of this location could readily result in some patches with a significantly higher COF than others.

4. 4/19/77 - 10 a.m. 53 year old female registered nurse working in the health department, SIC 9199, with 25 years experience with establishment #601 was walking in office in haste and slipped on a "freshly waxed" floor, fell to floor sustaining a hematoma to the left leg, requiring first aid treatment only.

a) footwear: laced nursing shoe, "Avalon Thrust" soles, good condition.

b) work surface: vinyl tile, suspected as being "freshly waxed" -- exceptionally slippery -- by the injured employee who also reported that four other persons had slipped that same week as a result of the "freshly waxed" floor. The Physical Plant Department indicated that the waxing compound used and waxing procedures used were selected after in-place COF measurements.

c) tasks performed at site: transit area, high traffic area within larger office. On this occasion, conducting a busy clinic, injured employee was attending to patient's needs, walking very fast.

d) employee task and biomechanics: possible low vertical forces and/or reduced area of foot/surface interface contact area, no turning or sidestepping involved.

e) housekeeping: no outstanding characteristics. Floor clean, waxed, buffed.

f) environment: adequate, apparently no obstructions.

g) COF: the BIGFOOT device was employed for friction testing as below:

1) location 1: approach to site, vinyl tile hallway (office) 4-5 feet prior to site, according to injured employee. Avalon Thrust sole sample, worn condition:

$\bar{x} = .6$
$s = .02$
$n = 5$

2) location 2: site, vinyl tile hallway (office), Avalon Thrust sole, worn condition:

$\bar{x} = .546$
$s = .057$
$n = 5$

3) location 2: site, Avalon Thrust sole, smooth, new condition:

$\bar{x} = .59$
$s = .06$
$n = 5$

4) location 2: site, leather sole sample, worn condition:

$\bar{x} = .35$
$s = .024$
$n = 7$

The coefficient of friction values observed for the sole type as indicated as involved, Avalon Thrust, are high but are within the slippery range of work surfaces measured using this sole material. Observations made with leather, moreover, were also indicative of a slippery condition. It appears that wearing shoes with high friction soles may not prevent slip, on a low friction surface. Measurements were made almost two months after the event and the injured employee indicated that in her subjective estimate, frictional properties had improved.

5. 6/15/76 - 9 a.m. 23 year old female secretary I working in SIC 9199 with 3 1/2 years experience with establishment #601 was exiting restroom, descending 5 step staircase to main hallway (bottom riser is significantly shorter than the others in the series) slipped on the hallway floor, recovered balance, spraining an ankle (bodily reaction) resulting in ten lost workdays.

a) footwear: unknown

b) work surface: the work surface traveller is confronted with the immediate juxtaposition of three different surface materials at this location:

inside women's restroom: ceramic tile entry and staircase; "non-skid" epoxy surface hallway; (site) - linoleum tile.

c) tasks performed at site: transit, to and from breaks, high traffic area.

d) employee task and biomechanics: perhaps abnormal stepping behavior and therefore foot placement due to radically shortened step riser.

e) housekeeping: clean, no hazardous conditions observed at time of field visit. Hallway floor waxed and scuffed.

f) environment: fluorescent lighting, subjectively perceived as slightly dimmer than other basement hallway areas observed. Moderate office noise.

g) COF: leather sole samples were used on the BIGFOOT device at each of three locations:

1) location 1: approach, interior of women's restroom, ceramic tile flooring, just inside doorway. (1"-2" x 1"-3" tiles)

$\bar{x} = .435$
$s = .031$
$n = 5$

2) location 2: approach, cement surfaced with "non-skid" epoxy encrusted with flake material to enhance frictional properties, entry landing and staircase, measurements made on landing.

$\bar{x} = .42$
$s = .038$
$n = 5$

3) location 3: site, linoleum tile at base of steps:

$\bar{x} = .43$
$s = .038$
$n = 5$

The frictional properties of the site, while bordering on "slippery" are not slippery enough to be considered a significant hazard.

The difference between the means of the measurements obtained at the various locations does not suggest that changes in COF were a significant causal factor.

From all available data, the most probable cause of the accident and the most significant hazard at this site is the short riser (approximately 3.5") of the ultimate downward step. After negotiating four step risers of normal height (approximately 7") the work surface traveller is confronted with a short step onto a different surface type. Analysis of stairway accidents shows that "mis-stepping" is a frequent causal type related to falls and, further, that most of these missteps occur while mounting or dismounting stairways from a regular surface. The design problem of this stairstep compounds the complex biomechanical task of negotiating stairs and this area should be considered high risk for both slipping and misstepping.

6. 2/17/76 - 12:57 p.m. 59 year old female supervising clerk working in SIC 9199 with 12 1/2 years experience in establishment #601 was reporting back to work after lunch break, exiting restroom, slipped in hall outside restroom on dry floor, skidded 8 inches and recovered balance straining back with no lost time. The entry to the restroom is up 4 steps from the hallway, then a 5 foot entry to the door. The stair risers are all approximately 7 inches except for the last step down to the hallway which is approximately 3 1/2 inches in height.

a) footwear: unknown

This accident occurred in the same location as accident #5 and involved essentially similar circumstances.

7. 11/16/76 - 7:50 a.m. 61 year old female senior account clerk working in SIC 9199 and having 6 1/2 years experience with establishment #601 was walking towards her desk (reporting to work), stepping from carpeted floor to parquet (wood) floor, slipped and fell to floor suffering multiple contusions but resulting in no lost time.

a) footwear: unknown

b) work surface: area is a large office with several corridors arranged throughout and surfaced with carpet for walking. The remainder of the area, i.e., between carpet runners and around desks, etc., is parquet.

c) tasks performed at site: office and transit, moderate traffic area.

d) employee task and biomechanics: unknown other than walking.

e) housekeeping: clean, no loose objects on floor at time of observation.

f) environment: large office with perhaps 50-100 desks. Good fluorescent lighting -- moderate office noise level.

g) COF: the BIGFOOT device with leather sole samples was used to evaluate the frictional properties. Note: The exact location had two days prior to the visit, been resurfaced with other material. Much of the area, however, retained the carpet-to-parquet arrangement and measurements were made at another area, stated by employees to have the same carpet and wood types and to be "similar" to the actual site.

1) location 1: surrogate approach to site, carpet runner, clean.

$\bar{x} = .544$
$s = .022$
$n = 5$

2) location 2: surrogate site, parquet (wood) floor, clean.

$\bar{x} = .366$
$s = .0365$
$n = 5$

Reasonable evidence exists for suspecting the work surface as the primary hazard associated with the cause of this fall accident injury:

- The surface at the site type was observed to have a mean COF of .366, well within the slippery "range", i.e., COF less than .43 when measured using a leather sole.

- The change in coefficient of friction from carpet to wood, approximately .18, was probably the most significant factor involved in the accident, especially since it is known that the "slip" occurred on the first step from the carpet to the wood. The injured employee had insufficient opportunity to adjust her walking gait from a high surface coefficient of friction to a lower coefficient. (The difference in mean coefficients of friction was significant at the .01 level of confidence, as indicated by using the t-test formula.)

8. 10/18/76 - 3:26 p.m. 63 year old female junior clerk typist working in SIC 9199 with two years experience in establishment #601 was walking quickly with crepe soles, of unknown condition, stumbled on the carpeted floor ("stumble" defined as a type of fall induced by excessive friction in which the motion of the foot is prematurely arrested resulting in a loss of postural control) and fell against the leg of a small table resulting in a contusion to the knee and then fell same level to the floor. No lost workdays.

a) footwear: crepe soles, condition unknown

b) work surface: industrial carpet, approach also carpet.

c) tasks performed at site: office transit area.

d) employee task and biomechanics: unknown other than "walking."

e) housekeeping: clean, no obstructions, no exceptional characteristics of carpet.

f) environment: lighting good, fluorescent.

g) COF: BIGFOOT, fitted with a crepe soled shoe:

1) location 1: approach to site, carpet, approximately 3-4 feet prior to site in path:

$\bar{x} = .96$
$s = .025$
$n = 5$

2) location 2: site, carpeted:

$\bar{x} = .98$
$s = .021$
$n = 5$

The exceptionally high COF may be related to the incident. Crepe soles show polar extremes in frictional properties -- they have been identified as being involved in other similar "high-friction" stumble events, and are notoriously slippery when wet, a low COF situation.

Education as to footwear selection from a safety standpoint appears to be the priority countermeasure.

9. 6/16/76 - 7:45 a.m. 53 year old female senior clerk typist working in SIC 9199 with five years experience in establishment #601 was in restroom, tried to release doorstep (mounted to and hinging from base of door with rubber foot) with foot, slipped and fell sustaining a contusion to the back with unknown lost time.

a) footwear: unknown

b) work surface: vinyl sheet, waxed.

c) tasks performed at site: transit, breaks, high traffic area.

d) employee task and biomechanics: standing on one foot and manipulating object with the other foot.

e) housekeeping: excellent, clean, no obstructions on day of field visit; apparently a "non-skid" type of wax or other floor treatment applied.

f) environment: lighting adequate.

g) COF: BIGFOOT with leather sole sample:

1) location 1: site, vinyl tile.

$\bar{x} = .714$
$s = .017$
$n = 5$

More than one year elapsed between event and measurement. The type of floor treatment and condition at time of event is unknown. Standing on one foot and pushing, manipulating or kicking with the other foot is an intrinsically unstable body position. No COF problem existed at the time of visit. However, a similar restroom on the same floor, measured on the same day, showed lower COF values (see accident #10). It is thus possible that lower COF values existed at the time of the accident.

10. 2/1/77 - 12:55 p.m. 49 year old female account clerk working in SIC 9199 with 14 years experience in establishment #601, was entering restroom and slipped on dry floor and fell down on both knees resulting in contusions to the knees but no lost workdays (report related that event was related to the footwear but the specific type was not identified).

a) footwear: unknown

b) work surface: the area presents four different flooring materials:

1) hallway and entry corridor -- terrazzo with marble.

2) "non-skid" epoxy border and strip in front of door.

3) restroom "lounge" area -- linoleum tile.

4) restroom toilet area -- ceramic tile of variable dimensions.

c) tasks performed at site: transit, breaks, moderate to high traffic area.

d) employee task and biomechanics: entry to restroom requires pushing open door against return spring (normal exertion for this type door).

e) housekeeping: no exceptional characteristics noted during field visit. Surface #3, above, is the only one which has regular surface treatment (wax and buff).

f) environment: lighting adequate.

g) COF: BIGFOOT with leather sole samples:

1) location 1: approach, main hallway, terrazzo:

$\bar{x} = .442$
$s = .08$
$n = 5$

2) location 2: approach, corridor entry to restroom, terrazzo:

$\bar{x} = .46$
$s = .044$
$n = 5$

3) location 3: possible site, "non-skid" epoxy with "non-skid" flakes embedded, entryway border at doorway:

$\bar{x} = .39$
$s = .041$
$n = 5$

4) location 4: possible site, restroom lounge area, linoleum tile:

$\bar{x} = .58$
$s = .07$
$n = 5$

5) location 5: not related to event but interesting in comparison of the four different surface materials one is required to negotiate in order to use the facilities. Ceramic tile of variable dimensions (1"-2" x 2"-3"):

$\bar{x} = .487$
$s = .054$
$n = 5$

The exact details of the fall could not be recalled. However, the significantly lower COF of the entry strip (which had the appearance of a high COF treatment), coupled with the need to push open the door, suggests that this is one of a common class of accidents, foot slipping to rear on threshold when pushing to open a door.

11. 3/12/76 - 4 p.m. 64 year old female (reported by supervisor as overweight) intermediate clerk working in SIC 9199 with 16 years experience in establishment #601 was leaving work, walking out into hallway in haste to catch bus carrying large and heavy (20+ lbs.) stack of papers, slipped as she was abruptly turning in hallway on "slick" floor reported as "recently waxed," fell to floor sustaining contusion and strain to torso and broken pair of glasses resulting in one lost workday.

a) footwear: unknown

b) work surface: linoleum tile in main hallway (site) and in office traffic area (approach).

c) tasks performed at site: transit, high traffic area, in hallway, few people exit at this location.

d) employee task and biomechanics: as demonstrated by supervisor, made an abrupt 90 degree turn in hallway and pivoted on one foot, high horizontal forces from "throwing other side of body around" to follow through on pivot.

e) housekeeping: no outstanding characteristics, surface waxed, not recently buffed, clean.

f) environment: fluorescent lighting adequate.

g) COF: BIGFOOT device fitted with leather sole samples:

1) location 1: approach to site, inside office -- linoleum tile, clean, good surface:

$\bar{x} = .54$
$s = .035$
$n = 5$

2) location 2: site, main hallway, linoleum tile, good condition, clean:

$\bar{x} = .43$
$s = .033$
$n = 5$

A statistically significant difference in mean coefficients of friction between locations 1 and 2 was found at the .001 level of confidence.

The COF at the fall site was on the boundary of the "slippery" range. The difference in COF between the office and the hallway may have contributed to the accident. The task, rapid turning of a heavy person carrying a heavy mass of paper that needed to be held together, imposed very severe requirements on the work surface. The foot probably pivoted and it is possible that this converted the frictional situation from static to dynamic, with a corresponding reduction in effective COF.

12. 10/26/76 - 7:50 a.m. 54 year old female junior clerk typist working in SIC 9199, with 1 1/2 months experience in establishment #601 was reporting to work in the morning at the front entrance to the building, slipped on stone surface and fell to same level sustaining contusion to knee but resulting in no lost time.

a) footwear: unknown

b) work surface: level walkway -- smooth stones (approximately 2-3" diameter) embedded in and protruding from concrete. Stones worn smooth and have "polished" appearance.

c) tasks performed at site: transit, periodic high traffic volume on reporting to and leaving from work.

d) employee task and biomechanics: unknown if injured employee was dismounting staircase onto walkway or was fully on walkway.

e) housekeeping: clean at time of field visit. Reportedly close to an area under construction at the time of the event and may have been subject to layers of fine dust.

f) environment: outdoor, possibility of morning dew on surface (propinquity to marine environment).

g) COF: BIGFOOT device employing leather shoe sole samples.

1) location 1: approach, stairway, bricks:

$\bar{x} = .456$
$s = .045$
$n = 5$

2) location 2: approximate site (exact stone unknown)

$\bar{x} = .39$
$s = .035$
$n = 5$

The mean COF of the site, .39, is within the "slippery" range and also has a lower COF than the approach. Embedded stones typically become polished and smooth, and these had not been etched or sandblasted.

13. 5/20/77 - 9 a.m. 54 year old female data entry coordinator working in SIC 9199 with 18 years experience in establishment #601 was walking to her desk in a large room, slipped on the "slippery" floor, lost balance, twisted foot, fell to floor sustaining minor bruises to the head with no lost time.

a) footwear: sandals, composition soles of indeterminate composition. Injured employee has three or four pairs of this exact footwear and wears it exclusively.

b) work surface: linoleum tile, reported as "freshly-waxed" by the injured employee.

c) tasks performed at site: office, transit, moderate traffic area, injured exployee was actually traversing a corner spot off the normal path. This spot is a low-traffic area.

d) employee task and biomechanics: walking and beginning to make a 90 degree turn.

e) housekeeping: no outstanding characteristics.

f) environment: fluorescent lighting adequate.

g) COF: exact site was long a wall edge at a corner in a transit route. BIGFOOT device used as follows:

1) location 1: injured employee's shoe fitted on BIGFOOT device (same shoe).

$\bar{x} = .22$
$s = .018$
$n = 5$

2) location 1: BIGFOOT fitted with leather sole sample.

$\bar{x} = .43$
$s = .029$
$n = 5$

The primary hazard related to the causation of this accident would appear to be the footwear involved. The surface, as measured with leather, was on the borderline of the "slippery" range. At the time of the observation the injured employee firmly held that the floor was a significant hazard and the sole cause of her accident. The demonstration using her shoe appeared to change her opinion. Upon a re-visit she still blamed the floor as being slippery but had switched her footwear to oxfords with crepe-soled material.

14. 10/21/76 - 6:45 a.m. 56 year old male division chief in SIC 9199 with 29 years experience in establishment #601 was reporting to work, ascending exterior staircase at entrance, running, slipped on steps damp from morning dew, and fell against iron handrail sustaining a contusion to the shoulder resulting in one lost workday.

a) footwear: unknown

b) work surface: exterior staircase, riser height of three inches, tread depth of fifteen inches. Construction consists of single bricks 15" x 3". Leading edges of bricks slightly rounded from wear.

c) tasks performed at site: transit, high traffic area.

d) employee task and biomechanics: possibility of low vertical forces from extended posture and lengthened stride while running. Also possibility of misstepping from rapid stepping.

e) housekeeping: adequate at time of observation.

f) environment: high humidity due to proximity to marine environment resulted in coating of dew on surface.

g) COF: BIGFOOT, fitted with leather sole samples in lieu of unknown exact footwear. Not tested under wet conditions due to properties of leather.

1) location 1: approach, on middle of landing in middle of sets of stair steps:

$\bar{x} = .378$
$s = .014$
$n = 6$

2) location 2: site, leading edge/frontal portion of brick step tread, tester used on nine bricks on step under investigation:

$\bar{x} = .357$
$s = .033$
$n = 9$

The step in question, when tested under dry conditions with leather was found to be within the slippery range. No significant difference between the approach and the site exists. This staircase would benefit from roughening of the brick material.

15. 4/21/76 - 7:30 a.m. 29 year old female data entry operator in SIC 9199 with 1 1/3 years experience in establishment #601 was reporting to work, was descending interior staircase from main floor to basement, slipped on the penultimate step, missed the last step and fell to the floor sustaining a contusion to the knee requiring medical treatment.

a) footwear: unknown

b) work surface: terrazzo stair step surface is worn and smooth.

c) tasks performed at site: transit, periodic high volume traffic area.

d) employee task and biomechanics: descending staircase, other details unknown.

e) housekeeping: adequate.

f) environment: adequate.

g) COF: BIGFOOT fitted with leather sole sample. No approach measurements were taken because injured employee had negotiated 20-30 like steps prior to event and first floor surface, negotiated prior to staircase, is of like material.

$\bar{x} = .42$
$s = .03$
$n = 9$

The COF value of the site is on the borderline of the "slippery" range.

16. 5/26/77 - 8:40 a.m. · 19 year old female (5'4", 155 lbs.) food handler in SIC 2099 with six months experience in establishment #610 was cooking hamburgers at grill in kitchen, stepped and turned to the right to reach buns cooking at end of grill (four feet away), stepped on approximately five to six inch diameter spot of water, slipped and caught self with hand on hot grill sustaining second and third degree burns to the hand resulting in nine lost workdays.

a) footwear: laced rubber soled oxford, worn condition.

b) work surface: quarry tile, acid-etched but treatment over three years old. Possible grease saturation.

c) tasks performed at site: fast food preparation, some transit; usually a one or two person work station with occasional traffic from outside the work station.

d) employee task and biomechanics: stepping to side pivoting with foot and reaching. Haste, peak performance demand period.

e) housekeeping: frequent water spills in location as a whole, difficult to effect immediate correction during rush situation.

f) environment: hot, noisy.

g) COF: BIGFOOT, fitted with neoprene sole samples as below:

1) Location 1: approach, quarry tile, dry.

$\bar{x} = .52$
$s = .092$
$n = 8$

2) Location 2: site, wet conditions.

$\bar{x} = .315$
$s = .061$
$n = 5$

3) Location 3: site measured with leather sole sample, dry conditions.

$\bar{x} = .608$
$s = .061$
$n = 5$

In terms of a slipping hazard, the COF of this floor as measured using leather is well outside the "slippery" range. Measured using neoprene, the COF is high (.52) but within the range found for slippery surfaces using neoprene sole materials. This difficulty in interpretation demonstrates the limitations of COF measurements. There is probably not a problem when dry. Wet conditions on this floor, however, do appear to be distinctly hazardous (COF .315), especially when unexpected and negotiated with the foot pivoting and with a requirement to reach. Wet conditions are an occasional feature of this type of operation. The source of the water in this particular case was the result of the task performed by another employee, who was thawing out frozen turnovers and storing them under the grill for immediate use. The thawing process involves running the water faucet over the turnovers, in a rack, then carrying the rack to the grill; the dripping rack was the source of the floor surface wet conditions. It may be difficult for workers to mop their water spills during a rush period, if they detect the spill. A freshly mopped, damp floor has similar COF properties to one with a puddle. Effective countermeasures should deal with equipment modifications of the turnover thawing rack in order to prevent spills.

17. 2/5/76 - 8 a.m. 61 year old female intermediate clerk typist in SIC 9199 with 29 years experience in establishment #601 was reporting to work, had entered the lobby on the main floor from outside where it was raining and slipped because floor was wet and shoes were wet, and fell to the floor sustaining a sprained ankle resulting in ten lost workdays.

a) footwear: unknown

b) work surface: terrazzo lobby laid in approximately 2' x 2' sections framed by 1/4" brass stripping. Center of lobby has large area which is a medallion executed with different colors of marble with 1/4" brass stripping.

c) tasks performed at site: transit, high traffic volume area.

d) employee task and biomechanics: unknown other than "walking."

e) housekeeping: no surface finish, wet conditions due to "tracked-in" rain water from outside.

f) environment: ambient environment, rain, produced hazardous conditions.

g) COF: BIGFOOT, fitted with various sole samples. Event occurred 20-30 feet from entrance, so that injured employee had walked over 20-30 feet of flooring similar in material and conditions to those at site of fall.

1) Location 1: terrazzo floor surface, dry, leather.

$\bar{x} = .354$
$s = .027$
$n = 6$

2) Location 2 (site of fall) terrazzo floor surface with some brass divider strips represented in area measured.

leather, dry	leather, wet
$\bar{x} = .319$	$\bar{x} = .738$
$s = .026$	$s = .058$
$n = 6$	$n = 5$

neoprene, dry	neoprene, wet
$\bar{x}$ = .47	$\bar{x}$ = .70
s = .027	s = .031
n = 5	n = 5
chemgum, dry	chemgum, wet
$\bar{x}$ = .43	$\bar{x}$ = .66
s = .027	s = .015
n = 5	n = 5

3) Location 3: medallion area, terrazzo floor, contains high component of brass divider strips. Measured dry with leather sole.

$\bar{x}$ = .297
s = .012
n = 6

The general area of the site is in the slippery range even when dry, but slips on this floor when dry are very rare. Possibly, users have adjusted their gait to the frictional properties of the floor which has a smooth and glassy appearance. The only problems observed in the last two years in this specific area of the building and type of flooring have been related to wet conditions. The floor was subjectively tested for slipperiness when wet by walking and sliding on a specially wetted area using shoes with chemgum soles. The floor was subjectively extremely slippery and had the feel of walking on ice. However, it should be noted that the instrumental measurement did not show this greatly decreased effective COF when wet.

18. 5/24/77 - 9:30 a.m. 27 year old service worker in SIC 3661 with 2 3/4 years experience in establishment #609 while pulling wire samples from a machine, was reaching for a bolt cutter and slipped on "slick" floor, reached for and grabbed barrel while falling, head struck against box, sustaining a contusion to head resulting in an injury requiring medical treatment.

a) footwear: unknown

b) work surface: "steel-treated" concrete floor, with subjective "feel" of extreme slipperiness. Floor was originally so treated to meet environmental demands (low airborne shoe-sole abraded particulate) of a prior project using same space. Contrasts with established transit route which runs throughout length of plant floor and has been recently etched to enhance frictional properties.

c) tasks performed at site: machine operation, production, materials handling, transit; low to moderate traffic area.

d) employee task and biomechanics: low vertical and high horizontal forces bearing on base of support as a result of reaching task.

e) housekeeping: surface clean, no protrusions or loose objects observed throughout the plant.

f) environment: excellent lighting and low noise levels, unusually so for moderate to heavy industrial operation.

g) COF: BIGFOOT fitted with leather sole samples:

1) Location 1: etched walkway.

$\bar{x} = .262$
$s = .01$
$n = 5$

2) Location 2: accident site, unetched concrete floor.

$\bar{x} = .197$
$s = .005$
$n = 5$

The COF value of the accident site is typical of almost the entire work surface of this large plant. Four other unetched locations were measured in the vicinity of the accident site and three of the four mean COFs were below .2. This is the most slippery dry floor measured during this project. Despite the inherent slip hazard of this establishment's floor, slips are a very rare occurrence, according to the establishment's safety representative. Apparently the workers are accustomed to the consistent, uniform slippery condition and have adjusted their walking gait, etc. accordingly. However, this accident illustrates that the COF is too low to permit work activities such as pulling and reaching. The etching process used on defined walkways did not increase COF to a generally acceptable safe level.

19. 5/27/77 - 4:30 p.m. 25 year old female secretary (5'10", 170 lbs.) working in SIC 8221 with 2 years experience in establishment #608 was leaving work, descending exterior cement staircase, was making 90° turn at bottom of a set of stairs at a landing when she slipped on "slippery" edge of a step, attempted to catch self but fell to landing, sustaining contusion to the buttocks and a sprain to the wrist, requiring medical treatment.

a) footwear: buckled sandals with synthetic rubber sole material, low heel height.

b) work surface: exterior staircase, cement with leading edges fitted with non-skid guards. Guards are of the bolted-on steel type with non-skid material inlaid in one-quarter inch strips running parallel to the direction of the leading edge and alternating with one-quarter inch strips of bare steel of the guard itself. The front edge of the tread guard is smooth steel but is an eighth inch in width at maximum. This front edge is very smooth to the touch and is rounded by wear. Thirteen inch tread, five and one-half inch riser.

c) tasks performed at site: strictly transit, high traffic volume, services eight floors of office and laboratory building with poor elevator service.

d) employee task and biomechanics: foot taking main weight of body was pivoting while angled and supported only by leading edge of step.

e) housekeeping: untreated surface, clean, no obstructions.

f) environment: this area quite shaded from afternoon sun, low illumination/poor step edge detection could have been a factor.

g) COF: BIGFOOT, fitted with neoprene sole sample:

1) Location 1: approach measurement taken on landing prior to set of stairs on which accident occurred. Six steps in a set, happened on sixth step:

$\bar{x} = .414$
$s = .0449$
$n = 5$

2) Location 2: accident site, steel and non-skid material tread (leading edge of bare steel inclines acutely downward. It is impossible to make measurements on this edge with current equipment).

$\bar{x} = .828$
$s = .065$
$n = 5$

The stair is of a safe construction. The high friction properties of the tread would not lead to an expectation that a foor in a horizontally level attitude would slip on the tread. However, it is likely that the foot was placed non-horizontally and rested only on the smooth rounded front edge of the step, for which no COF measurements were possible.

20. 7/11/77 - 7:30 p.m. 23 year old female food service worker in SIC 8062 with 3 1/2 months experience in establishment #605 was working in kitchen preparing snack trays, while walking in haste going to get a knife which was not in its normal location, turned abruptly around steam kettle and slipped on wet portion of freshly mopped quarry tile floor surface, recovered balance and did not sustain an injury.

a) footwear: laced oxford wedge with leather-like composition soles.

b) work surface: quarry tile (approximately 5" x 5" tile squares), conditions wet.

c) tasks performed at site: food preparation, transit, moderate to high traffic area.

d) employee task and biomechanics: in haste, turning abruptly.

e) housekeeping: surface untreated, no objects on floor or protrusions into aisleway, floor clean.

f) environment: noisy; humid; steam kettle in area; very cramped workspace - small aisle widths and blind corners.

g) COF: BIGFOOT fitted with composition soles:

1) Location 1: accident site, dry quarry tile floor.

$\bar{x} = .851$
$s = .04$
$n = 5$

2) Location 2: same site, thoroughly wet quarry tile floor.

$\bar{x} = .378$
$s = .022$
$n = 5$

3) Location 2: same site, just damp so as to replicate freshly mopped condition of accident.

$\bar{x} = .30$
$s = .06$
$n = 5$

The COF value of the freshly mopped (damp) quarry tile floor site is low and well into the generally accepted "slippery" range. The dry floor had an adequately high COF, but the difference in COF between wet and dry conditions is very large (.55). The task of turning the corner in haste involved pivoting the foot which may have been a precipitating factor.

21. 5/19/77 - 6:05 p.m. 29 year old male firefighter in SIC 9199 with eight years experience in establishment #602 was cleaning up dishes in station after dinner, was carrying dishes to sink, sidestepped quickly to avoid other firefighter who, with back turned, was mopping floor, slipped on wet soapy area of floor, recovered balance, tore ligaments in knee (previous knee strain 6 years prior) and lost 21 workdays.

a) footwear: a synthetic rubber sole, reported similar to neoprene, on laced workboots.

b) work surface: 2" x 2" terrazzo tiles, sealed with unknown coating about 6 years previously; conditions were wet and soapy.

c) tasks performed at site: area used for preparing and eating meals of firefighters, periodic moderate traffic area.

d) employee task and biomechanics: quick sidestepping, which enhances chance of misstepping as well as momentarily having out of balance body weight. Carrying objects would have made it more difficult to regain lost balance. Reluctant to drop fragile objects.

e) housekeeping: surface unwaxed, very clean, area mopped twice daily.

f) environment: adequate in all respects.

g) COF: BIGFOOT fitted with neoprene sensor for all tests:

1) Location 1: approach, one step prior to site, dry terrazzo tile floor.

$\bar{x} = .556$
$s = .045$
$n = 6$

2) Location 2: site, terrazzo tile floor under wet conditions only.

$\bar{x} = .451$
$s = .052$
$n = 14$

3) Location 2: site, terrazo tile floor under wet and soapy conditions as per conditions of event.

$\bar{x} = .23$
$s = .03$
$n = 6$

The COF value at the injury site when wet and soapy is in the extremely slippery range. The difference in COF from the dry surface to the wet and soapy surface was very large (.326) -- a large difference. The quick sidestep, made in order to avoid the mopper results in imposing high horizontal forces on the floor (both to accelerate sideways and to decelerate again) and also could have involved a misstep or a pivot.

22. 4/26/77 - 11 a.m. 43 year old female junior clerk in SIC 9199 with 3 weeks experience in establishment #602 was on break in the restroom, had washed hands, walked across room to towel dispenser, dried hands, turned to exit and slipped on a wet spot on floor, fell and struck against floor sustaining a contusion to the back resulting in unknown amount of lost time (injured employee retired following accident).

a) footwear: unknown

b) work surface: single sheet vinyl linoleum, water spots when injured employee walked across floor to towel dispenser.

c) tasks performed at site: break, low traffic area.

d) employee task and biomechanics: turning abruptly while walking, may have still been pivoting or recovering from pivoting at time of "slip."

e) housekeeping: adequate in all respects except for provision to prevent water spillage by area users. "Astro-gloss" by Universal floor treatment.

f) environment: adequate lighting, incandescent.

g) COF: BIGFOOT, as below:

1) Location 1: accident site, dry vinyl linoleum with leather shoe sole sample.

$\bar{x} = .3$
$s = .034$
$n = 5$

2) Location 2: same site, leather, wet conditions.

$\bar{x} = .48$
$s = .018$
$n = 5$

The dry COF value of the site is low and within the slippery range. Subjectively, wet conditions make the floor more slippery although this effect could not be demonstrated in COF measurements.

23. 5/5/77 - 3 p.m. 36 year old (5'11", 175 lbs.) male laborer in SIC 9199 with two years experience in establishment #602 was performing an electrical installation in reservoir work shed, was standing on a ladder set at 65° pitch with center of top rung resting on vertical wall beam for top support, was reaching 40 inches to right of center of ladder to tighten a clamp with a wrench, ladder pivoted on one leg, ladder slipped, injured employee fell onto corner of table saw table sustaining a contusion to the chest and fell to the floor resulting in a lost time injury involving unknown number of lost workdays.

a) footwear: injured employee's footwear not applicable to accident; ladder equipped with lateral grooved tread rubber feet hinged to the ladder.

b) work surface: concrete slab, small amount of sawdust on floor at time of site evaluation.

c) tasks performed at site: shop equipment set up, electrical installation.

d) employee task and biomechanics: reaching position affected ladder set up, ladder pivoted.

e) housekeeping: possibly some sawdust on floor, power cords on floor, no floor finish treatments.

f) environment: work environment cluttered with large shop power tools - ladder set up directly over table saw.

g) COF: BIGFOOT scale pulling same ladder in same set-up position as at time of accident (corrected for mass and angle of ladder):

$\bar{x} = .38$
$s = .025$
$n = 5$

The COF between the ladder and the floor was much less than one. This would have not been an inherent problem in the performance of this work task had it not been for improper ladder placement which precipitated the event. The angle of ladder inclination was less than the OSHA standard of 75 1/2 degrees (1910.26(c)(3)(i)) and the top was unsecurely and unsafely supported (1910.26(c)(3)(iv)). The ladder, further, was placed too far away from the work location for safe body positioning and was placed adjacent to a hazardous

piece of machinery. The injured employee was very limited in ladder experience and his supervisor, in the same room, failed to check and/or correct the ladder set-up. This accident is of interest to the study, however, because of the task biomechanics which precipitated the "slip."

24. 8/8/77 - 12:40 p.m. 32 year old (5'3", 121 lbs.) female bookkeeper-administrative assistant in SIC 8221 with five months experience in establishment #608 was on break, was walking abreast with coworker to cafeteria on six foot wide exterior concrete walkway, made a step well to the right in order to accommodate two other persons walking abreast in opposite direction, right foot slipped off the edge of the walkway. She recovered balance, but strained ankle (strained ankle one week prior), requiring medical treatment.

a) footwear: sandals, buckled fasteners, crepe soles having a 1/2" sole thickness and 2 1/2 to 3 inch heel height.

b) work surface: new concrete walkway, 6 feet wide; slight perceptable incline downwards to edge at site; pock-marked intermittent rough and smooth areas; surface rolls over smoothly at edge. Majority of area is of the rough texture.

c) tasks performed at site: transit, high traffic area.

d) employee task and biomechanics: sidestepping enhances potential for unbalancing and misstepping.

e) housekeeping: exterior area, apparently clean, uncluttered and free from hazardous surface conditions.

f) environment: ambient environment adequate in all respects; work environment crowded, sufficient space for four persons walking abreast on walkway not provided.

g) COF: BIGFOOT fitted with footwear involved in injury - crepe-soled sandal:

1) Location 1: approach to site, rough concrete area of walkway.

$\bar{x} = .56$
$s = .041$
$n = 5$

2) Location 2: site, smooth concrete area at edge of walkway, level.

$\bar{x} = .39$
$s = .034$
$n = 5$

Injured employee placed foot on portion (edge) of walkway that sloped sideways and had a lower COF than the main portion of the walkway. The sideways slope of the walkway edge would require a high tangential force, and thus a very high COF, to avoid slipping.

25. 4/20/77 - 3:30 p.m. 41 year old female (5'5", 205 lbs.) registered nurse working in SIC 8062 with seven years experience in establishment #60t while performing patient care duties, was exiting ward office/kitchen area carrying a cup of water, slipped on a dry area of the floor inside the office, fell to floor sustaining no injury.

a) footwear: oxford nursing shoes, composition low-density rubber soles, worn.

b) work surface: vinyl tile; wax treated, massive buildup - surface scuffed, dingy, in need of buffing.

c) tasks performed at site: transit, low to moderate traffic area.

d) employee task and biomechanics: no extraordinary factors reported, overweight condition may have contributed to actual fall once the loss of balance situation had been precipitated by the slip.

e) housekeeping: floor clean, surface in need of maintenance.

f) environment: adequate in all respects.

g) COF: BIGFOOT fitted with leather:

1) Location 1: approach, high traffic area midway from sink area (point of origination) to site.

$\bar{x} = .44$
$s = .057$
$n = 40$

2) Location 2: site.

$\bar{x} = .365$
$s = .043$
$n = 50$

The COF value at the accident site is within the "slippery" range. There is a statistically significant difference in COF between "approach" site and the accident site but this difference may not be important as the total floor space is the injured employee's normal work station.

26. 7/19/77 - 5:15 a.m. 35 year old male dispatcher working in SIC 37 with unknown amount of experience in establishment #606 was dismounting forklift. Foot slipped on bare steel spot of fender which is commonly used as step area. He recovered balance on ground, straining knee, aggravating an old injury (previous surgery).

a) footwear: neoprene soles - work shoe, oxford type.

b) work surface: side/fender of forklift, painted but in area used as step (site) is worn bare and smooth. Site surface is mostly level but is at beginning of downward curve of body, so that some of site slopes downward.

c) tasks performed at site: mounting and dismounting powered industrial truck.

d) employee task and biomechanics: Injured employee was dismounting: moving sideways to right from seat and elevating self stepping on site, center of mass not over stepping area.

e) housekeeping: Not applicable.

f) environment: adequate, lighting good, no excessive noise.

g) COF: BIGFOOT with neoprene:

1) Location 2: level portion of site, bare steel fender.

$\bar{x} = .40$
$s = .06$
$n = 5$

This work surface related injury involves egress from a powered industrial truck. A portion of the fender adjacent to the cab area is routinely used as a stepping area. This is the site. The painted finish has worn away and the surface is bare smooth steel with a COF value of .4, well inside the "slippery" range when measured with neoprene. Part of the worn area is in the beginning of the downward curve of the body shape. A foot positioned here to support body weight would experience this moderately low COF, as recorded on the level, and an incline which increases the requirements for tangential forces to avoid slipping.

27. 10/27/77 - 8:25 a.m. 33 year old female intermediate account clerk working in SIC 9199 with 13 years experience in establishment #601 was descending rear staircase in haste on way to photo taking session, slipped off leading edge of next to last step, fell down to ground level but struck against last step with buttocks. Contusion to buttocks. Two lost days. Was holding handrail.

a) footwear: platform sandals with Hypalon Quabaug type sole material.

b) work surface: staircase with rubberized tread and riser, made with alternating zones of smooth and textured surface. Point of slip on leading edge of step was smooth rubber sloping downwards.

c) tasks performed at site: transit.

d) employee task and biomechanics: in haste, foot struck step at glancing angle.

e) housekeeping: clean, no obstructions.

f) environment: lighting fluorescent, reported to have been inadequate at time of accident and to have been subsequently upgraded.

g) COF: BIGFOOT fitted with Hypalon Quabaug:

1) Location 1: leading edge of stair step with foot of friction tester on leading edge.

$\bar{x} = .461$
$s = .064$
$n = 5$

2) Location 2: other stair step on main part of tread, relief-textured tread surface (grooved).

$\bar{x} = .69$
$s = .05$
$n = 5$

The COF of the leading edge of the stair as measured using Hypalon Quabaug is adequate in absolute terms but is very low compared to other surfaces measured using the same sole material. The leading edge of the stair could thus be considered as unexpectedly slippery. The difference between the main body of the tread surface and the leading edge

(site) is significant (.23). The biomechanical factors would appear to play a significant role in the causation of this injury (haste, putting foot down on step,edge with a glancing blow). The use of rubber as the surface material could be interpreted as a "non-slip finish" (1910.24(f)) but the measured COF is not sufficiently "non-slip" for such a sensitive location as a tread edge.

28. 10/4/77 - 1:15 p.m. 44 year old female (5'4", 140 lbs.) EDP coordinator working in SIC 9199 with 13 years experience in establishment #601 was walking in haste outside of her normal work area in walkway area of large room used as office, slipped on "slick" floor, broke fall with hand but fell to floor. Contusions to wrist and buttocks.

a) footwear: oxford type shoe with composition soles - good condition.

b) work surface: vinyl tile - feels slippery, scuffed appearance.

c) tasks performed at site: transit, storage of boxes.

d) employee task and biomechanics: no outstanding characteristics.

e) housekeeping: clean, surface appears neglected - visual examination indicates several layers of wax but not buffed.

f) environment: lighting adequate.

g) COF: BIGFOOT fitted with composition sole:

1) Location 1: approach - 7'-8' prior to site in path of injured employee - in other room.

$\bar{x} = .247$
$s = .032$
$n = 5$

2) Location 2: site.

$\bar{x} = .208$
$s = .012$
$n = 7$

The COF values observed indicate that this floor surface/sole combination was well inside the "slippery" range at the time of the observation. No significant difference in mean COF was found between the approach area which was also slippery and the site ($P>.001$). The injured employee indicated that her subjective estimate of the slipperiness of the accident site at the time of the observation was approximately equal to that at the time of her fall. The appearance of the floor indicates that several layers of wax have built up and that the surface is scuffed, dull

and slippery. Regular buffing would enhance both the appearance and the frictional properties. This accident supports the tenet that regular maintenance of wax treated floors is an important engineering solution to slip and fall accident injuries.

29. 5/6/77 - 8:30 a.m. Female clinical aid working in health services in SIC 8221 with 2 years experience in establishment #607 was dismounting a high stool. The stool was supported by smooth steel "gliders" rather than feet on wheels. She was trying to rise to her feet and push the stool away from her at the same time. Her foot caught in rung of stool, stool slid out from under her before she had fully risen but she recovered her balance at the cost of a strained ankle.

a) footwear: not applicable; stool had 1" diameter smooth steel gliders on each of four legs.

b) work surface: vinyl tile, waxed, hallway area with small alcoves for inset desks.

c) tasks performed at site: transit, patient screening, clerical, lobby.

d) employee task and biomechanics: high horizontal forces due to pushing stool back with foot.

e) housekeeping: unknown surface treatment, no obstructions, surface clean, uncluttered, shiny and smooth.

f) environment: fluorescent lighting, recently reduced in foot candles to avoid glare off highly reflective surface.

g) COF: BIGFOOT employed as below:

1) Location 1: under desk where stool sits, leather sole.

$\bar{x} = .331$
$s = .024$
$n = 6$

2) Location 1: same site, pulling stool with scale, steel "gliders" on legs, COF corrected for mass of stool.

$\bar{x} = .205$
$s = .019$
$n = 5$

The floor surface COF was definitely within the "slippery" range. In this work task, frequent mounting and dismounting of stools is necessary, and the employees have evolved a method of dismounting which relies on "scooting" the stool

back. This in turn relies upon a moderately low COF between the stool runner and floor. If the foot becomes caught in the stool, balance is lost and it may be difficult to recover without injury.

30. 11/8/76 - 10 a.m. 41 year old female registered nurse working in health services in SIC 8221 with unknown experience in establishment #607 was ascending concrete staircase and slipped on second step from landing but recovered balance, resulting in a strained ankle. No lost time.

a) footwear: nursing shoe - oxford, rubber soles - exact type of rubber material unknown.

b) work surface: concrete stair steps.

c) tasks performed at site: transit.

d) employee task and biomechanics: ascending - stepping up and forward.

e) housekeeping: unwaxed, clean, no obstructions, reported as no problems at time of accident.

f) environment: wel lit, natural lighting.

g) COF: BIGFOOT fitted with Avalon Thrust (a type of synthetic rubber frequently used on nursing shoes):

1) Location 1: on landing, concrete surface similar to accident site as it was before modification.

$\bar{x} = .492$
$s = .0268$
$n = 5$

2) Location 2: accident site (modified since accident, concrete covered with steel tread with 1/4" abrasive non-skid inlays).

$\bar{x} = 1.0+$ (off scale)
$s =$ unknown
$n = 5$

The COF measured at the concrete surrogate site using Avalon Thrust is adequate in absolute terms but very low compared to other floor surfaces measured using this sole material. The surface was thus probably unexpectedly slippery to the injured employee. The step as modified since the accident has a very high COF.

31. 12/6/76 - 2 p.m. 45 year old female registered nurse at Health Services in SIC 8221 with unknown experience in establishment #607 was sitting on a high stool at a desk, reaching/leaning over to the right and forwards to hand a piece of paper to a patient seated at the side of the desk and below level of stool when stool slid backwards and injured employee fell backwards onto the floor sustaining contusion to coccyx. No lost time.

a) footwear: not applicable - injured employee's feet were resting on rung of high stool at time.

b) work surface: vinyl tile, waxed, hallway area.

c) tasks performed at site: transit, patient screening, clinical, lobby.

d) employee task and biomechanics: the reaching activity resulted in tipping the stool, lowering the vertical and increasing the horizontal forces on the stool. The stool base was propelled backwards: injured employee's feet were resting on stool, not floor, and employee could not reestablish stable balance by relocating feet.

e) housekeeping: unknown surface finish and floor care. No obstructions, surface clean, uncluttered, shiny and glossy.

f) environment: fluorescent lighting, reduced foot candles to avoid glare from the highly reflective surface.

g) COF: BIGFOOT device employed as below:

1) Location 1: at site with leather sole.

$\bar{x} = .359$
$s = .04$
$n = 5$

The floor surface COF is within the slippery range. The primary hazard in the accident is in the performance of the work task: leaning excessively far rather than getting up from the stool and stepping to the desired location, and resting feet on rung of stool rather than on ground (presumably because of height of stool).

32. 7/29/77 - 8:15 a.m. 40 year old female assistant dean (5'5", 120 lbs.) working in SIC 8221 with unknown experience in establishment #607 was reporting to work, descending familiar exterior metal mesh staircase with non-skid stripping fitted on leading edges of treads, slipped on 2" x 2" spot where non-skid stripping had worn away, recovered balance, strained back. No lost time.

a) footwear: composition soles on slip-on shoes.

b) work surface: exterior metal mesh (relief patterns) stair, with 3" wide non-skid stripping cemented on leading edge, poor maintenance, several spots where non-skid stripping had worn away.

c) tasks performed at site: transit.

d) employee task and biomechanics: descending staircase, possible low vertical forces on stepping.

e) housekeeping: clean, no obstructions at time of site evaluation; non-skid material in ill repair.

f) environment: natural lighting good, potential for wet films from early morning/late afternoon dew, although stated to be dry at time of accident. Dry at time of site evaluation.

g) COF: BIGFOOT fitted with somposition soles:

1) Location 1: approach, metal mesh stair step with non-skid stripping in place, one step above site.

$\bar{x} = .77$
$s = .056$
$n = 6$

2) Location 2: site, metal mesh stair step, spot at which non-skid stripping is worn away and bare metal is exposed.

$\bar{x} = .253$
$s = .026$
$n = 6$

Both a low COF (.25) and a large change in COF (difference of .52) appear to be significant factors in this work surface related injury. The primary hazard is a lack of

maintenance of the non-skid stripping. Such maintenance is of the utmost importance because a low COF such as .25 does not constitute as great a hazard as an unexpected radical change in COF from one step to the next. Workers can adjust their gait and walking behavior in order to safely negotiate even a very slippery floor surface if the COF retains spatial and temporal continuity.

33. 2/10/77 - 4:30 p.m. 24 year old female EDP clerk in SIC 9199 with unknown amount of experience in establishment #601 was walking in location outside normal work area, slipped on "slick" vinyl tile floor, caught self on ground with hand, strained wrist. No lost time.

a) footwear: wood sandals with neoprene soles.

b) work surface: large office area, waxed vinyl tile.

c) tasks performed at site: transit, clerical, moderate traffic area.

d) employee task and biomechanics: stated as simply walking.

e) housekeeping: waxed, not buffed, dull wax build-up; clean, open area, no protrusions or hazards.

f) environment: adequate fluorescent lighting.

g) COF: BIGFOOT fitted with neoprene sole sample:

1) Location 1: accident site area.

$\bar{x} = .369$
$s = .015$
$n = 5$

2) Location 2: normal work area, in traffic area adjacent to injured employee's desk.

$\bar{x} = .21$
$s = .012$
$n = 7$

The frictional properties of the work surface site are in the "slippery" range. The injury site had a COF higher than the injured employee's normal work area by .16.

34. 6/17/77 - 11 p.m. 27 year old male waiter (6', 180 lbs.) in SIC 2099 with two years experience in establishment #610 was cleaning up, walking in kitchen in haste and was carrying a soup tureen filled with cups and spoons behind a counter. He was negotiating a 90° turn and slipped on a dry "slippery" area of the floor, and fell to floor sustaining a hip contusion resulting in one lost workday.

a) footwear: laced half-boot height street shoes with worn composition soles.

b) work surface: quarry tile acid-etched two years prior, specified location has been a high fall frequency area.

c) tasks performed at site: transit, materials handling, food preparation, high traffic area.

d) employee task and biomechanics: carrying was a possible factor; route requires two adjacent 90° turns in opposite directions and haste may have contributed to some degree of postural overextension.

e) housekeeping: no finish applied to floor. Site directly in front of an ice machine which reportedly contributes occasional wet patches and slippery objects on the floor at this area. Conditions were reportedly dry at the time of the accident. The floor surface is exposed to grease due to the extensive deep fat frying at this location.

f) environment: lighting poor in area - may preclude detection of wet spots and spills.

g) COF: BIGFOOT fitted with composition sole sample:

$\bar{x} = .529$
$s = .032$
$n = 5$

The COF of the dry site surface is on the boundary of the "slippery" range when using composition soles. However, comparison with other like floors, etched and unetched, indicate that a significant degradation in the non-skid feature has occurred at this accident site. Acid-etching is an excellent technique for increasing friction properties of quarry tile but periodic evaluation of COF is necessary to maintain the non-skid feature. The biomechanics of making two quick acute turns in opposite directions are

complex and accentuate the potential for misstepping. Most of the previous falls at this location have been due to wet patches or ice particles on the floor.

35. 8/01/77 - 5:20 p.m. 21 year old male stretch-forming machine operator in SIC 37, at establishment #606, with two weeks experience in operating the stretch-forming machine. While the injured employee was reaching to put an object in the machine, his left foot slipped off the edge of a raised portion of his work surface. He recovered balance, but strained his foot.

a) footwear: unknown

b) work surface: a smooth level steel surface about 8' x 3'. The long edges are surrounded by a trough, 5" deep by 3" wide, and these in turn are surrounded by an additional level steel surface that is, however, about 2" below the center portion. The inner and outer portions of the surface look the same in color and texture.

c) tasks performed at site: machine operation including loading and removal of work.

d) employee task and biomechanics: reaching, loading objects into machine.

e) housekeeping: adequate in all respects.

f) environment: large noisy machinery, good lighting.

g) COF: BIGFOOT fitted with leather sole:

$\bar{x} = .567$
$s = .037$
$n = 5$

The COF at the accident site appears to be comfortably outside the "slippery" range. However, placing the foot on the edge of the work surface will result in high tangential forces and a slip will follow.

36. 11/01/76 - 9:30 a.m. 56 year old female senior secretary working in SIC 8221 with 20 years experience at establishment #607 was making photocopies. This required leaving her normal work location and walking to another building. She descended a diamond metal mesh tread stair case, and opened a door to pass through engineering shop. On approximately the fourth step into the shop she slipped on a "slick" floor and fell, sustaining a fractured hip, resulting in 44 lost workdays.

a) footwear: composition soled sandals

b) work surface: smooth concrete shop floor.

c) tasks performed at site: engineering shop, heavy machinery for educational purposes; also used for transit route as it is a "shortcut" to another building which houses the main offices of this academic department. Light to moderate traffic, seasonal variance.

d) employee task and biomechanics: reported as normal walking.

e) housekeeping: clean, no hazardous surface conditions. The injured employee expressed the subjective impression that the floor had been waxed at the time of the accident and was also waxed at the time of the site observation/evaluation. No visual or tactile evidence was found to support this impression, and it is uncertain whether the concrete had been sealed.

f) environment: adequate in all respects, quiet, lighting adequate.

g) COF: BIGFOOT, as below:

1) location 1: approach, diamond mesh steel tread stair step, composition sole sample:

$\bar{x} = .668$
$s = .033$
$n = 5$

2) location 2: approach, lab floor at base of staircase and in front of door entering into engineering lab in which event occurred. Composition sole sample:

$\bar{x} = .508$
$s = .029$
$n = 5$

3) location 3: one of two possible sites, as best recollected by injured employee, 3 or 4 steps into lab. Composition sole sample:

$\bar{x} = .406$
$s = .04$
$n = 5$

4) location 3: same location as #3, with leather sole sample:

$\bar{x} = .335$
$s = .043$
$n = 5$

5) location 4: second possible site, four to five steps into the engineering lab. Composition sole sample:

$\bar{x} = .38$
$s = .025$
$n = 5$

The COF values at the accident site surfaces are within the "slippery" range but are not very low. A significant difference in slipperiness exists between the site and approach one (.29) and approach two (.13). A range of approximately .3 in work surface COF is probably an excessive burden in terms of changing one's gait within five or six paces. This feature of the route is probably more hazardous because it is not in the injured employee's normal work area. It is also a "short cut" and not the specified transit route.

37. 8/30/77 - 3 p.m. 41 year old female principal clerk working in SIC 8062 with more than two years experience in establishment #604 was carrying some papers from her normal work location (office) to another building down the block and across the street. She was ascending stair steps at the entrance, stumbled on the second to the top step, tripped on penultimate step, caught self on landing with left arm and strained neck, requiring medical treatment.

a) footwear: sandals with Avalon Thrust soles, good condition.

b) work surface: concrete stairs (six steps in set, good riser/tread dimension ratio, rough appearance). No handrail.

c) tasks performed at site: transit.

d) employee task and biomechanics: stair climbing and carrying.

e) housekeeping: dry, clean.

f) environment: adequate, outdoor natural lighting.

g) COF: BIGFOOT fitted with Avalon Thrust shoe soles:

1) location 1: approach, second step from bottom.

$\bar{x} = .93$
$s = .04$
$n = 5$

2) location 2: site, second step from top.

$\bar{x} = .9514$
$s = .045$
$n = 5$

This high COF means that a foot can "catch" unexpectedly on a step just prior to placement, leading to a "stumble" and, in this case, a loss of coordination followed by a trip over the edge of the next step. A determination that the specific work surface is at fault due to excessive COF, however, cannot be made.

38. 4/29/77 - 7:10 a.m. 31 year old male (5'2", 110 lbs.) welder in SIC 3731 with six months experience in establishment #603. He was starting work in a new location, and was standing at the edge of an empty elevator shaft on the top deck of a ship's hull under construction. He was pulling welding leads and hoses up through the empty shaft (5' x 5') which was fitted with handrails but not with toe boards, He slipped and fell under the handrail, into the elevator shaft, a distance of 10 feet to the deck below, the shaft opening there being covered with a piece of plywood. He sustained abrasions and contusions to the knees and legs.

a) footwear: leather soled work boots.

b) work surface: steel decking painted with epoxy, welding grit present at time of observation.

c) tasks performed at site: transit, new ship construction.

d) employee task and biomechanics: high horizontal forces -- pulling of leads up through shaft requires considerable force.

e) housekeeping: data unavailable at time of event which was the first few minutes of work at this location, reportedly grit free surface; at time of observation, some grit evenly dispersed on surface area, numerous tripping hazards such as cables, objects on floor, etc.

f) environment: adequate natural lighting from windows, high noise level.

g) COF: BIGFOOT fitted with leather sole sample:

1) location 1: site.

$\bar{x} = .482$
$s = .048$
$n = 5$

The surface coefficient of friction is just outside the "slippery" range. The very high horizontal forces associated with the task being performed, however, led to a "slip." The severity potential of the results of the fall were accentuated by the lack of a toe board around the elevator shaft.

39. 4/18/77 - 8:10 a.m. 54 year old (5'7", 129 lbs.) male equipment technician working in SIC 8221 with 14 years experience in establishment #607 was carrying light boxes and ascending concrete steps, slipped with leading foot, put out hand to attempt to catch self, wrist turned on impact, fractured wrist.

a) footwear: leather-soled work boots, fair condition.

b) work surface: 5-step staircase, cement with non-skid stripping. Edges concrete and somewhat rounded. Riser height = 6", step depth = 8". Staircase was equipped with handrail. Approach -- hallway with asbestos sheet flooring.

c) tasks performed at site: transit, injured employee very familiar with location.

d) employee task and biomechanics: was carrying boxes, using both hands, not using handrail. Stepping a total height of 12" and increased lateral distance because he intentionally omitted first step from staircase negotiation, i.e., stepped directly to second step.

e) housekeeping: clean, no obstructions.

f) environment: dim fluorescent lighting (high ceiling).

g) COF: BIGFOOT fitted with leather sole.

1) location 1: approach.

$\bar{x} = .489$
$s = .06$
$n = 5$

2) location 2: site.

$\bar{x} = .579$
$s = .01$
$n = 5$

The first step onto a staircase is most likely to involve a placement of the sole of the foot at an angle on the edge of the step, a condition likely to result in a slip if the swing arising from a push by the rear leg is not sufficient to carry the person onto the next step. This condition is accentuated if an attempt is made to take two steps at a time. Although the step treads had an adequate COF, the edges of the steps were rounded and smooth.

40. 8/22/77 - 7:30 p.m. 32 year old male firefighter working in SIC 9199 with 8 years experience in establishment #602 was emptying refuse, carrying a small light trash can, and descending stairs at the rear of fire station. On the second step from bottom, the injured employee put foot slightly too far forward on worn wooden step and slid forward towards ground. Injured employee fell to ground, fracturing ankle and losing 5 work-shifts +10 light duty shifts (45 calendar days).

a) footwear: laced oxfords with synthetic rubber soles worn smooth, no tread remaining.

b) work surface: wooden staircase, 20 year old 2" x 9" boards for steps, tread depth = 9", riser height = 7". Steps badly worn, with cup shaped depressions so that upper surface sloped downwards. Steps were worn nearly through the entire thickness. Wood was smooth. No other surface conditions obtained at time of accident. Stairs had handrail.

c) tasks performed at site: access exit from fire station, low traffic area, used 2 or 3 times a day.

d) employee task and biomechanics: descending steps, carrying bulky object, did not use handrail.

e) housekeeping: badly worn, wood splitting, smooth, nails protruding 1/4" - 1/2".

f) environment: late dusk. One low wattage incandescent bulb located approximately 12 feet above site - poor lighting.

g) COF: no measurements available since stairway was replaced by a completely new (but identically constructed) wooden staircase after the accident. A higher wattage bulb was installed to improve visibility. The worn nature of the treads resulted in a downward slope of about 1 vertical inch in about 4 horizontal inches, or an angle of about 14^{o}. A step down onto such a downward sloping surface will impose high tangential forces and need a high COF to avoid slipping.

41. 3/26/77 - 6:45 a.m. 31 year old female hospital surgical clerk working in SIC 8062 with 3 1/2 years experience in establishment #605 was reporting to work, in the surgical nurses' locker room. She was late and was getting gowned in haste when she realized she didn't have all the required clothing and would have to go downstairs to the laundry. She exited the locker room (en route to the elevator) into the main hallway, turned abruptly to the right and put her foot down at an angle on a portion of the hallway floor very near to the wall (negotiating a greater than 90° angle), slipped and fell to floor sustaining contusions to knee, ankle and hip, requiring medical treatment.

a) footwear: surgical booties - disposable paper slip-ons with drawn tie-string around ankle, with anti-static strip running length of sole. Injured employee wore booties inside out in the interest of fashion. The booties had been used and were embedded with wax. Unenforced work rules exist prohibiting wearing booties inside-out and outside the surgical area.

b) work surface: site - one step out of nurses' locker room - hospital hallway, main floor. Vinyl tile treated with wax. Visual observation of the site several days following the accident suggested a glossy waxy build-up on the area of floor abutting the wall as contrasted with the dull appearance and feel of the more frequently traveled middle of the hallway.

c) tasks performed at site: transit and materials handling route. Frequent pushing of wheeled carts.

d) employee task and biomechanics: possible high horizontal and low vertical forces due to haste and walking behavior.

e) housekeeping: on two visits made to the site, location was clean and well-swept. Buffed, but waxy build-up on floor along wall.

f) environment: fluorescent lighting, average to slightly dim at site location.

g) COF:

1) difference in frictional properties between booty material right side-out and wrong

side-out was determined by employing the UFTM on a laboratory formica table top. See Table A for results.

TABLE A

	$\bar{x}$	s	n
Booties right side-out	.23	.018	5
Booties wrong side-out	.276	.006	5

A significant difference in means was found at the .001 level of confidence.

2) field measurements were made at the establishment approximately two months following the accident to determine the difference in slipperiness between the middle of the hall and the edge near the wall. Because of the trip hazard presented by the UFTM's power cord at the exact site, measurements were made nearby at a different location in the same hall. Access to approach sites within the nurses' locker room was not available. Pieces of surgical booties turned inside-out were affixed to leather footwear samples. See Table B for results.

TABLE B

	$\bar{x}$	s	n
Middle of hall	.282	.021	10
Edge of hall, along wall	.23	.029	5

A significant difference in means at the .001 level of confidence was found.

3) The BIGFOOT device was utilized to make measurements at the site. A piece of surgical booties turned inside-out was affixed to a leather footwear sample for measurements ($\bar{x}$ = .2496, s = .018, n = 5).

The coefficient of friction along the edge of the hallway was found to be .05 lower than the middle of the hallway. COF for booties turned wrong side-out was .05 lower than right side-out.

All COF values, middle of hall, near wall, booty inside or right side-out are within the slippery range. Any of these parameters in conjunction with the human factors problems (haste, negotiating sharp turning angle and misstepping) are plausible conditions for the occurrence of the event.

42. 5/6/77 - 1:15 p.m. 42 year old female (5'3", 135 lbs.) senior custodian in SIC 8062 with 2 1/2 years experience in establishment #604 was making up bunk beds in doctor's sleeping quarters and was pushing bunk bed back against the wall when she slipped and fell to floor sustaining a strained back (previous back injury three years ago). Injury resulted in 20 lost workdays.

a) footwear: negative heel shoe with rubber-like synthetic sole.

b) floor surface: vinyl tile. Subjective estimate when walking is that friction is quite good. Finished with Astro-gloss by Universal. Dry.

c) tasks performed at site: normal tasks at area work surface are primarily transit.

d) employee task and biomechanics: high horizontal forces - pushing the bunk bed at shoulder height; possible leaning at acute angle - low vertical forces. Exact feet positioning unknown.

e) housekeeping: no objects, obstructions or hazardous work surface conditions observed throughout the establishment. Astro-gloss by Universal floor finish, well buffed.

f) environment: adequate in all respects, lighting fluorescent.

g) COF: BIGFOOT, as below:

1) Location 1: at site, neoprene sole.

$\bar{x} = .79$
$s = .095$
$n = 5$

2) Location 1: at site, leather sole.

$\bar{x} = .719$
$s = .075$
$n = 5$

3) Location 2: under bed using neoprene sole, comparison of non-traffic area of floor to site.

$\bar{x} = .884$
$s = .08$
$n = 5$

4) Location 3: area of floor at other end of bed (possible site, although location #1 is usual site to stand when pushing bunk bed).

$\bar{x} = .872$
$s = .066$
$n = 5$

All COF readings are well out of the "slippery" range, and a slip would not have been expected even in light of the slip-hazardous biomechanics of high horizontal forces (pushing) and low vertical forces (leaning). There were no witnesses to the event.

43. 8/17/77 - 9:10 a.m. 23 year old crane rigger working in SIC 3731 with two years experience in establishment #603 was stacking sections of inner bottoms (sections, for construction of ship's hull) on dock. He was standing on top of inner bottoms cutting loose crane's rope and hook from sections, turned around to dismount, slipped on wet steel surface, fell and struck leg against steel long (part of inner bottom's structure) sustaining a puncture to the leg resulting in a lost time injury with an unknown number of lost workdays.

a) footwear: steel-toed laced work boots with neoprene soles, well worn.

b) work surface: on top of stack of inner bottoms sections, steel surface covered with epoxy paint, wet due to recent inclemency. Most work surfaces in shipyards are also covered with welding grit.

c) tasks performed at site: heavy industrial materials handling for new ship construction, using 80 ft. crane to stack large sections for ship's hull.

d) employee task and biomechanics: turning and stepping, uncertain which foot slipped - the turning or the stepping foot.

e) housekeeping: temporary exterior work site.

f) environment: rained the previous night, most surfaces wet, high noise levels from heavy machinery.

g) COF: BIGFOOT fitted with neoprene sole:

1) Location 1: inner bottoms section painted with epoxy and tested dry.

$\bar{x} = .556$
$s = .05$
$n = 5$

2) Location 2: inner bottoms section surface painted with epoxy and tested wet.

$\bar{x} = .378$
$s = .025$
$n = 5$

The COF readings observed for the injury site under wet conditions are well inside the "slippery" range. Workers at this establishment must work at many temporary work sites and other hazardous surfaces. The wet conditions found at this establishment are due primarily to environmental factors.

44. 5/12/77 - 11:50 a.m. Shipfitter with three years experience working in SIC 3731 with two years experience in establishment #603 was engaged in welding a bracket in place on a ship's hull. He was standing on the edge of a 60 foot high deck pulling welding lead up from 20 foot high level, slipped on dry steel deck when a connection in the lead broke apart. He fell sustaining a strained back resulting in a lost time injury.

a) footwear: work boots with leather soles, worn condition.

b) work surface: structural steel plate painted with epoxy, possibly some grit in evidence on surface.

c) tasks performed at site: new ship construction; welding, chipping, sand blasting.

d) employee task and biomechanics: horizontal forces as a result of pulling, posture extended backwards from resistance of heavy welding lead which counterbalanced backwards horizontal forces, when lead broke resistance suddenly and drastically reduced counterbalance. Insufficient time to regain balance by moving feet.

e) housekeeping: exterior, temporary work site makes it difficult to regulate hazardous surface conditions such as wetness, welding grit, etc. Surface conditions were not a direct factor in this case.

f) environment: noisy, warm.

g) COF: BIGFOOT fitted with leather sole.

1) Location 1: ship hull's deck, smooth steel plate, epoxy painted, some grit in evidence.

$\bar{x} = .537$
$s = .041$
$n = 5$

This surface/shoe sole material interface does not have an unusually low COF. The slipping hazard is to be found in the forces acting upon the body: the sudden removal of strong horizontal forces, used to pull heavy weight from below, when the weight was removed. This removal was followed by rotation of the body. As the body rotates, the ratio of horizontal to vertical force at the point of contact with the ground (heels) increases until these slip. Hence the accident is reported as a slip.

45. 4/19/77 - 3 p.m. 58 year old male (5'5", 130 lbs.) sanitarian (custodian) working in SIC 8062 with two and one-half years experience in establishment #605 was sweeping food services loading dock. He was walking and applying pressure on push broom handle when push broom handle broke away from the broom head causing injured employee to slip on small puddle on concrete dock and fall backwards to the dock sustaining a back strain resulting in two lost workdays.

a) footwear: flat-heeled oxford laced shoes with rubber sole material in good condition.

b) work surface: rough textured concrete loading dock, condition wet.

c) tasks performed at site: delivery, materials handling, manual lifting, usage of unpowered industrial carts. Periodic high traffic area.

d) employee task and biomechanics: injured employee exerted horizontal forces and was applying pressure on broom handle. Release of the counter-pressure from the broom handle resulted in a loss of balance.

e) housekeeping: apparently various puddles on this dock which is located on the shady side of the building are a frequent occurrence and considered a "normal" feature. Source of the water is uncertain.

f) environment: Outdoor environment. Good natural lighting at time of accident.

g) COF: NBS - Brungraber Tester fitted with neoprene sole samples:

1) Location 1: food services loading dock, rough concrete surface tested dry - approach.

$\bar{x} = .544$
$s = .034$
$n = 8$

2) Location 2: site, loading dock, tested on available puddle at or about exact site location.

$\bar{x} = .7$
$s = .032$
$n = 5$

The COF measured dry was within the "slippery" range for surfaces tested using neoprene soles. The COF measured wet was higher than when measured dry. Subjectively, no difference in slipperiness between wet and dry concrete was observed. The primary event leading to the accident was the breakage of the broom handle. However, the injured employee felt that slipping in the puddle contributed to his failure to retain balance.

46. 1/27/77 - 2:50 p.m. 22 year old female food service worker working in SIC 8062 with one year and 9 months experience in establishment #605. At end of shift she was washing dishes and was walking from one end of dishwashing machine to other, through hallway where tray carts are brought from the nursing wards, and slipped on wet floor (water spilled by coworker who was pushing silverware cart and upset water on cart) and struck against the sharp edge of a storage shelf on the inside of a tray cart sustaining an abrasion to the inside of the forearm requiring medical treatment.

a) footwear: laced oxfords with wedge-type heels with flat compound soles with some wear evident.

b) work surface: quarry tile hallway with small puddle.

c) tasks performed at site: materiald handling route - hand pushed tray and dish carts; transit route for dishwashing staff. Periodic high traffic route.

d) employee task and biomechanics: walking.

e) housekeeping: wet conditions common in this area because of dishwashing activities - frequent spills of carried objects and leaks from machinery. No established procedure for immediate mopping up of spills. Unused dish carts left out in the middle of a 20 foot wide hallway rather than stored alongside far wall.

f) environment: work environment of area generally cluttered with carts, crowded with people and insufficient work space to detect fall or collision hazards and to recover balance prior to striking some object once balance has been lost.

g) COF: BIGFOOT fitted with composition sole material as below:

1) Location 1: approach, dishwashing hallway on quarry tile surface, dry conditions.

$\bar{x} = .511$
$s = .028$
$n = 8$

2) Location 2: site, quarry tile, wet conditions.

$\bar{x} = .511$
$s = .033$
$n = 5$

The measured values of COF are on the boundary of the "slippery" range for both dry and wet conditions. However, subjectively the floor was extremely slippery when wet, so that the COF measurements under wet conditions probably do not reflect the degree of slipping hazard.

47. 5/24/77 - 5:30 a.m. 58 year old female food service worker (5'8", 175 lbs.) working in SIC 8065 with three and one half years experience in establishment #605 was just starting her shift, and was walking and carrying a large cafeteria tray with six small paper cups of cream to her work station in the trayline. She was rounding the corner at the end of the trayline, slipped on a small spot of water on floor and fell to the floor sustaining a contusion to the hip and an abrasion to the elbow.

a) footwear: white restaurant-type oxford shoes, laced, with smooth, worn rubber-type shoe sole material.

b) work surface: kitchen, quarry tile flooring, wet conditions.

c) tasks performed at site: food preparation materials handling area, moderate traffic, periodic work station area for high density of personnel per square foot of floor area.

d) employee task and biomechanics: walking and carrying large object which may have done more to obscure her detection of the work surface condition hazard than it did to affect the biomechanical forces exerted in the act of carrying because of the light weight. Balancing the paper cups may however have been a factor.

e) housekeeping: water spot of undetermined origin; probably spilled by coworker but not corrected or perceived as spilled.

f) environment: work environment cluttered and crowded, insufficient space.

g) COF: NBS - Brungraber Tester fitted with neoprene-soled "shoe" as below:

1) Location 1: approach, quarry tile kitchen floor tested under dry conditions:

$\bar{x} = .41$
$s = .042$
$n = 8$

2) Location 2: site, quarry tile kitchen floor tested under wet conditions to replicate characteristics of event.

$\bar{x} = .546$
$s = .042$
$n = 8$

The COF readings at the site under dry conditions correspond to the "slippery" range measured using neoprene. Although the COF readings under wet conditions were higher than those under dry conditions, the floor was subjectively very slippery when wet. This indicates a difficulty with making useful COF measurements on wet surfaces.

48. 8/25/77 - 9:04 a.m. 20 year old female (5'2", 160 lbs.) food service worker working in SIC 8062 with one year experience in establishment #605 was finishing serving trays from tray cart in third floor ward kitchen and was preparing to return tray cart with dirty dishes to the basement dishroom. She was walking out of the ward kitchen, was pushing swinging door open (outwards) with right hand and reaching for tray cart handle with her other hand (to the left and slightly behind her position), when she stepped in an unnoticed small puddle on the floor, slipped, put out hand to catch herself on wall, and sustained a sprain to the wrist requiring medical treatment.

a) footwear: oxford waitress/nursing shoes, lace with synthetic rubber soles in good condition.

b) work surface: vinyl tile ward kitchen, waxed.

c) tasks performed at site: food service ward kitchen with microwave ovens, refrigerator, etc. for distribution of meals on the ward. High traffic volume at meal service periods with many people coming and going from room.

d) employee task and biomechanics: pushing forward and reaching to the side, body weight not directly over base of support; horizontal forces from pushing motion.

e) housekeeping: source of water unknown, spilled by coworker; floor treated with wax, clean and buffed.

f) environment: work environment had been congested with food service staff workers and nursing staff members while food service was in progress. Ambient environment adequate in physical characteristics.

g) COF: Universal Friction Testing Machine fitted with neoprene shoe sole material as below:

1) Location 1: approach to site, waxed vinyl tile floor, clean and dry.

$\bar{x} = .57$
$s = .043$
$n = 5$

2) Location 2: site, same surface but tested under wet conditions (small puddle) to simulate characteristics of accident event.

$\bar{x} = .41$
$s = .051$
$n = 5$

The COF readings for the dry surface of the accident site are on the boundary of the "slippery" range for measurements using neoprene. The reliability of the wet COF reading is uncertain. Subjectively, the floor was considerably more slippery when wet than when dry. An adequate COF is needed to support the horizontal forces associated with the tasks being performed. The spill on the floor was undetected and therefore the drop in COF, a significant one, was unexpected.

49. 1/12/77 - 6:30 a.m. 18 year old female fast food hostess working in SIC 2099 with two years experience in establishment #610 was cooking at grill in kitchen, slipped on a small wet spot on quarry tile floor and, attempting to avert a fall, put hand on hot griddle grill sustaining a burnt right wrist resulting in a lost time injury with ten lost workdays.

a) footwear: unknown

b) work surface: quarry tile. This establishment has an acid-etching program but a subjective estimate of slipperiness at grill area indicated that, if the surface had been treated, it had degraded with age.

c) tasks performed at site: food preparation, low volume traffic area. Work station for one or two persons requiring frequent side stepping and reaching.

d) employee task and biomechanics: cooking involving reaching, sidestepping.

e) housekeeping: source of wetness unknown. Work surface was clean and uncluttered at time of observation.

f) environment: well lighted, hot, noisy, busy and crowded. This event occurred during a rush hour.

g) COF: BIGFOOT fitted with neoprene sole on kitchen quarry tile surface as below:

1) Location 1: accident site, floor dry.

$\bar{x} = .61$
$s = .049$
$n = 5$

2) Location 2: accident site, floor wet.

$\bar{x} = .315$
$s = .049$
$n = 5$

The COF reading under dry conditions is not in the slippery range. However, the COF measured under wet conditions is in the slippery range. Subjectively, the floor appeared very slippery to the investigator when wet and not slippery when dry.

50. 5/12/77 - 8:45 a.m. 23 year old male shipfitter working in SIC 3731 with three years and six months experience in establishment #603 was engaging in dogging a plate down (applying horizontal force to pneumatic hammer to join seam of two steel plates preparatory to welding). He was standing on painted plate steel, changed his foot position for better leverage, slipped on wet steel deck, and fell to surface on back sustaining a strain to the back.

a) footwear: work boots, three-quarter length, laced and leather soles, worn.

b) work surface: plate structural steel painted with epoxy paint, some welding grit, wet condition.

c) tasks performed at site: new ship construction, hull assembly.

d) employee task and biomechanics: holding heavy powered tool at chest height, high horizontal forces from applying pressure on power tool. Foot was moved to new position and may not have been firmly "planted" when slip occurred.

e) housekeeping: temporary exterior work site.

f) environment: outdoor environment, adequate natural light, drizzling.

g) COF: BIGFOOT fitted with leather sole:

1) Location 1: epoxy painted structural steel under dry but slightly gritty conditions.

$\bar{x} = .54$
$s = .034$
$n = 5$

2) Location 2: accident site, epoxy painted structural steel, wet and slightly gritty.

$\bar{x} = .366$
$s = .023$
$n = 5$

The COF under dry conditions was not in the slippery range. Under wet conditions, the measured COF was lower than when dry (even though a leather sole sample was used, which

usually gives higher COF readings under wet conditions), and was in the slippery range. This low reading for COF under wet conditions may be associated with the presence of wet welding grit.

IV. ANALYSES OF INJURY RECORD DATA

Two main types of injury data were analyzed:

- tabulated data from state worker's compensation agencies
- data from review of First Reports of Injury

Each of these sources was reviewed with the aim of:

1. Determining the frequency of work surface related accidents, especially those involving inappropriate coefficient of friction.
2. Identifying the basic characteristics and accident circumstance profiles of work surface related accidents.

Of the two sources, the data from the First Reports of Injury was by far the most valuable for accomplishing both of these aims.

4.1 DATA FROM STATE WORKER'S COMPENSATION AGENCIES

Attempts were made to obtain data tabulated by state worker's compensation (WC) agencies which was related to work surface accidents. Although it was recognized prior to data collection that it was unlikely that the state WC agencies would provide much detail, it was hoped that these data sources would be of value in establishing the frequency of some very simple factors, such as SIC classification, for which large numbers of cases are needed. However, even this limited goal was not met due to the inadequacies of state worker's compensation tabulated data.

4.1.1 Limitations of Data

Each state was asked to send copies of any published data on falls or work surface accidents. Of the 50 states contacted, 20 responded.

In reviewing the data from each WC agency for information about work surface related accidents, severe limitations were found which rendered the data almost meaningless for the purposes of this study. Three types of problems were found:

1. lack of applicable tabulations

2. problems with the coding system used by the state WC agency (i.e., modified ANSI Z16.2)

3. lack of comparability between states

Only published data (i.e., pre-existing tabulations) were obtained from the state WC agencies. Of the 20 states responding, only 11 had tabulated data on falls or work surfaces. Only nine had tabulated data by industry and fall type or industry and work surface type and only six of these had data by three-digit SIC code. Of these, only two states used the standard SIC classification method for industry in the publications received. Of course, in order to determine the fall risk by SIC code it is necessary to estimate the number of workers by SIC in the state; otherwise, it is not possible to separate the effects of industry size differences from the differences by SIC in the risk of having a fall injury or other work surface related accident by SIC. Of the states for which data was available on falls by SIC classification, only New York was felt to have a sufficient size and diversity of industrial population to warrant including a tabulation of rates of work surface related injuries by industry in this report (see Section 4.1.2).

A major problem with the data from the state WC agencies is that most of those which do tabulate data, use the ANSI Z16.2[3] (Standard Method for Recording Basic Facts About the Nature and Occurrence of Work Injuries) or an adaptation of it. The ANSI Z16.2 provides for eight coding categories (nature of injury, part of body affected, source of injury, accident type, hazardous condition, agency of accident, agency of accident part, and unsafe act), but normally the state WC agencies, and others using the ANSI Z16.2 to analyze data from injury records, use only the first four coding categories. Thus, what is normally available from the state agencies is data on nature of injury (e.g., cut, bruise, fracture), part of body, source of injury, and accident type (e.g., fall, caught in, struck by, struck against, etc.). Some states use the coding categories for "agency of accidents" rather than the coding category for "source of injury." This coding method has severe limitations that are

particularly serious for a study of falls or work surface related accidents. These limitations include:

- Failure to identify all falls. The ANSI Z16.2 records only one accident type for each injury. The accident type recorded is the event which actually injured the employee. This means that for accident sequences which have more than one event, not all of the accident types in the accident sequence will be recorded. In particular, if a person falls, but is injured in the event which occurred after (or before) the fall, this case will not be recorded as a fall. There are many fall accident circumstances of this type. For example, persons may frequently:

  - fall and contact a hot or cold object (recorded as a "contact with temperature extremes" accidents); or fall and contact a caustic substance (recorded as a "contact with caustic substance" accident

  - slip, but recover balance and become injured as a result of the involuntary motion to recover balance (recorded as a "bodily reaction" accident)

  - fall and become caught in machinery (recorded as a "caught in" accident)

  Indeed, an employee may have almost any type of accident as a result of a slip or fall; none of which will be identified as a fall in ANSI Z16.2 tabulations, if the subsequent accident type is the one which directly inflicts the injury.

  While the fact that the ANSI Z16.2 method does not record multiple events may not be exceptionally damaging for some accident types, this limitation is very damaging for an analysis of falls. It is estimated that approximately one quarter of the fall related accidents are of the type that would not be recorded under the Z16.2 coding method (see Section 4.2 for tabulation of number of falls by results).

This is a particularly limiting fact when it is considered that it is often the fall event in the accident sequence which is the most important in terms of countermeasures development. For example, if a person falls and strikes a hot surface, it is often more important to address the prevention of the fall, rather than the prevention of contact with hot surfaces, the latter being in many cases only "accidentally" involved.

Fall types in terms of results, not precipitating events. The ANSI Z16.2 coding method uses two broad categories for falls: fall from elevation and fall on the same level. Although these two categories are subdivided into a few more detailed categories, most state WC agencies do not tabulate falls by the detailed categories. The categories for fall type used by the Z16.2 method are more a measure of the result of the fall, rather than the events that led up to it. For example, a person could trip over an object (precipitating event) and fall on the same level, or from an elevation, or recover his balance and not fall at all. Each of these three results of the fall would be reported differently in the ANSI Z16.2 method although the precipitating events were the same. The event which led up to the accident (i.e., the trip) would not be recorded at all, despite the fact that this event is more important for countermeasure development. Throughout the analysis of data conducted for this study, the attention is given to the precipitating events and not to the results of the fall, which may be considered as largely accidental and often are irrelevant in terms of determining how to control an accident. For similar reasons little emphasis is given to data on nature of injury or part of body affected: these are the results of the fall and do not give much indication of what can be done to prevent the fall or how the fall is related to work surfaces.

- Definition of "source" results in misleading coding of "work surface." Most adaptations of the ANSI Z16.2, involve coding the "source of injury" for each accident. The source of injury is the "object, substance, exposure or bodily motion which directly produced or inflicted the previously identified injury." Typically, the First Report form asks "name the object or substance that directly injured employee." For falls this definition results in a misleading use of the code "work surface" as the source of injury. In most falls, the employee strikes against the work surface as a result of the fall; therefore, under strict definition of "source," it is the work surface that "directly inflicted the injury." Consequently most tabulations of falls using the ANSI Z16.2 coding method, showed the work surface as by far the most frequent "source of injury." (Indeed, it is often the only source of injury; even if an employee trips over an object, it is usually the work surface that actually inflicts the injury.) It is felt that the current emphasis on the characteristics of the work surfaces as an area for concentration in addressing the problem of falls, may in part be based on a misunderstanding of what is meant by data which shows "work surface" as the major source of injury for falls. This data does not mean that the work surface was necessarily the cause of the fall (or even that it was a contributing factor); it merely confirmed the obvious, if not trivial, fact that the injury in most falls (i.e., cut, bruise or fracture) is inflicted by contact with the work surface.

  Moreover, in the case of falls from an elevation, it is almost necessarily the work surface onto which the employee fell (not the surface from which he fell) that is recorded, because it is the former surface which actually inflicted the injury. For this reason it is not possible to identify the type of work surface on which an employee was standing prior to a fall from an elevation (except for those few specific types of surfaces identified as subcategories of the Z16.2 category for "fall from elevation," e.g., "fall from ladder")

from data using the Z16.2 method. Of course, it is the surface that the employee fell from that is important for counter-measure development.

Only a few state WC agencies code "agency of accident" (i.e., "the object, substance, or premises in or about which the previously named hazardous condition existed"). The corresponding question on the First Report form is "what machine, tool, substance or object was most closely connected with the accident." Most of these WC agencies do not code the "hazardous condition" which gives the "agency of accident" category meaning. In addition, the terms "agency" and "source" are frequently used interchangeably, making the value of data on "source of injury" for falls even more suspect. Again, while these limitations of the ANSI Z16.2 coding method may not greatly affect all accident types, they are severely damaging to any analysis of tabulated data on falls.

As a result of these limitations of the ANSI Z16.2 method, which is almost invariably used by the state WC agencies, the data from these agencies on falls and work surface related accidents is of little utility for this study. The Bureau of Labor Statistics has initiated a uniform coding system for the state WC agencies known as the Supplementary Data System (SDS). This system has approximately 35 participating states and the first data from this system will be available in 1978. This system makes it possible to obtain data from participating state WC agencies which is uniformly coded for SIC, occupation and the first four categories of the ANSI Z16.2, i.e., source, not agency of accident. This type of data will be a significant advance over what is currently available. With data from the SDS program it will be possible to evaluate, to some degree, SIC and occupation as they relate to falls on a national basis (comparison between states must be limited, due to the fact that not all of the states record the same types of cases in terms of the severity level for cases reported; e.g., some states record all those cases with over three days lost, others with over $100 in benefits, etc.). Comparison of SIC and occupation by state is not currently possible, without the SDS program, due to the widely different coding systems used for SIC and occupation. With the SDS program it will also be possible to resolve some of the problems arising out of the differences in the use of

The terms "source" and "agency." However, this data will still have many of the problems inherent in the ANSI Z16.2 method as they relate to falls, because the SDS program is based on the first four categories of the Z16.2 program. Although the data from the SDS program will be of value it is not available at this time.

4.1.2 New York State WC Data

The New York State Department of Labor and the Workmen's Compensation Board have published tabulations[1] of the characteristics and costs of work injuries in New York State for worker's compensation cases closed in the period 1966-1970. These include tabulations by agency of accident. TABLE 4-1 gives a breakdown by agency of accident of number of compensated injuries and compensation awarded for all agencies classified as work surfaces. For the same period the total number of compensable injuries (all agencies of accident) was 595,019 and the total compensation awarded was $1,140,950,300. Inside surfaces are given as agency of accident for about 38% of the compensable injuries with work surface as agency (accounting for about 33% of the compensation awarded), but only 7% of these inside surfaces are identified further.

TABLE 4-2 shows compensable injury rates (per 100 man-years) for the industries listed in the same publication.[1] The publication lists number of compensable injuries by industry. These numbers were converted to rates using employment figures from County Business Patterns.[4] The New York publication[1] also lists the number of injuries by accident type and by agency of accident for each industry. These are given as percentages in TABLE 4-2, for three accident types and for work surface as agency of accident. It may be noted that the accident types are limited to falls on same level, falls to a different level and slips combined with overexertion. The results are what might be expected: painters and decorators have a higher than average percentage of injuries as fall to different level, and the same applies to roofing and sheet metal work. Clothing manufacturers, clothing/department stores, restaurants, hotels/motels and hospitals are examples of industrial classifications with a much higher than average fraction of their compensable injuries being falls, same level. Since slips are combined with overexertion (handling) accidents little useful information can be gleaned about slips on work surfaces.

The New York publication[1] also includes numerous cross-tabulations: no additional categories are included however.

TABLE 4-1

NUMBER OF COMPENSABLE INJURIES AND AWARDED COMPENSATION, NEW YORK STATE, 1966-1970, BY AGENCY OF ACCIDENT, FOR WORKING SURFACE AGENCIES

	Number	Amount (in $000's)
Working Surfaces: Total	120,682	$291,152.7
Special instances of working surfaces	527	2,029.7
Elevated-not indicated	363	1,497.2
Opening-not indicated	9	89.1
Level-not indicated	5	0.8
Ships in construction	28	78.3
Other vehicles in construction	76	95.0
Not indicated	22	32.4
Floor-inside surface	45,366	95,126.1
Threshold	404	1,070.6
Linoleum covered	63	203.5
Carpet covered	827	2,118.3
Concrete, tile	755	1,801.2
Metal	301	619.0
Stone, marble	70	165.4
Temporary	1	0.1
Trap door, chute	370	1,083.4
Pits-garbage, etc.	315	759.2
Not indicated	42,260	87,305.5
Outside surfaces	23,345	45,173.1
Road and driveway	1,143	2,416.1
Sidewalk, alley	2,138	4,042.6
Grounds, yards and parks	1,484	2,824.7
Parking lot	2,375	3,951.0
Woods, streams, farms	222	302.9
Curbs	910	1,471.9
Railroad tracks	259	346.2
Cliffs, hills	464	1,029.6
Excavations	921	2,680.1
Not indicated	13,429	26,108.0
Stairs (incl. those of machines, etc.)	16,608	35,736.3
Scaffolds and stagings	4,111	22,311.8
Platforms and ramps	4,449	10,695.8
For loading	1,513	3,166.1
Machinery, boiler	408	1,041.5
Railroad, subway	73	157.2
Other platform	1,084	2,581.9
Runway, catwalk	263	936.6

TABLE 4-1 (Continued)

	Number	Amount (in $000's)
Platforms and ramps (cont'd.)		
Ramps, slopes-in door	749	$ 1,674.9
Gangplank	179	525.9
Plank over opening	165	583.1
Not indicated	15	28.6
Roofs (roof openings and skylight)	1,013	5,437.7
Fixed objects used as working surface	7,635	24,736.8
Bldg. in construction or demolition	4,445	14,772.6
Window, wall opening	120	932.3
Other building parts	636	1,968.5
Other structure-construction, demolition	194	937.0
Other structures-not in constr. or demo.	432	1,409.0
Poles, trees	462	1,721.7
Elevated bins, tanks	300	639.7
Rack, skid	540	1,088.0
Fixed furniture	54	76.5
Other and not indicated	452	1,191.6
Portable objects used as working surface	17,628	49,905.3
Ladder	11,817	35,907.5
Chairs, other seats	1,378	3,190.1
Saw horses	140	444.4
Other furniture	327	701.1
Containers, packages	774	1,622.6
Piles	619	1,747.4
Sitting on chairs	2,137	5,315.6
Other and not indicated	436	976.6

TABLE 4-2

COMPENSABLE INJURY RATES BY SIC FOR 100 INDUSTRIES, NEW YORK STATE, 1966-1970, WITH PERCENTAGE BY SELECTED ACCIDENT TYPE AND AGENCY OF ACCIDENT

SIC #	Industry Name	Total Injuries/ 100 Man-Years	Injuries as % of Total for SIC: Falls on Same Level	Falls to Diff. Level	Slips (Not Fall) or Overexertion (Handling)	Work Surface as Agency of Accident
07	Agriculture Services and Hunting	8.1	6.2	12.1	21.9	15.0
15	General Building Contractors	0.7	8.3	19.9	24.0	29.8
161	Highway and Street Construction	29.6	5.8	11.0	22.2	12.5
162	Heavy Construction, NEC	4.4	6.5	12.2	18.9	17.4
171	Plumbing, Heating, Air Conditioning	3.0	7.2	14.3	28.6	24.2
172	Painting, Paper Hanging, Decorating	12.1	6.0	38.2	27.3	47.6
173	Electrical Work	2.1	8.9	19.5	29.1	31.5
174	Masonry, Stonework, and Plastering	5.6	8.2	18.9	27.0	29.8
175	Carpentering and Flooring	5.2	7.0	22.4	23.7	31.3
176	Roofing and Sheet Metal Work	5.6	4.8	26.7	22.0	32.8
177	Concrete Work	6.8	10.9	16.0	21.3	28.2
1791	Structural Steel Erection	8.9	9.0	21.8	18.3	32.8
1794	Excavating and Foundation Work	7.3	7.2	11.4	20.2	14.6
1799	Special Trade Contractors, NEC	4.3	6.6	23.3	22.7	32.4
201	Meat Products	6.9	10.3	5.1	26.0	15.1
202	Dairy Products	7.2	14.9	11.7	32.9	25.4
203	Canned, Cured, and Frozen Foods	7.0	12.7	7.6	21.0	21.5
205	Bakery Products	4.5	12.3	6.9	29.2	19.6
208	Beverages	7.0	8.4	9.6	31.4	16.8
225	Knitting Mills	1.3	12.8	6.2	23.3	19.7
231	Men's and Boys' Suits and Coats	1.2	16.1	6.9	24.5	26.0
233	Women's and Misses' Outerwear	0.9	16.3	4.9	22.6	22.2
239	Misc. Fabricated Textile Products	1.5	9.1	5.1	21.7	14.8
251	Household Furniture	4.7	5.1	3.8	20.9	8.7
259	Miscellaneous Furniture and Fixtures	1.9	4.7	3.6	19.2	8.6
262	Paper Mills, Except Building Paper	4.6	7.3	5.9	24.1	16.2
264	Miscellaneous Converted Paper Products	3.3	6.1	4.3	21.9	10.3
265	Paperboard Containers and Boxes	3.7	6.8	5.2	21.9	12.4
27	Printing and Publishing	0.5	11.9	13.4	30.4	21.4
275	Commercial Printing	2.1	6.9	3.7	24.0	11.5
283	Drugs	1.7	11.0	5.7	29.4	19.3
284	Soap, Cleaners, and Toilet Goods	2.3	12.2	6.5	25.9	19.8

TABLE 4-2 (Continued)

SIC #	Industry Name	Total Injuries/ 100 Man-Years	Injuries as % of Total for SIC			
			Falls on Same Level	Falls to Diff. Level	Slips (Not Fall) or Overexertion (Handling)	Work Surface as Agency of Accident
307	Miscellaneous Plastics Products	3.0	6.2	3.1	16.1	10.0
314	Footwear, Except Rubber	2.4	8.7	3.3	24.8	12.4
327	Concrete, Gypsum, & Plaster Products	6.4	5.8	13.5	22.8	13.2
329	Miscellaneous Nonmetallic Mineral Products	3.7	6.4	4.2	28.9	13.0
331	Blast Furnace & Basic Steel Products	4.7	6.9	5.0	30.5	15.8
332	Iron and Steel Foundries	13.4	4.3	2.9	26.6	8.6
335	Nonferrous Rolling and Drawing	3.8	5.8	3.3	23.9	10.3
336	Nonferrous Foundries	5.1	4.0	1.6	24.2	6.7
342	Cutlery, Hand Tools and Hardware	3.7	4.5	2.5	22.2	8.1
344	Fabricated Structural Metal Products	6.0	4.7	5.8	20.9	11.3
346	Metal Stampings	4.2	3.7	2.0	16.7	6.2
349	Miscellaneous Fabricated Metal Products	3.7	5.8	2.7	25.0	8.8
353	Construction and Related Machinery	3.9	5.8	4.9	26.3	11.7
354	Metalworking Machinery	2.5	3.8	2.7	20.6	7.3
355	Special Industry Machinery	3.1	5.8	3.1	24.9	10.7
356	General Industrial Machinery	3.4	5.7	3.3	25.0	10.9
357	Office and Computing Machines	1.2	10.8	4.4	32.1	17.5
358	Service Industry Machines	3.7	5.2	3.9	26.5	10.8
359	Miscellaneous Machinery, Except Electrical	2.0	4.1	2.4	18.8	6.7
362	Electrical Industrial Apparatus	2.0	6.7	4.9	25.8	13.2
364	Electric and Wiring Equipment	2.9	6.3	3.4	23.2	10.9
367	Electronic Components & Accessories	0.9	10.2	4.5	27.2	17.1
371	Motor Vehicles and Equipment	5.3	7.9	3.2	29.9	13.6
372	Aircraft and Parts	1.5	9.0	4.9	29.3	17.0
386	Photographic Equipment and Supplies	1.6	8.9	4.0	33.9	15.7
39	Miscellaneous Manufacturing Industries	0.6	6.0	5.4	20.1	11.7
394	Toys and Sporting Goods	2.7	8.1	4.3	15.9	12.3
396	Costume Jewelry and Notions	2.4	6.6	3.6	16.8	10.4

TABLE 4-2 (Continued)

SIC #	Industry Name	Total Injuries/ 100 Man-Years	Injuries as % of Total for SIC: Falls on Same Level	Falls to Diff. Level	Slips (Not Fall) or Overexertion (Handling)	Work Surface as Agency of Accident
412	Taxicabs	5.0	2.9	1.0	28.0	3.6
421	Trucking, Local and Long Distance	5.5	7.6	13.3	31.8	13.3
44	Water Transportation	1.5	10.4	6.7	18.5	13.4
453	Air Transportation	2.4	11.3	7.3	34.6	18.8
481	Telephone Communication	0.6	12.3	12.1	39.6	31.9
49	Electric, Gas and Sanitary Service	0.9	8.5	10.9	27.8	22.6
5047	Meats and Meat Products	3.6	8.4	5.4	31.0	13.0
509	Miscellaneous Wholesalers	0.2	11.4	9.0	33.2	19.5
5095	Beer, Wine, and Distilled Beverages	2.4	9.5	13.9	37.9	18.1
521	Lumber and Other Building Materials	3.6	7.0	14.7	26.2	17.5
531	Department Stores	1.4	17.2	9.8	31.9	29.2
541	Grocery Stores	2.7	8.9	5.3	30.6	14.6
542	Meat and Fish (Sea Food) Markets	3.9	8.2	3.7	24.2	11.7
551	New and Used Car Dealers	2.0	8.2	4.8	28.0	14.8
554	Gasoline Service Stations	2.2	9.3	3.7	23.1	13.9
56	Apparel and Accessory Stores	0.7	20.6	17.2	29.5	41.3
57	Furniture and Home Furnishings Stores	1.8	9.5	9.4	43.6	18.8
58	Eating and Drinking Places	2.1	17.8	7.4	20.2	28.1
598	Fuel and Ice Dealers	4.2	11.5	14.4	30.9	22.3
599	Retail Stores, NEC	3.6	12.5	12.6	31.6	26.0
60	Banking	0.4	20.3	11.4	31.5	34.7
63	Insurance Carriers	0.4	23.6	10.4	27.5	38.0
651	Real Estate Operators and Lessors	2.1	13.3	17.5	25.7	31.5
701	Hotels, Tourist Courts, and Motels	2.4	19.6	10.3	25.2	32.1
721	Laundries and Dry Cleaning Plants	1.3	11.1	6.3	26.7	16.9
7218	Industrial Launderers	1.4	10.8	5.6	27.2	17.8
734	Services to Buildings	2.3	15.9	14.2	26.7	31.7
739	Miscellaneous Business Services	0.9	16.5	12.3	22.2	29.8
753	Automobile Repair Shops	3.4	5.5	4.6	23.6	9.1
754	Automobile Services, Except Repair	10.6	8.7	7.4	22.2	14.9

TABLE 4-2 (Continued)

SIC #	Industry Name	Total Injuries/ 100 Man-Years	Injuries as % of Total for SIC			
			Falls on Same Level	Falls to Diff. Level	Slips (Not Fall) or Overexertion (Handling)	Work Surface as Agency of Accident
76	Miscellaneous Repair Services	2.9	6.0	8.4	28.4	14.8
79	Amusement and Recreation Services, NEC	1.1	15.0	16.4	21.7	24.6
80	Medical and Other Health Services, Excl. Hospitals	0.8	21.3	8.7	38.6	32.0
806	Hospitals	0.9	16.7	5.5	39.0	24.9
81	Legal Services	1.0	20.4	12.1	27.4	35.6
864	Civic and Social Associations	3.0	15.6	15.6	22.5	28.5
867	Charitable Organizations	2.0	22.1	12.1	24.7	35.5

4.2 ANALYSIS OF FIRST REPORTS OF INJURY

In order to gain more insight into the accident profiles characteristic of slip and fall accidents, a series of approximately 3,000 First Reports of Injury were analyzed. These reports were obtained during a previous NIOSH study, "Feasibility of Securing Research Defining Accident Statistics," performed under contract CDC-99-74-38.[5] During this study, 621 establishments were visited nationwide in 1975 and 1976. Copies of the OSHA-100 Form (Log) and OSHA-101 or equivalent (First Report of Injury) were collected for a one year period. In all, about 22,000 First Reports are available. It should be noted that the establishments from which the reports were collected do not form a representative sample of the establishments in the U.S.; the selection was designed to include the 25 2-digit SIC codes with the highest number of injuries (i.e., highest product of injury rate and employment), and a range of size and geographical distribution. Nevertheless, the establishments cover a wide range of industries and slip/fall types and form a suitable data base from which to develop accident profiles.

These 22,000 First Reports were reviewed and all injuries involving slips, falls or a work surface were selected for further study. The total number of injury reports so selected was 3,270 (approximately 15% of the total), and their distribution by 2-digit SIC code is shown in TABLE 4-3, which also shows the number of establishments by 2-digit SIC code.

Of these 3,270, approximately 1,000 (actually 1,077) were coded using FRASE (Factor Relationship Analysis and Sequence of Events), a detailed relationship-preserving coding system for occupational injuries developed by SAFETY SCIENCES from work performed under NIOSH contract CDC-99-74-38,[5] and subsequently used in analysis of injuries for OSHA.[6] The types of coding phrases used in FRASE are shown in TABLE 4-4. FRASE allows for: 1) the coding of activities of the injured employee at the time of the accident, including any handtools, equipment, clothing or other objects involved; and 2) coding multiple events, including precipitating events, which did not result in injury but which led to the injuring accident type. Activities are coded in order of most general activity to specific task and finally to body positions and movements. Events are coded in the order in which they occur. There may be as many as five activities described and six events described in any single accident sequence description. This analysis method thus emphasizes the interaction between the injured employee and the environment and the machines and

TABLE 4-3

NUMBER OF "FIRST REPORTS" USED FOR ANALYSIS BY SIC CODE

SIC Code	Name of Industry	No. of Establishments	No. of Injuries	% of Total
15	General Building Contractors	35	153	5
16	Heavy Construction Contractors	24	68	2
17	Special Trade Contractors	28	231	7
20	Food and Kindred Products	28	225	7
22	Textile Mill Products	14	30	1
23	Apparel and Textile Products	33	53	2
24	Lumber and Wood Products	25	190	6
25	Furniture and Fixtures	17	65	2
26	Paper and Allied Products	23	180	6
28	Chemicals and Allied Products	21	90	3
30	Rubber and Plastic Products	25	69	2
32	Stone Clay and Glass Products	24	104	3
33	Primary Metal Industries	22	199	6
34	Fabricated Metal Products	25	110	3
35	Machinery, Except Electrical	28	177	5
36	Electrical Equipment and Supplies	28	167	5
37	Transportation Equipment	28	196	6
42	Trucking and Warehousing	25	167	5
50	Wholesale Trade	27	126	4
53	Retain General Merchandise	24	82	3
54	Food Stores	19	138	4
55	Automotive Dealers and Service Stations	27	52	2
58	Eating and Drinking Places	24	105	3
73	Miscellaneous Business Services	22	111	3
80	Medical and Other Health Services	29	60	2
UNK	Unknown	-	12	<1
	TOTAL	621	3270	100%

TABLE 4-4

FOUR TYPES OF CODING PHRASES

Type of Coding Phrase	
1) EVENT MODEL	• ACCIDENT TYPES • PRECIPITATING EVENTS • ACTIVITIES
2) LOCATION MODEL	RELATIONSHIP OF • INJURED EMPLOYEE, OR • OBJECTS TO OTHER OBJECTS
3) PLACES OF MOVEMENT MODEL	• PLACE TO • PLACE FROM WHICH EMPLOYEES AND OBJECTS MOVE
4) OBJECTS	• TYPE OF OBJECT • CHARACTERISTICS • PARTS

equipment being used in the environment, rather than merely the end results of the accident sequence.

The remaining 2,193 were coded using a simpler method, with the following factors:

- fall type
- accident type - result
- occupation
- site of accident
- floor condition
- type of work surface
- housekeeping involved
- carrying involved
- horizontal forces involved
- vertical forces involved
- hand task
- foot task

All 3,270 accidents could be analyzed by these factors, while only the 1,000 FRASE coded accidents could be analyzed by using the FRASE method.

The results of analysis by simple factors are described in the following tables.

TABLE 4-5 shows the distribution by fall type. Definitions are given in TABLE 4-6. As might be expected, 50% of the cases were characterized as slips. These events resulted in the accident types (results) shown in TABLE 4-7. Only about 60% of the events result in complete falls.

TABLE 4-8 shows the distribution by occupational category. Unskilled laborers make up only 12% of the work force but experienced 27% of the injuries.

TABLE 4-5

DISTRIBUTION BY FALL TYPE

Fall Types	% of Total
Slip	50
Trip	14
Misstep	10
Stumble	1
External Force	1
Postural Overextension	4
Loss of Support	7
Medical	<1
Unknown	12

TABLE 4-6

FALL TYPES

Slip:
Loss of traction on work surface.

Trip:
Movement in lower body arrested (but opper body velocity continues and causes unbalancing) due to contact with:
- fixed objects
- loose objects
- protrusions into aisles, etc.

Misstep:
Putting the foot down where there is no support, as in:
1) Putting foot down wrong, at an abnormal angle to surface or step on hose or similar object (e.g., resulting in a turned ankle)
2) Putting foot down where there is no surface - i.e., too far forward on a step edge.
3) Step in hole.

Stumble:
(1) traction of surface too great.
(2) trip over one's own feet.

External Force:
Pushed or pulled out of center of mass by object or other, or, employee attempts to move but is restrained by other (e.g., 2 firemen holding a hoseline - one jumps over a ditch, the other doesn't move, first one falls in ditch). Also, pulling on rope and rope breaks.

Postural Overextension:
Intentional or unintended - center of mass out of center of gravity.
- leaning
- reaching
- attempt to avoid

loss of balance

Loss of Support:
Platform collapses, moves, breaks
Handhold shifts, breaks, slips

Medical:
Loss of postural integrity due to health condition as
- faint
- heart attack
- "drop" disease - (unknown, as in "I was walking along and then I was picking myself up off the floor")
- postural hypotension
- vertigo

TABLE 4-7

DISTRIBUTION BY ACCIDENT TYPE

(RESULT)

Broad Accident Types: Results	% of Total
Fall to a different level	19
Fall on same level	26
Recovery to a different level	1
Recovery on same level	14
Fall unknown	10
Recovery unknown	1
Struck against object during fall: incomplete fall	10
Other	18

TABLE 4-8

DISTRIBUTION BY OCCUPATIONAL CATEGORY

Occupational Category	% of Total
Machine Operator	7
Transport Equipment Operator	8
Skilled Laborer	19
Unskilled Laborer	27
Professional	2
Clerical	8
Maintenance Worker	5
Manager/Supervisor	6
Production Worker	7
Service Worker	5
Trainee	1
Other Occupation	2
Unknown Occupation	4

TABLE 4-9 gives distributions by the remaining factors, which are self-explanatory.

Combinations of these factors were also tabulated. For example, of the slips, 16% occur on surfaces stated to be wet, 6.4% on surfaces stated to oily, 8.1% on surfaces stated to be icy, 0.7% on surfaces stated to be muddy, and only 3.5% on surfaces specifically stated to be slippery. In most cases the floor condition was not stated or stated to be normal. Fifteen percent (15%) occurred on "unusual" surfaces such as hoses, rocks, tool boxes, etc.

A further set of combinations is shown in TABLE 4-10 for the 2,193 cases coded using the simple factors only. This is arranged in the form of a tree. At each branch point the corresponding number of injuries is given, followed by two percentages. The first percentage is that of the number at the preceding node. The second is that of the total number of injuries (2,193). Not all branches of the tree are followed through to the same level of branching.

FRASE coding permits the printing of Accident Circumstance Profiles for accidents that can be selected to fall into desired groups. These groups can be general, e.g., all cases including the word ladder. EXHIBIT 1 shows a list of such cases, together with the number of cases, number of cases with zero days lost, number of cases with unknown days lost, and the average number of lost workdays for lost workday cases. These general listings can then be examined to determine more specific accident profiles. For example, stepping off the ladder was associated with nine accidents out of the 58 total (#122, 306, 343, 517, 900, 929, 931, 1183 and 1526). Accident #246 is a reminder that ladders are tripping hazards, and #2091 that ladders can be lifting hazards. Accidents #1195 and 1460 demonstrate that recovery from a slip or loss of balance can lead to injury. If desired, a more specific computer sort can be made. EXHIBIT 2 shows such a printout for ladder/step/rung broke or was broken. Only four accidents of the 58 were due to ladder failure of this type.

EXHIBIT 3 shows a printout for the general category of pushing, and EXHIBIT 4 shows the more specific cases which injured employee pushed/was pushing and injured employee slipped. This eliminates cases such as #85 in which the pushing was not related to the accident through a slip while pushing. EXHIBIT 5 shows cases in which pulling was involved. These cases have a greater severity than pushing, presumably because of the possibility of pulling an object

TABLE 4-9

DISTRIBUTION BY SELECTED FACTORS

	% of Total
Indoors/Outdoors	
Indoors	50
Outdoors	25
Not Stated	24
	100%
Site	
Normal Work Site	78
Parking Lot	3
Restroom/Lunch Room	2
Temporary Site (e.g., in duct work on top machine)	11
Not Stated	6
	100%
Floor Condition	
Stated to be Slippery	2
Oily	3
Wet	7
Icy	4
Muddy	<1
Normal	26
Other Unusual	19
Not Stated	39
	100%
Type of Work Surface	
Ramp/Slope/Incline	2
Stair	10
Ladder	6
Scaffold/Catwalk	2
Floor	33
Ground (Outdoors)	11
Other Surface	21
Not Stated	14
	100%
Housekeeping	
Housekeeping involved	22
Not Involved	78
	100%

TABLE 4-9 (Continued)

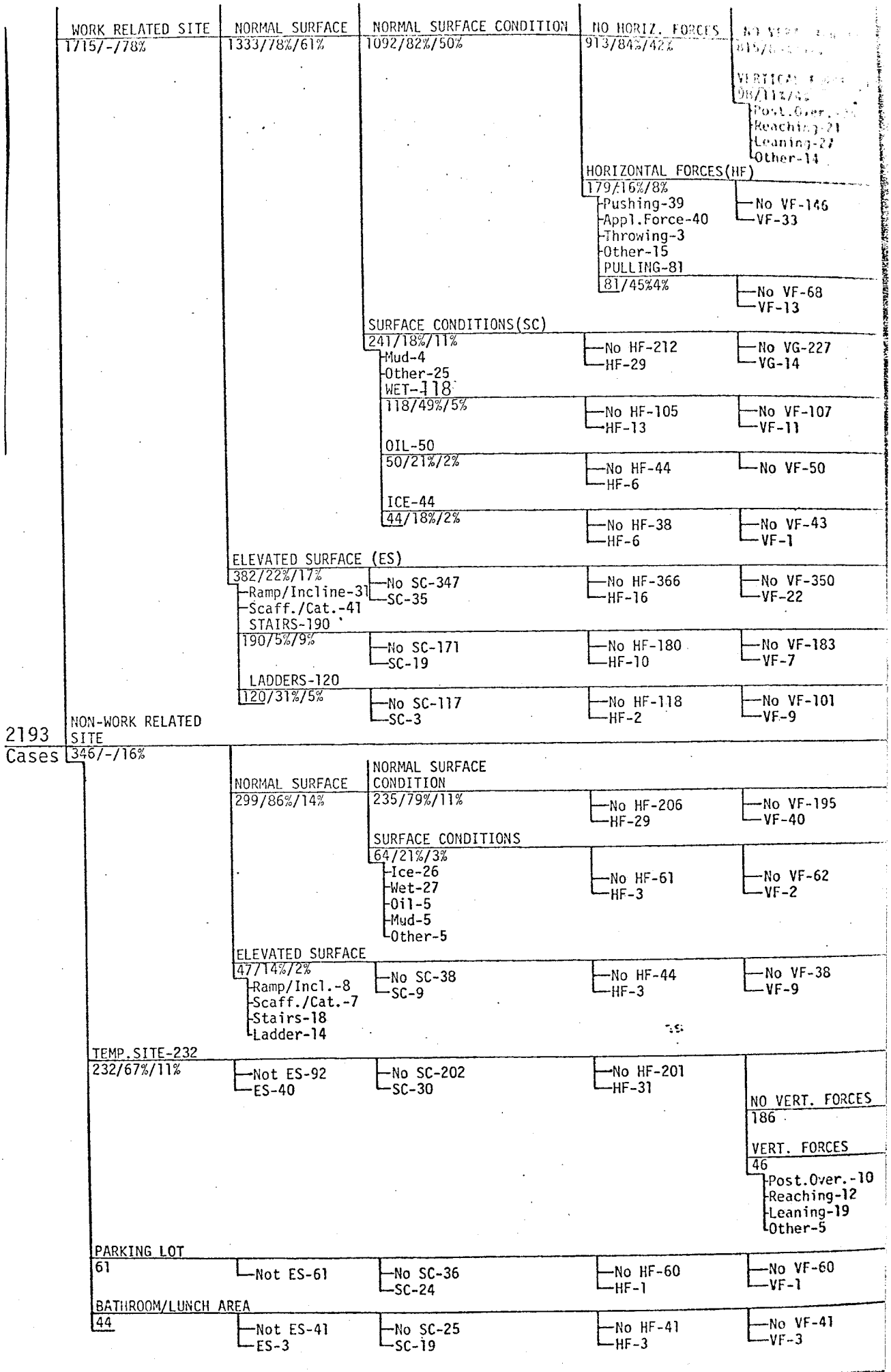
	% of Total
Horizontal Forces	
Pushing	3
Pulling	5
Throwing	<1
Catching	<1
Applying Force	3
Other	1
Not Related	88
	100%
Vertical Forces	
Postural Overextension	3
Reaching	2
Leaning	4
Other	1
Not Related	89
	100%

TABLE 4-9 (Continued)

	% of Total
Carrying	
Carrying	13
Not Carrying	87
	100%
Hand Task	
Dropping	<1
Grabbing	3
Holding	14
Handling	9
Picking Up	1
Using	1
Turning	<1
Placing	1
Tieing	<1
Other	1
No Stated Hand Task	69
	100%
Foot Task	
Jumping	1
Kicking	<1
Kneeling	<1
Running	1
Standing	15
Stepping Onto/From	21
Walking	32
Other	2
No Stated Foot Task	27
Climbing	3
	100%

TABLE 4-10

TREE SHOWING BREAKDOWN BY SELECTED FACTORS



SLIP	TRIP	MISSTEP	STUMBLE	EXTERNAL FORCE	POSTURAL OVEREXTEN.	LOSS OF SUPPORT	MEDICAL	OTHER	TOTAL
36%/13% 293	26%/10% 209	13%/5% 109	1%/<1% 8	1%/<1% 8	2%/1% 14	7%/3% 58	1%/<1% 1	14%/5% 115	89%/37% 815
39%/2% 38	15%/1% 15	7%/<1% 7	1%/<1% 1	7%/<1% 7	20%/1% 20	5%/<1% 5	0%/0% 0	5%/<1% 5	11%/4% 98
35%/3% 63	6%/<1% 11	6%/<1% 10	0	5%/<1% 9	9%/1% 16	26%/2% 46	0	13%/1% 24	16%/8% 179
31%/1% 25	6%/<1% 5	6%/<1% 5	0	5%/<1% 4	10%/<1% 8	28%/1% 23	0	14%/<1% 11	45%/4% 81
98%/11% 236	1%/<1% 2	1%/<1% 1	0	0	0	0	0	4%/<1% 9	18%/11% 241
97%/5% 115	2%/<1% 2	1%/<1% 1	0	0	0	0	0	0	49%/5% 118
100%/2% 50	0	0	0	0	0	0	0	0	21%/2% 50
95%/2% 42	0	0	0	0	0	0	0	4%/<1% 2	18%/2% 44
43%/7% 163	7%/1% 27	14%/3% 55	2%/<1% 6	1%/<1% 3	4%/1% 17	11%/2% 41	0	18%/3% 70	22%/17% 382
49%/4% 94	10%/1% 20	18%/2% 35	2%/<1% 4	1%/<1% 2	3%/<1% 6	3%/<1% 6	0	12%/1% 23	5%/9% 190
36%/2% 43	1%/<1% 1	11%/1% 13	1%/<1% 1	1%/<1% 1	7%/<1% 8	19%/1% 23	0	8%/<1% 9	31%/5% 120
51%/8% 178	9%/1% 31	12%/2% 42	1%/<1% 2	3%/<1% 9	7%/1% 25	8%/1% 27	0	8%/1% 29	-/16% 346
39%/4% 89	12%/1% 29	12%/1% 29	1%/<1% 2	4%/<1% 9	7%/1% 17	10%/1% 24	0	15%/2% 36	79%/11% 235
95%/3% 61	0	0	0	0	2%/<1% 1	0	0	3%/<1% 2	21%/3% 64
43%/1% 20	4%/<1% 2	28%/1% 13	0	0	15%/<1% 7	6%/<1% 3	0	4%/<1% 2	14%/2% 47
46%/5% 107	6%/1% 13	14%/1% 33	0	3%/<1% 8	9%/<1% 20	11%/1% 25	0	11%/1% 26	67%/11% 232
47%/4% 88	6%/<1% 11	16%/1% 29	3%/<1% 6	4%/<1% 8	11%/1% 20	13%/1% 24	0	13%/1% 24	80%/8% 186
41%/1% 19	4%/<1% 2	9%/<1% 4	0	4%/<1% 2	26%/<1% 12	11%/<1% 5	0	4%/<1% 2	20%/2% 46
52%/1% 32	20%/<1% 12	13%/<1% 8	2%/<1% 1	2%/<1% 1	0	0	0	11%/<1% 7	18%/3% 61
8%/1%	14%/<1%		2%/<1%		9%/<1%	2%/<1%	0	4%/<1% 2	13%/2% 44

over oneself if one slips (#1196) and the higher chance of injury if an object being pulled (rather than pushed) breaks (#1176).

TABLE 4-11 lists other exhibits containing accident profiles, with the expressions by which they were sorted.

EXHIBITS 1-28 demonstrating the various accident circumstance profiles are presented in their entirety in APPENDIX B (bound separately).

TABLE 4-11

EXHIBIT #	Circumstance Involved in Accident Profile
6	Sit/Sitting/Chair
7	External Force
8	Interaction Between Employees
9	Carrying
10	Door/Gate
11	Dock, Loading Dock
12	Going on Break or Home, Reporting to Work
13	Entering or Leaving
14	Scaffold
15	Catwalk
16	Platform
17	Makeshift Platform
18	Trip
19	Stumble
20	Loss of Support } as event type
21	Misstep
22	Reaching
23	Performing Other Tasks Requiring Horizontal Forces
24	Related to Housekeeping (Objects/Oil/Water or Floor, Protruding Objects)
25	Ice
26	Oil
27	Change in Coefficient of Friction (Icy Spot, Wet Spot, Slick Spot, Different Surface)
28	Wet (Wet, Water, Washing, Spraying, Spilled, Soap and Water, Mop)

V. DISCUSSION AND CONCLUSIONS

The field portion of this study focused upon coefficient of friction as a contributory factor to slip and fall injuries. It should be noted that slip and fall injuries on dry surfaces were found to be rather rare occurrences at the establishments studied, accounting for only about 5% of the total slips and falls, or about 1% of the total injuries. It is not possible to accurately compute similar ratios from injury records only, because sufficient detail is lacking to exclude, with certainty, slips on wet surfaces. An analysis of 3,270 work surface related injury records showed that 50% were related to slips, but only 3.5% of these (or 1.75% of the total slips and falls) occurred on surfaces stated specifically to be "slippery."

Although number of injuries of this type is small, the site measurements indicate the possibility that control should be possible, with as many as half of the slips being preventable. This is based upon the following findings made during the site observations:

- COF varied from below 0.2 to 1.0 or above over a range of work surfaces
- in one plant with a COF of 0.2 (extremely slippery) on a specially treated concrete floor, employees were able to adjust their gait to walking but tended to fall when performing tasks such as reaching and pushing
- employees generally seem to be able to adjust to a wide range of COF, provided that it remains uniform
- unrecognized changes of COF appear to account for most slips on dry surfaces, typically on walking from a high COF surface to a lower COF surface
- the same factor of lack of recognition appears to apply to wet and oily spots on surfaces as a cause of slips
- measurements over a floor in one large building showed that the main corridor had a consistent COF of about 0.4

(adequate). The rooms leading off the corridor tended to have COF values of about 0.6, and some side corridors were slippery with a COF of 0.2-0.3. This range in COF places a burden on employees, who must adjust their gait, and can be related to several slips.

- control of COF by etching of tile and concrete floors, and by proper waxing and buffing of vinyl floors, is quite feasible and is performed systematically by some of the organizations studied. The hospital with a thorough floor care program, which includes COF measurements, has a rate for slips and falls of only 28% of that of a nearby hospital with a less effective floor care program. Field measurements confirmed a significant difference in COF between a series of measurements in one hospital as compared to the other. This suggests that adequate floor care would be an effective countermeasure for many slips of this kind.

- other control measures shown likely to be effective include:

  - use of non-slip work surface materials and construction
  - careful checking and maintenance of key trouble spots such as stair tread edges, corners in corridors and doorways
  - improved housekeeping to prevent and clean up spills
  - testing shoes for specific tasks involving high horizontal forces on surfaces that cannot easily be controlled. An example is that of a welder in a shipyard, who pulls on welding cables and stands on wet steel covered with welding grit.

The situation regarding measurement of COF is unsatisfactory. There is no generally accepted instrument or procedure, and no standard samples of flooring and footwear that are readily available for field calibration purposes over a range of COF. The situation is worse for measurements on wet surfaces, where most slips occur.

Shoes form an obvious priority for future work. The materials that have a high COF on "high COF" floor surfaces tend to give a rapidly decreasing COF as the flooring increases in slipperiness.

It is not apparent that a criteria document regarding COF can be written at this time. Attention should instead be focused on the training needs associated with specific Accident Profiles for industries shown in TABLE 4-2 to be in especially high risk of falls, e.g., painters and decorators, roofing and sheetmetal work, clothing manufacturers, clothing/department stores, restaurants, hotels/motels, hospitals.

Fall accidents are likely to be most frequent and serious when certain concentrations of circumstances occur:

- loading docks, where there is an unguarded edge, a need for high horizontal forces in pulling and throwing, and a work surface that may be wet from rain or oily from forklifts.

- doorways, where there is often a change in surface, level, and lighting, and wet carried indoors from outdoors, a threshold strip of different COF, a need to push or pull the door, a traffic funnel where conflict requires sidestepping or other evasive action.

- handling hoses, which tend to leak water or fuel, resulting in slips, and other long coiled objects, such as rope, wire, welding leads, which require pulling, typically in a backward direction, thus obscuring vision, and resulting in a tripping or misstepping hazard.

- dismounting (in a backward direction), from a ladder, vehicle, scaffold or work platform. The surface onto which the person dismounts requires a high COF and freedom from loose objects (e.g., tools, equipment), holes, depressions, oil, spills, etc., but is often not adequately looked at while dismounting.

- tipping (and/or slipping of) a ladder or platform due to high horizontal forces in reaching or overextending

beyond the base of support, standing above top 3 rungs of ladder, setting up ladder on unstable support, or transferring laterally from ladder to platform often with ladder set up on low COF (slippery) surface.

- inappropriate use of makeshift platforms, particularly chairs or other objects, e.g., carts, with wheels.

- carrying heavy or bulky objects which impose a physiological burden and obscure view of foot placement along transit route or while ascending or descending stairs.

- unexpected work surface hazards (both indoors and outdoors) while hurrying or taking short cuts to and from work station while reporting to and leaving work or during breaks.

- lack of communication, coordinated activity, or insufficient workspace while working with or near co-workers, e.g., pulling on hose wrapped around a ladder on which another employee is working.

These high risk sets of circumstances are typical of the requirements necessary for preventing work surface related accidents, where training and housekeeping activities are likely to be more generally applicable than specifications for materials.

Accident circumstances and associated countermeasures related to other types of occupational fall accidents are fully discussed in another related report.(7)

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NOTE: APPENDIX A and APPENDIX B ARE TO BE BOUND TOGETHER IN A SEPARATE VOLUME.

APPENDIX A

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APPENDIX B

ACCIDENT PROFILES

LIST OF EXHIBITS

LIST OF EXHIBITS (Continued)