ANALYSIS OF METHODS FOR CONTROLLING LOSSES FROM SLIPS, TRIPS, AND FALLS AT XYZ COMPANY

by

Mark J. Paulson

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Investigation Advisor

The Graduate School
University of Wisconsin-Stout
February, 2002

The Graduate School
University of Wisconsin-Stout
Menomonie, WI 54751

ABSTRACT

	Paulson	**Mark**	**J.**
(Writer)	**(Last Name)**	**(First)**	**(Initial)**

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Analysis of Methods for Controlling Losses from Slips, Trips, and Falls at XYZ Company

This study provided an in-depth examination of losses resulting from slips, trips, and falls at an industrial facility. Areas of analysis included a comprehensive review of XYZ Company's loss records, a review of housekeeping policies/programs, testing of floor surfaces to determine the slip resistant characteristics, as well as the testing and evaluation of footwear options to determine the effectiveness and financial feasibility of this control option. These areas were examined in order to develop the detailed understanding of the loss problem at the facility necessary for solution development and implementation.

Methods of analysis included the use of an English XL slip meter to quantitatively determine the slip resistance of three types of flooring surfaces at the facility. Evaluated surfaces were tested under both uncontaminated and contaminated conditions to determine the ability of the flooring to provide adequate traction. A quantitative method was also developed using a force gauge to evaluate the slip resistant characteristics of footwear; experimental trials were conducted on a non-slip resistant and slip resistant boot to determine which boot performed better in XYZ Company's environments. Coefficient of friction values were generated from the footwear experiments, and a comparative analysis performed to evaluate the performance of the boots. An additional element of the study was a cost/benefit analysis examining the financial impact on XYZ Company of implementing a slip resistant footwear program.

Findings of the study indicated generally adequate levels of slip resistance on two of the tested surfaces, with a smooth concrete surface exhibiting low slip resistant properties. Results of the footwear tests indicated neither type of boot performed ideally on all of the tested surfaces; variations in sole design were determined to be the cause of the performance differences. Data obtained from the footwear experiments supports the slip resistant footwear selection criteria of ANSI/ASSE 1264.2-2001.

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Chapter 1: Statement of the Problem

Introduction

Injuries occurring from slips, trips, and falls in industrial work environments are a leading cause of occupational injuries. On a national level, these types of losses account for a significantly large percentage of injuries in the workplace. For the purposes of statistical comparisons, the Bureau of Labor Statistics classifies falls in one of eight separate ways. Falls are categorized as either:

1) A fall on the same level
2) A fall to the floor, walkway, or other surface
3) A fall onto or against objects
4) A fall to lower level
5) A fall down stairs or steps
6) A fall from floor, dock, or ground level
7) A fall from a ladder
8) A fall from piled or stacked material (Bureau of Labor Statistics, 2001)

The direct cause of slipping and falling is due to the absence of adequate friction between the floor surface and the footwear of the employee, these are classified as falls to the same level and account for the majority of falls—around 60% (Canadian Centre for Occupational Health and Safety, 2001). A wide variety of environmental characteristics can influence footwear traction. These include wet or oily surfaces, spills in the work area, hazards due to weather conditions (if working outside), loose mats or rugs, and the existence of flooring surfaces in the workplace which do not have uniform traction attributes (Canadian Centre for Occupational Health and Safety,2001).

The direct financial cost to industry resulting from slips, trips, and falls are a widespread problem nationwide. To illustrate the large contribution slips, trips and falls make to financial losses in business, Liberty Mutual compiled a workplace safety index which listed the 10 leading accident drivers in the workplace for the year 1998. Taken together, these combined losses are responsible for 86% of the total losses incurred from work related injuries. These are direct worker's compensation costs. Slips, trips, and falls were listed as the second leading cause of loss in the index, accounting for 11.46%, or 4.4 billion dollars per year (Liberty Mutual, 2001). It is important to note that the figure reported in the Liberty Mutual index only reflects the direct costs of the loss driver. Hidden costs such as a negative public image, costs associated with re-training employees to substitute for injured workers, and loss of production time all play a role in making the actual costs to the business much higher.

The XYZ Company processing facility which was the focus of this research study employs approximately 350 workers in the upper Midwest region of the United States. The operations of the plant involve the packaging of a variety of food products, including puddings, gel type products, and other dairy-based powdered beverages. In terms of the departmental organization of the facility, the plant is divided into nine functional production areas. Some of the processing lines are highly automated; others require more manual forms of labor to package the finished products. Additionally, some employees perform tasks in several different areas of the plant in carrying out their jobs. For example, the housekeeping and maintenance departments are highly mobile with their work responsibilities encompassing virtually all areas of the facility. Other employees may work in only one or two areas during the course of a typical work-shift.

Environmental conditions at XYZ Company vary substantially throughout the various production areas. For example, floor surfaces in some of the processing areas are nearly constantly wet when the line is operational. This may be either due to water used to keep the area clean, or product which occasionally is spilled on the floor. Other areas accumulate a fine layer of dry powder which can be difficult to see, and can drastically alter the traction characteristics of the flooring surface. Flooring surface types at the plant differ throughout the production areas as well, ranging from smooth concrete to coated surfaces, and in some areas brick flooring.

Losses resulting from injuries sustained during slips, trips, and falls have been increasing in frequency at this facility. For example, in the company's fiscal year 2000 (XYZ Company's fiscal year runs from June to June) the total number of STF incidents was 28. Worker's compensation costs for these injuries was $4,037. Additionally, the company recorded 95 days of restricted work duty. In fiscal year 2001, the facility saw a dramatic increase in losses. The total number of incidents actually decreased, yet the severity of the injuries increased to account for a total of $78,039 in compensation payments. This year also saw the number of restricted days increase to a dramatic 185 days, with 33 days recorded as completely lost. At the time this study was conducted, XYZ Company was seven months into the fiscal 2002 year. Data from this time period was not encouraging. Only a little over halfway into their fiscal year, the facility had already recorded 11 STF incidents, accounting for $23,738 in compensation losses and 19 days of restricted work. Seven days were recorded as entirely lost.

Losses from slips, trips, and falls have demonstrated an upward trend at this facility, resulting in direct financial losses and restricted and lost work days. Without the development and effective implementation of risk control methods to control these incidents, it is probable that these injuries will continue to result in losses for XYZ Company.

Purpose of the Study

The purpose of this study was to analyze risk control methods for reducing losses resulting from slips, trips, and falls at the XYZ Company processing facility located in the upper midwestern region of the United States.

Goals of the Study

The goals of this study consist of five areas of analysis which will serve as the framework for developing a solution to this loss-producing situation. The five goals of this study are:

1) To provide an analysis of existing internal standards regarding housekeeping and employee training practices which will be conducted to determine the scope of such policies and their ability to adequately control losses resulting from slips, trips, and falls.
2) To examine the loss records of Company XYZ in order to quantify the monetary loss to the facility resulting from slips, trips and fall related injuries.
3) To conduct slip resistance measurements on uncontaminated and contaminated surfaces at the facility using an English XL Variable Incidence Tribometer.
4) To conduct tests on slip resistant and non-slip resistant footwear to determine the

coefficient of friction for the footwear in the various facility environments. Such testing will quantify the ability of slip resistant footwear to provide a solution to the frequency of slips, trips, and falls.

5) To conduct a cost/benefit analysis to determine the financial cost to XYZ Company of providing slip resistant footwear to employees.

Background and Significance

Losses resulting from injuries sustained during slips, trips, and falls have been increasing in frequency at this facility. For example, in the company's fiscal year 2000 (XYZ Company's fiscal year runs from June to June) the total number of STF incidents was 28. Worker's compensation costs for these injuries was $4,037. Additionally, the company recorded 95 days of restricted work duty. In fiscal year 2001, the facility saw a dramatic increase in losses. The total number of incidents actually decreased, yet the severity of the injuries increased to account for a total of $78,039 in compensation payments. This year also saw the number of restricted days increase to a dramatic 185 days, with 33 days recorded as completely lost. At the time this study was conducted, XYZ Company was seven months into the fiscal 2002 year. Data from this time period was not encouraging. Only a little over halfway into their fiscal year, the facility had already recorded 11 STF incidents, accounting for $23,738 in compensation losses and 19 days of restricted work. Seven days were recorded as entirely lost.

Losses from slips, trips, and falls have demonstrated an upward trend at this facility, resulting in direct financial losses and restricted and lost work days. Such losses are symptomatic of deficiencies in the current control methods in place to manage STF incidents. Without the development and effective implementation of risk control methods, it is probable that these incidents will continue to result in significant financial losses for XYZ Company.

This study was a key initial step in developing and implementing the risk control strategies necessary to reduce the occurrence of slips, trips, and falls at XYZ Company. This work will provide the analytical framework which will examine both the extent of the problem, provide a quantitative analysis of the means to control the problem, and provide the cost justification necessary for management to make a well-informed decision regarding the implementation of any recommendations resulting from this study.

Definition of Terms

Adhesion: The tendency of two surfaces in forceful contact, with or without the presence of a lubricating interface, to stick together. This tendency is related to residence time, and in general becomes greater as residence time increases (ANSI/ASSE 1264.2-2001).

Coefficient of Friction: a constant that, when multiplied by the normal force between two bodies that are in surface contact, gives the force of friction between them necessary to start sliding (Academic Press Dictionary of Science and Technology, 2001).

Contamination: any undesirable solid or liquid material that rests upon a surface, or exists between two mating surfaces (ASTM F1646-95).

Footwear: any external covering of the foot intended for ground contact during ambulation, for example, shoes, sandals, slippers, etc. (ASTM F1646-95).

Pedestrian: a person using legs or leg surrogates (for example, prosthetic limbs, crutches, etc.) as the principal mechanism for locomotion (ASTM F1646-95).

Residence Time: The period of time between initial shoe contact with the test surface and the instant that relative motion is initiated. Residence time produces stiction and adhesion. Slip meters which apply the vertical and horizontal force components simultaneously avoid sticktion on wet or contaminated surfaces and adhesion on dry surfaces (ANSI/ASSE 1264.2-2001).

Slip: an accidental misstep threatening (or causing) a fall (Ultra Lingua Dictionaries, 2001).

Slip Resistance: The tendency of two surfaces in forceful contact, with or without the presence of a lubricating interface or contaminant, to resist relative motion (ANSI/ASSE 1264.2-2001).

Sticktion: The tendency of two surfaces in forceful contact, in the presence of a lubricating interface or contaminant, to bond together if there is a period of time between initial contact and initiation of relative motion, as a result of residence time (ANSI/ASSE 1264.2-2001).

Surface Characteristics: a set of terms considered to be the minimum needed to precisely describe the condition of a surface especially regarding slip resistance (material, contamination, slope, texture, hardness, coating, temperature) (ASTM F1646-95).

Walkway Surface: a structure intended to be used by a person attempting to walk (ASTM F1646-95).

Summary

Injuries resulting from slips, trips and falls are a significant source of financial loss for industry. On a national level, these types of incidents accounted for 4.4 billion dollars in direct compensation costs for the year 1998 (Liberty Mutual, 2001). Losses from slips, trips, and falls at XYZ Company reflect the national data; the occurrence of these types of injuries has been demonstrating an upward trend.

The XYZ Company processing facility in the upper midwestern region of the United States has continued to experience losses due to the occurrence of slips, trips, and falls. In the last three years of the company's loss history, a total of $105,814 has been recorded as the direct financial cost of worker's compensation payments. The financial losses do not reflect such additional factors as lost production time or re-training of substitute employees. Due to the upward trend in losses from STF incidents, it is highly probable that without the development and effective implementation of additional risk control methods losses at this facility will continue to occur.

Chapter 2: Review of Literature

Introduction

Injuries resulting from slip, trip, and fall (STF) incidents are a major source of loss to industry, with the majority (60%) classified as falls on the same level. (Canadian Centre for Occupational Health and Safety, 2001). According to OSHA, slips trips and falls account for the majority of accidents which occur in general industry (1997). This chapter will present a review of current literature in the area of STF research to include the following topical areas: an analysis of STF trends at the national and state level; a discussion of the environmental factors which contribute to STF incidents; and a review of research findings directed at quantifying methods to minimize the occurrence of slips, trips, and falls.

National Trends

On the national level, slips trips and fall are a major area of financial loss to industry. Across the United States, injuries resulting from these types of incidents have demonstrated several dominant trend characteristics when Bureau of Labor Statistics data from a three-year period was examined (1997, 1998, and 1999). The Bureau of Labor Statistics provides a comprehensive analysis of falls by examining demographic and worker characteristics. These case characteristics include occupational environment, age of the worker, length of service with the employer, number of days away from work resulting from the injury, and the type of injury incurred from the fall. The systematic grouping of case attributes in this manner reveals several distinct trends regarding falls to the same level. It is important to note that the Bureau of Labor Statistics includes in their definition of days away from work days with or without restricted work activity—the same criteria used by OSHA in determining workplace injury/illness incidence rates. Employees on restricted work duty are counted as being away from their usual jobs, and are recorded as lost workdays. For these reasons, the BLS data is useful in identifying trends and patterns in fall injuries at the national level, as well as providing beneficial criteria for examining individual businesses. The BLS figures for total number of same level fall injuries, occupation, and age category for the years 1997-1999 demonstrate several recurring loss trends.

For example, data compiled for the year 1997 by the Bureau of Labor Statistics reported that a total of 198, 128 injuries involving days away from work were a direct result of a fall to the same level. Of these falls, 31.2% occurred to operators, fabricators and laborers. In terms of age, the BLS data reported a fairly consistent frequency distribution over the range of employees between the ages of 25-64. Interestingly, the data also demonstrated a lower percentage of injuries for younger employees between the ages of 20-24, with only 8.1% of these workers injured in a fall to the same level (Bureau of Labor Statistics, 1999). Although this figure is significantly lower than the other reported age groups, this may be due to the fact that this age group represents those of student age who may not have yet found full-time employment.

Data from 1998 showed a slight reduction in the total number of falls to the same level, with 184,682 reported in the BLS statistics for that year. The percentage of these total injuries which occurred to operators, fabricators, and laborers was 29.9%--a slight drop of 1.2% from 1997. The age distribution percentages among workers remained virtually unchanged however, with the majority of injuries again occurring to workers between the ages of 35-44 with a percentage of 25.5%. The data for younger workers between the ages of 20-24 increased only slightly to 9.2% (Bureau of Labor Statistics, 2000).

1999 BLS data showed a significant rise in the injury totals for same level falls. The total number for this year increased to 190,701 total injuries, with the age distribution remaining for the most part unchanged, with the exception of the 45-54 age group. This age category saw a decrease in fall to the same level injuries of 2.4% Although small, this value does appear to have some degree of significance given the fact that the percentage of 45-54 year old workers in the workforce actually increased slightly from 20.6 in 1998 to 21.1 in 1999 (U.S. Census Bureau, 2001). The younger employees between the ages of 20-24 saw their percentage of same level fall injuries increase marginally to 10%, an increase of .8 percentage points. This increase in falls to the same level was disproportionate to the increase in percent distribution in the work force, however. Workers in this age category only increased their percentage slightly from 9.9 to 10% of the work force between 1998 and 1999 (U.S. Census Bureau, 2001). An increase was also observed in the percentage of injuries occurring to operators, fabricators, and laborers. This value increased slightly back to the previous 1997 level of 31.2%.

From this examination of the Bureau of Labor Statistics data, it is clear the case characteristics of falls to the same level have not shown much positive change over the three-year history which was reviewed. This pattern is brought out even more distinctly when such case characteristics as length of service, total number of days away from work caused by the injury, and type of injury are analyzed. For example, the BLS data for 1997 reported injuries from falls to the same level in comparison to length of service with the employer. The 1997 data demonstrated that the highest percentage of injured workers had been with the employer for a period of 1-5 years (31.5%), with the second highest percentage being with the company for more than 5 years (28 %). This comparison also showed another interesting trend; the rate of worker's injured from falls decreased for employees with shorter lengths of service. For example, for workers with the company for less than three months the rate of injury from falls to the same level was 13%. In contrast, for employees with the company for a slightly longer time of 3 months to 11 months the rate increased to 17.8% (Bureau of Labor Statistics, 1999). For service times between 1-5 and 5 or more years the percentage increased to 31.5% and 28%, respectively. These figures seem to indicate a greater degree of caution as newly hired employees are learning their jobs—new workers seem to be far less likely to be injured by a fall to the same level. This trend appeared to be reflected at XYZ Company as well. For example, many of the employees injured in STF incidents at XYZ Company had service times between 1-5 years; some of the worst STF cases occurred to workers employed at the facility for more than 10 years (It is important to note that this comparison may be limited in application; the loss data at XYZ Company may simply reflect the lack of newer employees present at the facility).

The 1998 data remained for the most part unchanged. Employees with service times with the company of 1-5 years still showed the highest percentage of injuries due to same level falls, while workers with lower service times were less likely to be injured in a fall. In fact, in 1998 employees who had been with a company for less than 3 months had an injury percentage of 13.8%, while for employees with service times of 3 months to 11 months the rate increased to 18.9%--a greater disparity than existed in the previous year

(Bureau of Labor Statistics, 2000). Data for 1999 closely reflected the findings for 1998, with little change in the percentages in relation to length of service. One of the exceptions for 1999 was that the percentage of injury for workers with lengths of service from 3-11 months dropped by 1% (Bureau of Labor Statistics, 2001). Aside from this minor drop, length of service time in comparison to same level fall injuries did not change by a significant margin.

Days away from work as a result of a fall to the same level injury exhibited a median value of 7 days absent from the job in the 1997 figures. The data also illustrated the potential for severity as well, 22.1% of cases involving time away from work required 31 or more days off, with the second highest percentage at 20.3% for cases involving 3-5 days off. The nature of the injuries from falls to the same level focused primarily on two dominant types in the 1997 BLS data. Sprains and strains were by far the largest percentage, with 35.7% occurring in this category. Bruises and contusions were the second highest injury with 18.5 % (Bureau of Labor Statistics, 1999).

Figures from 1998 reported similar findings. The median for days away from work as a result of same level fall injuries remained unchanged at 7 days. Cases requiring 31 or more days away from work were virtually unchanged at 22.9%. The percentages for 3-5 days off were 19.4%, reflecting only a slight reduction from 1997 levels. Sprains and strains remained the largest injury type incurred in falls to the same level, with the percentage essentially unchanged from the previous year at 35.9% (Bureau of Labor Statistics, 1999).

The loss trend characteristics observed in the aforementioned analysis did not show any significant deviation in the data for 1999. Although the median number of days away from work from falls to the same level dropped to 6 days, the number of cases which required 31 or more days away from work increased to 23.2%. Similarly, cases involving 3-5 days away from work increased to 21.1%--exceeding the percentage from the 1997 data. The percentage of sprains and strains resulting from falls to the same level also increased to 36.5%, the largest number in the 1997-1998 period.

The Bureau of Labor Statistics data is clearly indicative of a significant loss driver for business and industry, and manufacturing type jobs particularly. The recurrent theme throughout the national data is that injuries occurring from falls to the same level remain a persistent source of loss to industry. The data demonstrate that injuries from same level falls hold a high degree of risk for businesses, particularly given the large percentage of cases which resulted in employees spending significant amounts of time away from their jobs. This trend of losses from falls to the same level is not only seen in data from the national level, but is also reflected in state figures—a fact that further corroborates the persistent nature of the problem.

State Trends

The state worker's compensation records in which XYZ Company is located were examined in order to determine to what extent the trends observed in the national data were evident at the state level. Slightly more current data was available, with the years 1998 through 2000 providing the three-year loss history. The format of the information obtained at the state level did not include an extensive demographic analysis as did the national data. However, the state figures did provide dollar amounts paid in lost wage compensation, as well as total number of incidents reported by causes of injury and nature of injury. As was observed with the national statistics, the data obtained at the state level revealed several notable trends in losses resulting from slips, trips, and falls.

Perhaps the most striking trend which is evident from the state data is the rapid increase in the occurrence of slip, trip and fall related injuries within the three-year period. For example, in 1998 the state recorded 1,796 incidents of slips, trips, or falls. In terms of lost wage compensation payments, these incidents accounted for $4,196,089 in direct financial costs. The next year, 1999, the number of incidents increased sharply to 2,914. Total compensation payments were a significantly higher $7,127,526. The figures for 2000 claims showed slips, trips, and falls accounting for 3,204 incidents and $10,392,967. The years 1998-2000 saw an increase in the direct financial costs associated with slip, trip, and fall incidents of $6,196,878 (Wisconsin Department of Workforce Development, 2001).

It is interesting to note that when the increase in compensation cost is compared to the state's average annual employment rate for private industry, there is a correlation with the increases observed in the compensation figures (for direct comparison purposes, only the rates from 1998 and 1999 were used—no data was available for 2000). For example, average employment for 1998 was 2,281,100 workers, compared to 2,341,600 workers in 1999—an increase of 60, 500 workers (Bureau of Labor Statistics, 2001). This increase in workers corresponds to the compensation cost increase of $2,931,437 for slip, trip, and fall injuries which was recorded for 1998-1999. It is probable that the increase in the number of employed workers, and the subsequent increase in total number of hours worked, did have some impact on the higher compensation costs for slips, trips, and falls seen in the data. More workers employed in industry resulted in a greater exposure to the contributing hazards associated with these types of incidents, with a higher risk of injury occurring.

In contrast to the employment rate data, the incidence rate for total lost workdays actually declined from 1998-1999, from 4.0 to 3.6 (Bureau of Labor Statistics, 2001). These figures demonstrate that although more workers were employed in private industry and fewer workers were sustaining injuries which resulted in lost work days, the compensation costs of injuries resulting from slips, trips, and falls continued to increase. These findings provide further indication of the persistence and severity of slips, trips, and falls in industry, and illustrate the need for effective risk control methods to reduce the likelihood of these incidents occurring.

Claims which occurred from falls to the same level also increased from 1998 to 1999, with the total number of incidents increasing from 1,886 to 1,905 cases. The associated costs of these claims increased from $17,591,656 in 1998 to $18,438,972 in 1999. The year 2000 saw a slight reduction in falls to the same level, with 1,132 cases and $12,317,426 in compensation payments (Wisconsin Department of Workforce Development, 2001). It is important to note, however, that although the number of cases declined the average cost per claim was $10,881—the highest cost per claim average when compared to the previous two years.

The state also saw an increase in the frequency of strains and sprains during 1998-2000. Although the data did not specify the event or exposure which resulted in the sprain or strain, data has shown slips and trips (without falling), and falls to the same level to be one of the leading causes of injury in cases involving strains and sprains (Webster, 1999). The state data for 1998 showed a combined total number of sprains and strains injuries of 23,506 cases, which accounted for $79,861,149 in compensation payments. Figures for 1999 showed an increase in the number of these types of injuries to 29,302 resulting in $103,950,000 in direct costs. The 2000 data demonstrated only a slight downward trend, with 26,673 in total sprain/strain injuries and $101,510,000 in compensation payments (Wisconsin Department of Workforce Development, 2001).

The trends and patterns in cases involving slips, trips, and falls provide convincing evidence of the pervasiveness of the problem. At the national level, little change was observed in the data from 1997-1999. The percentage of incidences involving same level falls among operators, fabricators, and laborers remained virtually unchanged at around 30%. The percent distribution by age and length of service remained relatively constant as well, while the total number of falls to the same level increased in frequency in 1999. Likewise, compensation claim data at the state level has demonstrated a dramatic upward trend as well, particularly in an increased average cost per claim. The loss trend data, both at the national and state level, demonstrate the importance of developing and implementing risk control strategies designed to reduce the occurrence of slips, trips, and falls.

Causes of Slips, Trips, and Falls

Identifying risk factors which contribute to the occurrence of slips, trip, and falls can be a complex task. Numerous factors must be taken into consideration, including environmental conditions at the facility, housekeeping practices, flooring, footwear, and employee training (Canadian Centre for Occupational Health and Safety, 1999). In order to effectively identify and implement solutions to slip, trip, and fall incidents, it is imperative to recognize that these events represent abnormalities in the work environment (Feldman, 1998). By recognizing these incidents as "abnormalities", control can be achieved by designing and implementing an effective management system structured to deal with these causes (Germaine, Arnold, Rowan, Roane, 1998). This section will provide a detailed examination of these environmental causes, with the goal of developing an understanding of the risk factors which allow slips, trips, and falls to occur. The following section will elaborate on current research directed at controlling these environmental risk factors.

Environmental conditions. Numerous environmental conditions in industrial facilities can contribute to slips, trips, and falls. Jonathan Bell (1995), in advocating a re-design of the worker's environment using ergonomic based principles (i.e., change the environment to fit the worker), has delineated several key areas which should be considered to minimize the risk of slips, trips, and falls. These include wetness found in near proximity to doors and loading areas, condensation from storage tanks used in industrial processes, and fluids from vehicles and machinery. Bell also described the importance of recognizing cleaning fluids and spilled product from manufacturing operations as significant contributors to STF incidents (Bell, 1995). The accumulation of dust, dirt, and other types of debris from the facility's process can also add to the risk of injuries to employees (Di Pilla, 2001). Other common sources of environmental contaminants include chemicals, acids, oils, food byproducts, water, and residual cleaning agents (Feldman, 1998). External factors can play a role as well, particularly in winter conditions (Bell, 1995). Although these hazards are applicable to most general industry environments, food-processing industries often must address additional risk factors which result from their individual products.

Process hazards. Addressing the unique hazards of the poultry processing industry, OSHA has outlined in an advisory document designed for the poultry processing industry several critical areas which contribute to the occurrence of falls. In a 1997 study of the poultry industry (which involved OSHA visits of 51 randomly selected facilities) reviewed in the OSHA document, slips trips, and falls were one of the leading causes of injuries; these events resulted primarily in sprains, strains, and back injuries to workers (OSHA, 1997). Of falls to the same level, potential causes included floors, platforms, and stairways which may contain grease, water or blood, boxes and other items which may be placed in aisles and walkways, and uneven floors and holes used for drainage purposes (OSHA, 1997). Additionally, some of the causes of falls to a lower level may include missing railings along stairways and lack of guarding and toe boards on elevated work areas (OSHA, 1997). Although XYZ Company is not a poultry processing facility, some of the processes used are analogous in terms of a wet environment in many areas of the plant, and the high frequency of food-based products coating walking surfaces.

Contaminant characteristics. The effect of different substances coming into contact with flooring surfaces can significantly alter the slip resistant properties of the work environment. In a study of 27 industries, 20 of which were in the food industry sector, Leclercq, Tisserand, and Saulnier (1994) evaluated slip resistance as a function of several variables. One such variable investigated in the study was the influence of the viscosity of different substances in determining the coefficient of friction in a given environment. The authors tested several pollutants of varying viscosities, including oil (most viscous), greasy water, and uncontaminated water (least viscous) on different flooring surface types. Conclusions of the study determined that the viscosity of the pollutant was a common element in environments identified with low coefficients of friction. The more viscous the material, the greater the likelihood of slipping. Additional findings of the study were that the presence of uncontaminated water alone did not appear to create an area of low slip resistance, due primarily to its' low viscosity (Leclercq, Tisserand, and Saulnier, 1994). These findings confirmed the results of an earlier study which found evidence that heavier oil, such as those used in machinery, lowers the coefficient of friction more than lighter oils (Manning, Jones, 1993). The influence of different types of floor surfaces was also a significant variable influencing the coefficient of friction values.

Floor coatings. Another contributing factor which has been shown to lower the slip resistant properties of facilities is the application of floor polish, which creates an enhanced risk of slipping when water is present on the surface. This was one of the findings of a study which examined 20 different types of shoe soles and found that on polished floors with water coating the surface, the mean coefficient of friction decreased by 15-20% (Manning, Jones, 2001). On polished floors, the addition of other contaminants such as powders, snow, and chemical components can also contribute to the risk of slips (Feldman, 1998). In areas of the country which experience winter conditions, snow and ice may be tracked in by personnel, accumulating around doors (Corbin, 2000). Although floors with a high degree of polish are not typically present in the working areas of industrial environments, these surfaces may be present on site in entrance ways and reception areas—illustrating the need for comprehensive analysis of all areas of the facility when analyzing slip, trip, and fall incidents.

Housekeeping programs. The lack of an effective housekeeping policy at the facility, or the lack of consistent application of the policy, is another variable determining the risk of slip, trip, and fall accidents. OSHA has identified several general requirements for a housekeeping policy which businesses often fail to address. These housekeeping failures include failing to maintain a clean and sanitary condition in all areas of the facility, failing to provide a dry work area or not installing proper drainage and/or mats for wet processes, and not keeping aisles and passageways free from obstructions (OSHA, 1997). Many businesses also fail to design their floor and machinery layouts to adequately accommodate cleaning procedures (i.e., cleaning machines) or do not use the appropriate cleaning products for their flooring surfaces (Leclercq, Tisserand, and Saulnier, 1994). The improper mixing of cleaning chemicals can also result in a more concentrated mixture which degrades any slip resistant properties of the flooring surface (Sotter, 1995).

Additional causes. Other characteristics of the facility which can increase the likelihood of tripping in particular include such conditions as poor or inadequate lighting, uneven working surfaces, general clutter, and cords in the work area (Canadian Centre for Occupational Safety, 1999). In regards to slips, the probability of this type of accident is greatly increased by the presence of work zones which have different traction characteristics that "surprise" the worker traveling between them—resulting in a slip incident (Leclercq, Tisserand, Saulnier 1994). This unexpected loss of balance by the employee results in an immediate reaction in an attempt to stay upright, and is the most dangerous type of slipping situation (Leclercq, 1999). Poorly designed flooring in the facility which is ill-suited to the processes, as well as employees wearing footwear inappropriate for the work environment are other potential causes of slips, trips, and falls which will be discussed further in the following section on control methods.

Control Methods to Reduce Slips, Trips, and Falls

There has been a substantial amount of research directed at quantifying methods of controlling the work environment in such a way as to reduce the occurrence of slips, trips, and falls. Detailed studies have examined the effects of various types of flooring surfaces on slips and falls, including smooth resin based surfaces and more porous surfaces such as concrete. Other research has focused on the testing and evaluation of slip resistant footwear for employees, with the purpose of determining the best type of shoe/soling material for the environment. The following sections will provide an examination of the current literature regarding flooring surfaces/footwear, cleaning methods and procedures to increase traction, and the elements of effective housekeeping programs and employee training. Lastly, common quantitative methods of determining slip resistance will be reviewed to provide an overview of the advantages and limitations of the current instrumentation.

Flooring surfaces/ footwear. Research into the effect of flooring surfaces, and the inter- relationship between the floor, the contaminant, and the footwear, has provided a more detailed understanding of the variables which influence slips, trips, and falls. In a pioneering study in slip resistance research, Manning, Jones, and Bruce (1983) conducted a case study of footwear and slip resistance at a Ford Motor Company Transmission Plant with the purpose of finding the most effective footwear for this environment. The study evaluated several boots with different sole materials, including PVC, Nitrile rubber, Polyurethane, and footwear normally obtained by the employees. Using a testing method which measured slip resistance as a function of the angle of the foot, the authors conducted over 1000 measurements over a period of three years. Variables tested during the study were the effect of cleaning on the footwear, the effect of body weight, tread pattern of the boots, and velocity when a slip did occur. The effect of cleaning the boots prior to testing resulted in inconsistent results, it was determined that this was not a contributing factor in the test results. Further conclusions were that body weight and tread pattern were not determinant factors in slip resistance, but rather the extent of wear the boot exhibited. In the case of the Nitrile boots, the wet and oily environments were observed to have a polishing effect which diminished the slip resistant properties. The PVC footwear also tested poorly in these environments, presumably due to the hardness of the material. The study concluded that the use of footwear manufactured from cellular polyurethane performed the best under wet or oily conditions, and showed a high degree of durability (Manning, Jones, Bruce, 1983). This early study by Manning et al. focused largely on variables concerned with the footwear, other studies have investigated the effect of the flooring surface and type of contaminant.

Leclerq et al. (1994) conducted a study of 27 industrial facilities using a Portable Friction Tester with the objective of analyzing the differences in slip resistance due to flooring materials and the type of contaminant present on the surface. Findings of the study determined that floors with smooth surfaces, or only slightly rough surfaces, had their slip resistance drop sharply when a viscous pollutant such as oil was on the surface; the authors concluded that this was due to the viscosity level, more viscous materials are slower to drain away from the measuring device. Lastly, the authors found that cleaning the floor surface did not always increase its' slip resistant properties. Some surfaces, such as concrete, actually exhibited a decrease in the coefficient of friction. Comparative measurements were made before and after cleaning of several surface types and provided evidence that the permeability of the surface, viscosity of the pollutant, and efficiency of the cleaning process all determine slip resistance following cleaning (Leclercq, Tisserand, Saulnier 1994). Options a business may choose from to control slips due to poor flooring surfaces include the use of slip resistant coatings, the use of mats, abrasive strips, and abrasive painted on coatings (Bell, 1997).

The findings of Kim and Smith (2000) provided further evidence of the importance of the flooring surface in determining slip resistance, and further analysis of what variables cause a decrease in the coefficient of friction. Using a dynamic friction tester for measuring slip resistance and a laser scanning confocal microscope, the authors evaluated two different types of flooring (metal and perspex) of varying degrees of roughness before and after conducting friction tests with three work boots with soles made out of Nitrile rubber, PVC, and Polyurethane. Among the tested boots, the Nitrile material demonstrated less change in both flooring tests, only showing a 5% reduction in slip resistance in the Perspex flooring tests. Decreased height of the floor features (asperities) which occurred following the shoe tests provided evidence of significant topographic changes in the surface due to the transfer of material from the boot to the floor. The findings of this study illustrate the importance, when protective footwear is necessary, of understanding the type of flooring surface at the facility, choosing the appropriate boot material for the surface, and monitoring for wear of the boot sole.

In a follow up study, Kim, Smith, and Nagata (2001) examined in detail the mechanics of wear which occurred to the surfaces of work boots made out of the same three materials used in the previous study: Nitrile rubber, PVC, and Polyurethane. Using a Perspex flooring surface, each boot was rubbed 30 times on the surface and the topographic changes recorded by an electron microscope. In the case of the Nitrile and Polyurethane boots a reduction in slip resistance was observed, while the PVC boot's slip resistance improved slightly due to the way in which the surface of the PVC material was modified by the floor surface. The authors identified three distinct wear mechanisms which caused the deterioration of the boots' slip resistance: Abrasive wear, which involved the removal of polymer materials from the boot; ploughing, which created deep furrows and bulges on the sole surface; and fatigue wear, in which the boot sole exhibited cracks in the surface. Conclusions of the study were that mechanisms of wear are a substantial variable in determining the slip resistant properties of footwear, highlighting again the need for monitoring of wear in areas where protective footwear is used (Kim et. al., 2001).

In developing their walking traction test method for measuring slip resistance, Manning, Jones, and Bruce (1989) had concluded that coefficient of friction measurements should be related both to the roughness of the surface, as well as the amount of abrasion on the footwear in order to accurately assess slips and falls. In their later study of the surface roughness of a micro cellular polyurethane soling material and the corresponding effect on the coefficient of friction, Manning, Jones, Rowland, and Roff (1998) evaluated these variables and did determine that the surface roughness of the floor was indeed an influential factor in determining slip resistance. However, the authors concluded that the surface characteristics of the shoe sole played a much greater role than previously thought in determining slip resistance than the floor roughness. Data collected in the study demonstrated a high degree of statistical significance, yet general applicability to other environments and footwear was not possible due to the fact that the Manning et al. study only tested one type of sole material (Manning, et. al., 1998).

In a subsequent study, however, Manning and Jones (2000) evaluated the effect of soling roughness on the slip resistant characteristics of 20 different types of manufactured boot soles manufactured with a variety of commercially available materials. The coefficient of friction was evaluated on 19 different floor surface types contaminated with water, and four floor surfaces contaminated with oil. The soles of the footwear were tested when new, following abrasion by a belt sander, and after polishing to remove as much roughness as possible. Findings of the study were that the micro cellular polyurethane soling material was more slip resistant than the other materials in wet or oily conditions, and that the performance of all shoes was enhanced by the abrasion procedures. Manning et al. generalized this finding to caution that the use of harder soling materials such as dual density polyurethane, which do not wear as easily to form an abraded surface, do not provide a high enough level of protection against slips and falls (Manning, Jones, 2000). The conclusion that the micro cellular polyurethane provided better slip resistance mirrored findings of an earlier study conducted by Manning and Jones (1994). Although the use of slip resistant footwear has demonstrated effectiveness at reducing slips, it is not the only control method available. The use of specialized cleaning procedures and floor coatings is also an option for facilities with high losses resulting from slips and falls.

Cleaning methods/procedures to increase traction. Methods and procedures for enhancing the slip resistant properties of flooring surfaces involve essentially three types of techniques. These methods include the use of specialized cleaning chemicals, the application of floor coatings, and the use of chemical treatments which modify the flooring surface. Although these are all options for facilities experiencing losses from slips and falls, the most effective method will vary with the facility and the type of contaminants generally present in the workplace.

Research has shown that contaminants present on floors almost immediately reduce the slip resistance of that surface (Cleaning & Maintenance Management Online, 2001). The use of appropriate cleaning chemicals can be a key element to improving slip resistance. For example, the use of some detergent solutions can leave a residue on surfaces which builds up over time, contributing to reduced slip resistance. This problem can be avoided through the use of pH neutral cleaning solutions which remove contaminants without affecting the flooring surface—oil based contaminants common in the food industry should be removed using a water based degreaser to provide thorough cleaning (Preuss, 2001). The method used to apply the solution can also make a difference in the effectiveness of the cleaning. For example, the use of a deck brush instead of a mop provides more agitation at the floor surface—a condition which allows for more thorough removal of contaminants (Di Pilla, 2001).

The use of floor coatings can also be a means of improving slip resistance. Using this method of improving slip resistance, a coating containing abrasive components is applied directly to the surface to improve traction. This may include the use of abrasive paints or epoxy-type coatings containing aluminum oxide particles; the grit size will vary with the environment, with larger sizes generally used for industrial applications (Preuss, 2001). One significant limitation of these types of coatings is that due to the roughness of the surface they can be more difficult to clean well, requiring that the facility pay more attention to cleaning procedures to maintain them (Preuss, 2001).

For facilities with mineral containing floor surfaces (marble, granite, terrazzo, ceramic, quarry tile) the application of a chemical which modifies the surface is another control option. These types of products create microscopic pores in the surface which provides low areas for contaminants to drain away from the peaks, resulting in better traction (Cleaning & Maintenance Management Online, 2001). Some companies also offer non-chemical based surface modifications using a mechanical floor-scoring process, which involves cutting groove patterns into the floor surface to provide drainage for contaminants (Diamond Safety Concepts). Another product claims to improve slip resistance by applying a chemical which reacts with the silica in many flooring surfaces to create microscopic "suction cups" which enhance traction (Aegis Floorsystems Inc., 2001). Di Pilla (2001) warned that although numerous manufacturers provide products that claim to improve slip resistance, substantial differences in actual performance have been observed. Facilities should obtain patch samples and test them in their unique environments to determine their effectiveness prior to installation (Di Pilla, 2001). Cleaning methods and procedures to improve traction can be highly effective at increasing the slip resistant characteristics of the workplace, but they are only one component of an effective control program. A well-designed housekeeping program is also a key element in preventing slips and falls.

Housekeeping programs/policy. The Occupational Safety and Health Administration, under the general requirements for walking/working surfaces, has delineated the basic expectations for employers regarding housekeeping policy. This regulation states at 29 CFR 1910.22 (a) (1) that:

> "All places of employment, passageways, storerooms, and service rooms shall be kept clean and orderly and in a sanitary condition".

And in the following section (a) (2) that:

> "The floor of every workroom shall be maintained in a clean and, so far as possible, a dry condition. Where wet processes are used, drainage shall be maintained, and false floors, platforms, mats, or other dry standing places should be provided where practicable".

It should be noted that although the OSHA standard does address some specific walking/working surfaces such as ladders and scaffolding, for the most part the requirements are performance based: employers have substantial freedom to design programs to suit the environments in their respective facilities. The implementation of an effective housekeeping policy represents the first option for a company, this is the least expensive method of controlling the causes of slips, trips, and falls (Bell, 1997).

Independent standards organizations have also developed guidelines for maintaining slip resistant areas. For example, the American Society for Testing and Materials has issued guidelines which address walking surfaces in relation to the design and construction of new and existing buildings. Some of the specific criteria of this standard include changes in surface level in transition zones, the use of carpeting, the use of mats and runners, proper illumination, and guidelines concerning the design of stairs (ASTM F1637-95). Although the ASTM standard does establish criteria for safe walking surfaces, it does not specifically address issues unique to industrial environments—working surfaces are disregarded in the standard. Although the ASTM guidelines provide more detail on walking surfaces than the OSHA position on housekeeping, there is a definite lack of specificity which does not allow the ASTM standard to be used as a comprehensive standard for industrial settings with a variety of processes.

Addressing the limitations of earlier standards, ANSI (2001) has issued guidelines that are intended to be applied to industrial and workplace situations. This standard recommends the use of slip resistant footwear, the development of written housekeeping programs, and the selection of surface treatments to enhance the traction characteristics of problem surfaces. A significant component of this standard is that it establishes a slip resistance guideline of .50 for walking surfaces in the workplace, although the standard does not set guidelines for the slip resistance of wet surfaces (ANSI/ASSE 1264.2-2001).

The National Safety Council has also outlined the basic elements of an effective housekeeping program which industrial facilities should implement as a hazard control measure. The NSC (1992) has taken the position that housekeeping is a continual improvement process that must be integrated with all operations of the facility in order to be effective. This includes such practices as color coding tools to make sure they are put in their proper place, maintaining clear aisles by reducing scrap and minimizing spillage, and removing water, oil and grease from floor surfaces promptly (NSC, 1992). Advantages of a well-designed and integrated housekeeping program include improved work efficiency, improvements in morale, and a reduction in the risk of employees injuring themselves from slips, trips, and falls (NSC, 1992). The guidelines of the National Security Council, while providing more detail on implementing housekeeping programs in industrial environments, still remain somewhat broad in scope.

The International Loss Control Institute has also taken a position regarding housekeeping in the workplace, although the ILCI recommendations provide additional guidance lacking in other organizations' standards. For example, Bird and Germain (1986) recommended the use of housekeeping inspections as a means of controlling the facility housekeeping practices. The authors stated that the use of housekeeping inspection forms which provide a quantitative score in specific facility areas may be beneficial in providing performance feedback on the effectiveness of housekeeping efforts. This use of inspection forms as a means of providing performance feedback may be one method of establishing a mechanism for continual improvement in housekeeping, as envisioned by the National Security Council position. The use of inspections as a monitoring and feedback tool is also cited by the International Risk Management Institute as essential to encouraging improvement in housekeeping practices (Germaine, Arnold, Rowan, Roane, 1998).

The Canadian Centre for Occupational Health & Safety has outlined specific criteria for designing an effective company housekeeping policy (1997). Principle components of a good program should include clean up procedures during the shift, daily cleaning, proper waste disposal, removing unneeded materials from the work area, and the use of inspections to monitor the effectiveness of the program. Additionally, a well designed program should integrate housekeeping procedures in all of the following areas:

1) Employee facilities
2) Surfaces
3) Maintenance of light fixtures
4) Maintain adequate clearance in aisles and stairways
5) Control spills
6) Maintain good housekeeping of tools

7) Maintain plant buildings and equipment
8) Dispose of waste promptly
9) Organize storage areas (Canadian Centre for Occupational Health & Safety, 1998).

Developing, implementing, and monitoring a housekeeping program which contains these elements will provide a large degree of control over the occurrence of slips, trips, and falls at facilities. It is also important not to neglect the fact that preventing areas from becoming dirty in the first place is the most effective solution. In the concluding statements of their research study on the slip resistance of soiled surfaces in industrial environments, Leclercq et al. (1994) mentioned the case of a workshop which developed a more efficient operation process for its' milling machine. The modified operation resulted in less particulate debris, therefore succeeding in engineering out the danger of slipping on the metal filings. This remains first and foremost the preferable solution to housekeeping problems, yet is not always possible in all operations. Some industries may use processes which require areas to be nearly always contaminated (such as wet processes), with daily housekeeping activities not an effective option (Bell, 1997). In such cases, the use of personal protective equipment such as slip resistant footwear may be a necessary control measure. If the use of PPE is required to provide adequate control of slips and falls, well-designed employee training programs are essential for effective implementation.

Employee training. Training programs essentially fall into two categories; training which focuses on the recognition of STF hazards and basic housekeeping practices, and the training of employees in the use of any personal protective equipment which is deemed necessary for the job. Areas of the facility which may require the use of PPE such as slip resistant footwear should be identified by conducting a hazard assessment of the workplace to determine the potential risk of an STF accident (Cravens, 1998). Employee training should include specific instruction in how to work safely with the materials in the workplace, as well as how to identify STF hazards in the facility (Canadian Centre for Occupational Health & Safety, 1997). The training of employees in the hazards pertinent to their environments, and the protective measures they must comply with to ensure adequate protection, is an important initial step in addressing losses from slips, trips, and falls (Johnson, 1997).

If a hazard assessment of the facility determines that the use of slip resistant footwear is a necessary means of controlling the risk of STF incidents, employee training is essential for effective implementation. In order to be effective, employee training programs on the use of slip resistant footwear to protect against slips, trips, and falls need to contain several key elements. Areas of training regarding the use of slip resistant protective footwear should include the following:

1. A detailed explanation of the workplace characteristics which present the danger of an STF occurring.
2. An explanation of the need for protective footwear based on the conditions in the area where the tasks are performed.
3. When the protective footwear is required.
4. An explanation of the proper use and limitations of the footwear.
5. The company policy on obtaining footwear.

6. The maintenance and care of the footwear, as well as the expected longevity of the footwear under workplace conditions. (Johnson, 1997).

When the use of protective footwear is necessary to guard against the risk of slips in the workplace, training must be an integral part of the solution. Programs which include these components will ensure that training of employees is comprehensive, and that the longevity of the footwear is adequately monitored. In addition to monitoring the condition of employee footwear, specialized instruments are available which allow for the direct measurement of the flooring surface—a method which can be invaluable in assessing the slip hazard present at a facility, and for providing feedback on the effectiveness of cleaning methods.

Quantitative methods for measuring slip resistance. Many instruments exist for the measurement of slip resistance. Although there is currently much debate over the application and methodology of the various instruments, this section will provide a brief overview of some of the principal devices used in researching slips and falls. Six common types of instruments used to measure the slip-resistant characteristics of flooring surfaces are listed below:

1) Horizontal Drag Slip Meter
2) Horizontal Dynamome Pull Meter
3) Force Gauge Method (B. Finder, personal communication, November 2001)
4) James Machine
5) Portable Inclinable Articulated Strut Testers
6) English XL Variable Incidence Tribometer

The Horizontal Drag Slip Meter measures the force required to pull an object across the surface being evaluated. According to ASTM protocol, this method is suited for measurements conducted on wet surfaces (Miller, 1999). The use of drag sled type devices has come under criticism, however, for their inability to manipulate the contaminant film in the same manner as the human foot does—principally due to the fact that drag sleds lay flat on the flooring surface while taking measurements (Vidal, 2000). Additional limitations of drag sled devices include the effect of residence time, in which the surface of the instrument rests on the contaminant for a time prior to taking readings. This phenomenon (known as "sticktion") may lead to inaccuracies in determining slip resistance; measurements may be unrealistically high on slippery surfaces (Vidal, 2000). Other limitations include inconsistent results in applying the horizontal force; the Horizontal Pull Slip Meter attempts to address this issue of consistency by using a motorized device to apply the force (Miller, 1999).

The Horizontal Dynamome Pull Meter is a variation of the drag sled discussed above. The essential difference is that the Dynamome Pull Meter uses a 50-pound weight and a calibrated Neoprene surface to determine the coefficient of friction by dividing the horizontal force required to move the object by the vertical 50-pound weight (Miller, 1999). Critics of this type of instrument claim that significant variations in measurements occur due to the fact that the machine is pulled by hand. ASTM precision measurements have determined the standard deviation on wet surfaces to be .05 (Miller, 1999). The primary limitation of the Horizontal Dynamome Pull Meter is the same as for all drag sled type devices: the orientation of the device flat on the floor surface does not accurately reflect the manner in which a person's foot strikes the floor prior to slipping.

It should also be noted that the drag sled devices discussed above do not measure the slip resistant properties of footwear, but rather the characteristics of the floor surface. These methods are therefore limited in their ability to provide performance data on different types of footwear in various conditions.

A test method which is able to quantify the slip resistant properties of footwear directly, through the use of a force gauge, has demonstrated the ability to produce applicable results in industrial environments (B. Finder, personal communication, November 2001). This method is a modification of the drag sled models mentioned previously. In order to take measurements, a force gauge is attached to the toe area of the footwear to be evaluated. A weight is placed in the shoe. The force gauge is then pulled until the footwear begins to slip on the floor surface; the force (in lbs.) required to move the footwear is then read directly from the instrument and recorded. As with the other drag sled methods, some limitations of the force gauge method involve the effects of sticktion and consistency in the amount of pulling force which is applied to the instrument.

Although these are legitimate criticisms of this test method, it should be noted that no method currently in use provides an absolute reference for determining slip resistance. Meaningful results can be achieved by comparing test data from the same instrument, and providing for isolation of variables in the experimental design (Miller, 1999). In this sense, the limitations associated with the various devices are to some degree unimportant so long as comparisons involve measurements from the same device. Although this does not allow for generalization to be made with broad applicability, it does allow for evaluations to be conducted on a case-study basis with some validity. Instruments which have attempted to more closely replicate the motions of the human foot during a slip incident include the James Machine and Portable Inclinable Articulated Strut Testers. Both of these devices have sought to overcome some of the limitations of drag sled methods.

The James Machine is a laboratory-based method which uses a mechanical arm pressing on a test pad to determine the coefficient of friction. Aside from this machine's applicability problems for field studies, it also has difficulty measuring slip resistance on wet surfaces (Miller, 1999). Portable Inclinable Articulated Strut Testers are similar to the James Machine in design, with a movable arm pressing against a test pad (Miller, 1999). Articulated Strut Testers also attempt to replicate the actual walking motions of the human foot, and measure the relationship between the angle, the applied force, and the surface (Vidal, 2000). In contrast to the James Machine, articulated strut testers have been determined by ASTM to be applicable to wet environments (Miller, 1999). Although effective at determining the COF of flooring surfaces, Articulated Strut Testers can be difficult for non-professional users to implement due to the fact that it is not a direct reading instrument (Miller, 1999). This limitation of Articulated Strut Testers was addressed with the development of the English XL.

As with the James Machine and the Portable Inclinable Articulated Strut Tester, the English XL Variable Incidence Tribometer is designed to simulate the striking motion of a person's foot as they place it on a flooring surface by applying both vertical and horizontal force simultaneously. A piston operated by compressed air is activated, causing a special sensor material to strike the floor. The angle at which the piston strikes the floor is gradually increased until the device records a slip. At this point, the slip index value is read directly from the protractor scale on the instrument. The scale ranges from 0 to 1.0, with a slip index value of .5 to be considered a fairly adequate traction reading and 1.0 representing the highest degree of traction (English, 2001). A significant advantage of the English XL as a measurement device is the fact that because the sensor material does not rest on the flooring surface prior to the test, there is no influence of sticktion on the results. The English XL also has an ASTM standard for its use which has determined it to be suitable for measuring the slip resistance of wet surfaces (ASTM F1679-96).

Summary

Slips, trips, and falls are a significant source of loss for businesses. At the national level, data from the Bureau of Labor Statistics highlights the persistent nature of the problem. Figures from the three-year period reviewed demonstrated little significant change. The persistent nature of accidents caused by slips, trips, and falls was brought out in the analysis of the data at the state level as well, with the total number of slips, trips, and falls falling slightly but the average cost per claim increasing. The increase in the direct financial costs of slips and falls at the state level between 1998-2000 was $6,196,878, a figure which underscores the importance of controlling slips, trips, and falls in the workplace.

Conditions in industrial environments vary considerably, yet some environmental causes have been identified as risk factors which contribute to the occurrence of slips, trips, and falls. Some of these causes include the use of wet processes in plant operations, the contamination of the flooring surface by various pollutants such as grease, oil, and powders, and variations in flooring surface type. Other causes involve the lack of an adequate internal company policy regarding housekeeping. Failure to design the facility layout to accommodate thorough cleaning in all areas can also be a problem, as well as the prevalence of transition zones in the facility with different slip resistant characteristics—workers moving from one area to another may be more likely to slip and fall when encountering a more slippery zone unexpectedly.

Methods of controlling slips, trips, and falls can involve a variety of approaches. Solutions can include the development of an effective housekeeping program, the use of specialized flooring surfaces/floor treatments, or the use of slip resistant footwear by employees in areas with a high risk of slipping. Research studies involving the evaluation of footwear in relationship to environmental characteristics of the workplace have illustrated the importance of choosing the proper protection for the area, and closely monitoring the effects of surface wear on the boots—a variable which has been closely linked to the risk of slipping. If it is determined that slip resistant footwear is a viable solution, the design of a training program to instruct workers in such topics as use and maintenance is essential for successful implementation and monitoring of the program.

Chapter 3: Methodology

Goals of the Study

The goals of this study were designed to provide a detailed analysis of losses resulting from slips, trips, and falls at XYZ Company and to quantify the implementation of slip resistant footwear as a risk control method. Prior to the testing of the footwear, slip resistance readings were taken for both uncontaminated and contaminated flooring surfaces to quantify the degree of risk present. The objective of these analyses was to provide the comprehensive understanding of the loss-producing situation necessary for solution development. The goals of the study consisted of the following five areas:

1) To provide an analysis of existing internal standards regarding housekeeping and employee training practices which will be conducted to determine the scope of such policies and their ability to adequately control losses resulting from slips, trips, and falls.
2) To examine the loss records of XYZ Company in order to quantify the monetary loss to the facility resulting from slips, trips and fall related injuries.
3) To conduct slip resistance measurements on uncontaminated and contaminated surfaces at the facility using an English XL Variable Incidence Tribometer.
4) To conduct tests on both slip resistant and non-slip resistant footwear to determine the coefficient of friction for the footwear in the various facility environments. Such testing will quantify the ability of slip resistant footwear to provide a solution to the frequency of slips, trips, and falls.

5) To conduct a cost/benefit analysis to determine the financial cost to XYZ Company of providing slip resistant footwear to employees.

A detailed description of the procedures used to achieve each of these goals is provided in the following sections.

Internal Housekeeping Program/Policy Analysis

To assess the effectiveness of XYZ Company's internal housekeeping policy, the program was evaluated in terms of written policies/procedures and employee training focused on slips, trips, and falls. The program/policy analysis was conducted by obtaining copies of the corporate and facility policies on housekeeping, and evaluating the content of the documents. The employee training program materials were evaluated in a similar manner, by obtaining copies of the materials and examining their content. It was not possible at the time this study was conducted to evaluate the facility's conformance to the internal standards, as the facility was in a non-operational period until product demand increased. Therefore, the housekeeping analysis was confined to the following elements:

1) Content and scope of corporate policy regarding housekeeping
2) Content and scope of facility policy concerning housekeeping practices/procedures
3) Content and scope of employee training on slips, trips, and falls in the workplace

Loss Records Analysis

Loss data was obtained from XYZ Company for the previous two complete years, and data from the first 7 months of the company's 2002 fiscal year. Loss data included the following information:

1) Date of the injury
2) Department in which the injury occurred
3) Whether the injury was an incident or recordable
4) The worker's compensation cost of the claim
5) Number of restricted days
6) Number of lost days
7) Slip, trip, and fall injuries as a percentage of total incurred compensation cost

The criteria detailed above was entered into a Microsoft Excel spreadsheet and analyzed to identify loss trends. To accomplish this, the data was organized by functional department, with separate totals for each area of the facility in the six categories. Grand totals for the fiscal year were also tabulated. Using this format, it was possible to develop a loss profile of slips, trips, and falls at this facility in order to ascertain the severity of the problem. Additionally, the spreadsheet analysis provided for identification of high loss areas within the facility, as well as providing the financial data (in terms of worker's compensation dollars) to perform a cost/benefit analysis for proposed solutions.

Slip Resistance Testing

Tests to evaluate the slip resistant properties of the floor surfaces at XYZ Company were conducted using an English XL Variable Incidence Tribometer. The English XL was selected for slip-resistance measurements due to its ability to obtain accurate results in either wet or dry conditions. This type of device is designed to simulate the striking motion of a person's foot as they place it on a flooring surface. A piston operated by compressed air is activated, causing a special sensor "foot" to strike the floor. The angle of the piston striking the floor is gradually increased until the device records a slip. At this point, the slip index value is read directly from the device. The scale ranges from 0 to 1.0 with a slip index value of .5 to be considered a fairly adequate traction reading, and 1.0 representing the highest degree of traction (English, 2001). In designing the experimental protocol ASTM F1679-96 was used as the standard method for taking measurements with the English XL on wet or dry surfaces. This standard delineates the preparation of the test sensor material, the preparation of the test surface, operating pressure, and the operational procedure for taking measurements with the English XL.

Slip Resistance Test Method: English XL Variable Incidence Tribometer.

1) Select an area of uncontaminated flooring.
2) Measure slip resistance using English XL Tribometer.
3) Increase angle of incidence until a slip occurs; record the highest slip index value which did not allow a slip to occur.
4) Repeat step 3 at each of the four compass orientations to ensure a representative sample, average the results.
5) Contaminate floor area with substance common to the work area.
6) Repeat steps 3 and 4.

Footwear Testing

Footwear tests were conducted to determine the coefficient of friction for non-slip resistant footwear and slip resistant footwear to determine their effectiveness in XYZ Company's environments. Two different types of work boots were used for the testing. Floor surfaces evaluated in this portion of the study were identified based on the spreadsheet analysis which identified high areas of loss by department. The methodology used to test the footwear employed the force gauge method for evaluating footwear. This test method was designed to measure the point at which the footwear began to slip on the floor surface as an indication of the ability of the footwear to resist slipping. The horizontal force recorded by the force gauge was then divided by the vertical force between the surfaces (i.e., the weight of the boot) to establish a coefficient of friction (COF) measurement. This type of test has demonstrated the ability to provide applicable results in industrial environments (B. Finder, personal communication, November 2001) The experimental protocol used for the testing of the footwear is detailed below:

Footwear Testing Method: Force Gauge.

1) Select a clean 3' x 3' floor area to conduct the test and mark area with tape. Divide floor area into 2 separate areas with tape. Two individual sections were used to test the footwear. Footwear was tested in each section under uncontaminated and contaminated conditions to provide a representative sample (six measurements in each section). Force measurements from each section were averaged and the results compared to determine the repeatability of the test method.
2) Clean footwear to be tested with a mild cleaning solution to remove any

debris. Dry thoroughly. Prior to testing, all footwear will either be worn or sanded with 150 grit sandpaper in order to remove the silicone mould release agent which is present on new shoes. Weigh footwear.

3) Attach Wagner force gauge to toe area of footwear. Place 5.0 lb. weight inside the boot in order to simulate the downward pressure which would occur in actual wear conditions. Place boot in test section and record the force necessary to slide the boot from a resting state. Repeat six times for the footwear and record the results. Repeat procedure in the second section of flooring. Average the measurements for each section.
4) Contaminate the flooring section to be tested with the material common to that area of the facility. Ensure a uniform application of the contaminant film.
5) Attach Wagner force gauge to toe area of footwear. Place 5.0 lb. weight inside the boot in order to simulate the downward pressure which would occur in actual wear conditions. Place boot in test section and record the force necessary to slide the boot from a resting state. Repeat six times for the footwear and record the results. Repeat procedure in the second section of flooring. Average the measurements for each section.
6) Calculate the coefficient of friction for each type of footwear and surface by dividing the horizontal force recorded by the force gauge by the vertical force (weight) of the footwear.

Following the testing of the footwear and slip resistant properties of the flooring surfaces, a comparative analysis was conducted to determine the most effective footwear option for the tested surface. Results were compared using the slip index measurements from the English XL tests and the coefficient of friction values determined from the footwear experiments.

Cost/Benefit Analysis

A cost/benefit analysis was conducted to determine the feasibility of providing slip resistant footwear to employees of XYZ Company at the company's expense. Using the results from the loss records analysis conducted in the first part of the study, the financial costs of providing the footwear were evaluated against the losses in worker's compensation payments at XYZ Company. Subsequent recommendations for controlling losses at XYZ Company resulting from slips and falls were derived from this financial analysis.

Chapter 4: Results of the Study

Internal Housekeeping Program/Policy Analysis

The internal housekeeping program/policy for XYZ Company was analyzed by obtaining copies of the Company's documents regarding housekeeping. These documents consisted of housekeeping policy at the corporate level, policy at the facility level, and copies of employee training materials pertaining to slips, trips, and falls. The following sections detail the scope and content of each of these areas of analysis.

Corporate policy. At the corporate level, the purpose and scope of XYZ Company's housekeeping policy is to provide guidance to individual facilities in establishing the criteria to maintain acceptable levels of orderliness. Employees, supervisors, and managers are directed to oversee a list of safe practices relating to housekeeping (XYZ Company Internal Document, 2000). The components of the basic housekeeping practices outlined in the corporate policy are detailed below:

1) Maintain a clean and orderly appearance.
2) Keep areas clean and dry.
3) Clean up spills and loose material promptly.
4) Cover floor holes; install railings and toeboards.
5) Mark permanent aisles.
6) Use non-slip materials on wet surfaces.
7) Implement proper storage of materials and equipment.
8) Post floor loading and storage rack weight limitations.
9) Mark and illuminate exits; maintain free of obstructions.
10) Secure overhead materials.

11) Store combustibles and flammables properly.

12) Dispose of waste and scrap materials at regular intervals (XYZ Company Internal Document, 2000).   .

Although the corporate policy provides criteria for safe practices relating to housekeeping, it is only intended to provide a minimum starting point for facilities to consider in developing their own programs specific to their environments. This ensures some policy control at the corporate level, while enabling individual facilities to design and implement programs that address the unique concerns of their plant conditions. It is noteworthy that the only guidance on preventing slips was to use slip-resistant surfaces in wet areas—no mention was made of proper cleaning techniques, slip resistance measurement standards, or employee footwear criteria.

Facility policy. The facility which was the focus of this research study did not have a company policy specifically focused on the control of slips hazards, although a fall prevention program was in place which addressed slip and trips briefly in the text of the written program. The elements of housekeeping pertaining to slips and trips included in this program were:

1) Maintain walking and working surfaces in good order.
2) Keep temporary materials clear of employee travel areas.
3) Route utility connections out of the way.
4) Maintain proper storage of tools and materials (XYZ Company Internal Document, 1999).

The fall prevention program also contained a brief directive regarding the use of stairs and ramps which stated that slippery conditions should be eliminated before allowing the continued use of the surface. Facility policy, similar to the corporate level policy, did not provide criteria for evaluating the slip resistant characteristics of flooring surfaces (i.e.; an established test method and slip resistance standards). The use of control methods to reduce employee exposure to slip hazards, such as footwear, was also not addressed in the company policy. Although controls are not delineated in policy statements, XYZ Company does provide comprehensive employee training on STF awareness and hazard recognition.

Employee training program. Employee training on slips, trips, and falls is administered on an annual basis for all employees at XYZ Company. The focus of the training covers essentially three topical areas: hazard awareness, attitude, and action (Coastal Training Technologies Corp., 1999). Employees are instructed on how to recognize hazards in the workplace, hazards which may include outside environmental contaminants which are tracked in (such as snow or rain), deposits on the floor such as grease, oil, water, or food products, and changing direction too rapidly (Business & Legal Reports, 1997). Workers are instructed that the task of maintaining a workplace free of STF hazards is the responsibility of all employees, not just the worker who created the hazard.

This proactive approach is a key area of emphasis during the training session. STF instruction also addresses housekeeping issues such as prompt cleanup of spills, maintenance of leaking equipment, placement of cords and wires, adequate illumination, and proper storage of materials (Coastal Training Technologies, 1999). In addition to the lecture component and written materials, employees watch an accompanying videotape on slips, trips, and falls and take a quiz to test their retention of the key points covered during the training session. The quiz also serves to provide documentation for record keeping purposes.

Loss Records Analysis

A three-year loss history of injuries resulting from slips, trips, and falls (STF's) was obtained from XYZ Company to quantify losses and to identify trends at the departmental level. The data was entered into a Microsoft Excel spreadsheet and analyzed by department, incidents, OSHA recordables, worker's compensation cost, and any restricted or lost days. This data was totaled by department for each of the fiscal years. Totals for the entire year were also tabulated, as well as the percentage STF injuries contributed to the total incurred compensation cost for the year. Table 1 contains the results of the loss records analysis for XYZ Company's fiscal year 2000.

Fiscal year 2000. Although fiscal year 2000 showed relatively low losses in terms of direct compensation costs, this year exhibited substantial losses in production time due to restricted duty and lost workdays. Areas with the highest losses in this year were departments D, W, P, M, and H. Department W had the highest compensation cost, while department D recorded the largest number of restricted work days with a total of 51. Department H also recorded a significant number of restricted duty days with a total of 13. Totals for the year showed a large number of restricted duty days at 95.

Combined departmental totals for STF incidents were also high, with a value of 28 incidents. When STF losses were calculated as a percentage of total incurred losses, these injuries contributed 2.5% of the compensation cost. Despite the low dollar value associated with STF claims in fiscal 2000, the high number of incidents and restricted duty days indicate a significant loss in terms of production time. The high frequency of

STF incidents recorded in fiscal 2000 provided clear evidence of a significant potential loss area for XYZ Company, an area which showed an upward trend in the data from subsequent years.

Table 1

<u>Slips, Trips, and Falls Loss Analysis for XYZ Company—Fiscal Year 2000</u>

Department	Incidents	Recordables	Compensation Cost	Restricted Days	Lost Days
D	9	1	$284.00	51	0
W	5	1	$1,815.00	28	0
P	2	0	$522.00	0	0
Q	1	0	0	0	0
M	2	1	$743.00	3	0
H	5	2	$673.00	13	0
M2	2	0	0	0	0
S	1	0	0	0	0
T	1	0	0	0	0
O	0	0	0	0	0
Totals:	**28**	**5**	**$4,037.00**	**95**	**0**
Percentage of Incurred WC Cost:	**2.5 %**				

<u>Fiscal year 2001</u>. Table 2 contains the loss data for fiscal year 2001. Despite the fact that the total number of incidents decreased from 28 the previous year to 15, the compensation cost increased dramatically to $78,039.00. Large increases were also observed in the number of restricted work days from 95 in 2000 to 185 in fiscal 2001—

increases which were driven by significant losses in departments D, W, and M. The total number of lost days also increased from 0 the previous year to 33 in 2001. As a percentage of total incurred costs, STF injuries accounted for 49% of the total for 2001—an increase of 46.5% from the previous year. Results of the 2001 loss records analysis demonstrated an increasing trend in STF injuries at XYZ Company, with the direct financial cost increasing and the number of restricted and lost days also climbing upward.

Table 2

Slips, Trips, and Falls Loss Analysis for XYZ Company—Fiscal Year 2001

Department	Incidents	Recordables	Compensation Cost	Restricted Days	Lost Days
D	5	2	$45,586.00	62	8
W	3	1	$3,209.00	18	6
P	0	0	0	0	0
Q	0	0	0	0	0
M	3	1	$29,244.00	105	19
H	3	0	0	0	0
M2	0	0	0	0	0
S	0	0	0	0	0
T	0	0	0	0	0
O	1	0	0	0	0
Totals:	**15**	**4**	**$78,039.00**	**185**	**33**
Percentage of Incurred WC Cost:	**49 %**				

Fiscal year 2002. The loss data from 2002 continued to demonstrate an increasing trend in the losses associated with STF incidents, as indicated in Table 3. At the time this study was conducted, XYZ Company was 7 months into the 2002 fiscal year—data obtained was current for this period. Departments which showed high losses were D, Q, and H with the largest single loss occurring in department H. Although fiscal 2002 data exhibited marked reductions in the number of restricted and lost work days from the previous year, when the total cost was calculated as a percentage of total compensation cost the percentage increased dramatically to 63%--an increase of 14 percentage points from 2001 data.

The examination of XYZ Company's loss records for fiscal 2000, 2001, and 2002 revealed an upward trend in losses resulting from slips, trips, and falls. Significant losses were observed both in terms of direct financial cost and lost production time due to restricted or lost workdays. The records analysis also revealed the sharp upward trend in the cost of STF injuries over the three-year history. This trend was clear when STF injuries were calculated as a percentage of total incurred cost—percentages for the three years were 2.5%, 49%, and 63%, respectively. At the departmental level, areas of high loss over the three years occurred in departments D, W, H, Q, O, and M. These recurring areas of losses, and the flooring surfaces in these areas of the facility, were used to select the areas for slip resistance and footwear testing.

Table 3

Slips, Trips, and Falls Loss Analysis for XYZ Company—Fiscal Year 2002

Department	Incidents	Recordables	Compensation Cost	Restricted Days	Lost Days
D	2	1	$6,000.00	7	4
W	1	0	0	0	0
P	0	0	0	0	0
Q	1	1	$2,600.00	9	0
M	1	0	0	0	0
H	4	1	$10,138.00	3	3
M2	0	0	0	0	0
S	0	0	0	0	0
T	1	0	0	0	0
O	1	0	0	0	0
Totals:	**10**	**3**	**$18,738.00**	**19**	**7**
Percentage of Incurred WC Cost:	**63 %**				

Slip Resistance Testing

Based on the analysis of XYZ Company's loss records, three departments were selected for the slip resistance testing with the English XL Slipmeter: Departments D, W, and H. In addition to the significant losses which had previously occurred in these areas of the facility, the flooring surfaces in these areas provided a representative sample of the types of floors present at XYZ Company. The surface types in these three areas consisted of smooth concrete, a surface with a rough slip-resistant coating, and a brick surface with a rough slip-resistant coating.

Although departments M and Q also had significant losses, these areas were excluded from the testing. For department M, this was due to the fact that this is a materials management function which involves work in virtually all areas of the facility—making it impossible to isolate a single work surface for this department. Department Q was not included in the slip resistance evaluation because the large loss in this area which occurred in fiscal 2002 was not due to the flooring surface itself; the STF injury in this area was caused by an employee tripping over a carpeted surface. Table 4 contains the results of the measurements taken with the English XL on the three different surface types. Contaminated surface measurements were made using the contaminant which was most prevalent in that particular work area.

Table 4

English XL Slip Index Measurements for Three Uncontaminated and Contaminated Floor Surfaces at XYZ Company

Department	Surface Type	Dry	Contaminated	Contaminant
D	smooth concrete	.53	.26	Powder
W	rough coated	.99	.85	Water
H	coated brick	.98	.64	Water
			.41	gelatin + water

Note. The English XL Slipmeter determines the slip resistance of a flooring surface by means of a slip index, which is read directly from the instrument. The index has a range of 0 to 1.0, with the higher values indicative of greater slip resistance. Researchers have accepted .50 as the threshold for providing a safe walking surface (English, 2001).

The smooth concrete surface in department D showed the lowest slip index reading of all of the tested surfaces, with a value of .53 under dry conditions. When this surface was contaminated with loose powder, the result was a large decrease in slip resistance of nearly 50%. The slip index values recorded for department D show that the smooth concrete surface provided only marginal slip resistance under uncontaminated conditions; under contaminated conditions, this surface demonstrated extremely low slip resistance.

In contrast to the low values measured in department D, department W exhibited excellent slip resistant properties under dry conditions—a value of .99. When the surface was subsequently contaminated with water, the measurement decreased only slightly to .85. The cause of the discrepancy in measurements between departments D and W appeared to be attributable to the differences in surface type, with the rough abrasive coating found in department W greatly increasing the slip index value under dry and contaminated conditions due to the greater height of the surface features.

Floor surface measurements in department H (coated brick) also exhibited large slip index values under dry conditions with a reading of .98. Water, however, lowered the slip index measurement to .64, a substantial decrease in slip resistance. The largest reduction in slip resistance occurred when a gelatin-based product manufactured in department H was added to the floor surface. The resulting mixture of water and gel-product reduced the slip resistance of the floor surface to .41, the largest reduction in slip resistance of all the tested areas. This value was significantly below the accepted threshold of .50. The difference in the performances of the floor surfaces in departments W and H may again be attributable to the roughness of the floor coating in each area.

The tested surface in department W did appear to be subjectively rougher in appearance than the floor in department H, which may have allowed for greater contact with the measurement device during the testing procedure.

Footwear Testing

Following the measurement of the flooring surfaces for slip resistance with the English XL slipmeter, two different types of footwear were evaluated for their ability to maintain adequate traction in XYZ Company's environments. A non-slip resistant and a slip resistant boot were tested under dry and contaminated conditions using a force gauge to record the amount of horizontal force necessary to move the boot from a resting state. It should be noted that there was a difference in the degree of wear present for the tested boots. Boot A was newly purchased, while Boot B had been worn at the facility for approximately six months prior to the tests. This discrepancy was not determined to preclude meaningful results, however. In their study on the effect of shoe abrasion on slip resistance, Manning and Jones (2000) determined that slip resistance increased significantly when footwear was abraded with sandpaper (Manning, Jones, 2000). These findings complimented the results of an earlier study by Chiou, Bhattacharya, and Succop (1996) which found that old shoes had a significantly higher coefficient of friction value than new shoes on slightly oily surfaces, while COF measurements for medium and very oily surfaces for old and new shoes were fairly close. The authors hypothesized that the older shoes may provide sufficient roughness due to the normal wear of the shoes (Chiou, Bhattacharya, and Succop, 1996). Tread pattern differed between the tested boots as well, with boot A having a slightly raised textured pattern and boot B having a smooth surface. Each boot had channels for the dispersal of wet contaminants on the sole.

In order to provide some level of control over the difference in wear between boots A and B, boot A was abraded with 150 grit sandpaper prior to testing. This was intended to provide a degree of abrasion which would be similar to the wear characteristics of boot B, and to remove the silicone mould release agent which is present on new footwear. Footwear measurements were repeated six times in two adjacent floor sections to obtain a representative sample and to evaluate the repeatability of the experimental method. The floor surface was then contaminated with a substance common to the area and the measurement procedure repeated. Coefficient of friction measurements were established by dividing the horizontal force recorded by the force gauge by the vertical force between the boot and the surface (i.e., the weight of the footwear). Table 5 contains the results of the footwear tests on the various flooring surfaces.

Footwear measurements for department D showed some of the lowest COF values, particularly under contaminated conditions. This finding supported the results of the English XL measurements which also showed the smooth concrete surface found in department D to be the least slip resistant when contaminated. Both of the boots demonstrated a large reduction in the COF when loose powder was applied to the surface. Boot A showed a decrease in the COF of nearly 50 % when powder was present, compared to a similar drop in the COF for boot B. A notable difference in the measurements for boots A and B was that boot B exhibited much higher values on the smooth concrete surface than boot A. This characteristic was observed for both dry and contaminated conditions, indicating superior traction properties for boot B on the smooth concrete. In terms of repeatability, each of the trials conducted in this area obtained

Table 5

<u>Coefficient of Friction Values for Non-Slip Resistant and Slip Resistant Footwear for Three Uncontaminated and Contaminated Floor Surfaces at XYZ Company</u>

Dept.	Surface Type	Boot*	Trial #1 Dry	Trial #2 Dry	Difference In COF	Trial #1 Contaminated	Trial #2 Contaminated	Difference In COF	Contaminant
D	smooth concrete	A	.53	.57	.04	.27	.31	.04	Powder
D		B	.91	.80	.11	.39	.39	0	Powder
W	rough coated	A	.93	.99	.06	.94	.87	.07	Water
W		B	.84	.96	.12	.64	.67	.03	Water
H	coated brick	A	.90	.83	.07	.73	.80	.07	Water
H		B	.57	.68	.11	.54	.46	.08	Water

<u>Note</u>. Although the coefficient of friction (COF) measurement calculated under dry conditions is technically defined as the static coefficient of friction (SCOF) with the method used to obtain the readings, the strict definition of this term is not applicable to the contaminated readings due to the presence of the contaminant layer between the two contact surfaces (English, 1999). Contaminated COF readings are intended to represent the ability of the footwear to maintain some degree of contact with the surface despite the interference of a contaminant film.

*Boot A was a non-slip resistant type of boot; B was a slip-resistant type.

relatively close COF values; a notable exception to this was the uncontaminated experiments for boot B, which showed a deviation of .11 between trials.

In contrast to the smooth concrete surface, calculated COF values for the rough coated surface in department W were considerably higher for boot A. Values for the uncontaminated dry readings were .93 and .99 for trials 1 and 2, respectively. COF values for boot B for the dry trials remained relatively close to the measurements obtained for the smooth concrete surface, although a slight improvement in traction was observed for the second uncontaminated trial. When the floor surface was contaminated with water, boot A did not exhibit a large change in COF values—readings remained relatively high at .94 and .87. In contrast to the fairly consistent friction characteristics of boot A, boot B showed a marked deterioration in the COF when the rough coated surface was contaminated with water. Values dropped sharply to .64 and .67 for the two experimental trials, indicating a characteristic of the footwear which was inhibiting adequate friction between the floor surface and the boot sole. The COF measurements for department W showed a significant performance advantage for the non-slip resistant footwear (boot A) on the rough coated surface. The experiments conducted in department W also showed relatively consistent results between trials, although once again the largest deviation between experiments occurred for the boot B uncontaminated trial with a difference of .12 between measurements.

Boot A retained a performance advantage on the coated brick surface found in department H as well. Dry COF values for boot A were .90 and .83, while boot B recorded much lower values of .57 and .68 for the uncontaminated surface—the lowest dry measurement observed for any of the surfaces. Both of the boots showed a decrease in COF when water was applied to the surface. Contaminated values were less than the rough coated surface of department W with readings of .73 and .80 for boot A, and .54 and .46 for the boot B trials. The experiments conducted on the coated brick exhibited some consistency between trials, although again it was the dry COF values for boot B which showed the largest discrepancy between experiments with a difference of .11.

With the exception of the test conducted on the smooth concrete surface of department D, boot A was observed to perform better than B on the tested surfaces despite the fact that A was a non-slip resistant type of footwear. In terms of repeatability between experimental trials, boot B demonstrated the largest degree of deviation under uncontaminated conditions with a maximum value of .12 (department W) and a minimum of .11 (departments D and H). Results of the footwear testing showed boot B was able to maintain a higher degree of friction on the smooth concrete surface, while boot A provided more traction on the rough coated and coated brick surfaces under both uncontaminated and contaminated conditions.

A direct correlation was observed between the slip index readings taken with the English XL and the COF values obtained for boot A. For example, the smooth concrete surface showed the lowest slip index values of all the surfaces; the COF measurements for boot A also showed the lowest values of the tested surfaces. Similarities were also observed between the measurements taken in departments W and H. The rough coated surface showed the highest slip index value, while the COF for boot A also exhibited the highest values. The coated brick surface in department H had a lower slip index than department W (particularly for the wet reading), and a corresponding boot A COF slightly lower than the rough coated surface.

COF measurements for boot B were not found to correlate well with the slip index readings. For example, on the slipperiest surface—the smooth concrete—boot B recorded high COF values. Yet although the boot's COF values were higher for the rough coated surface in department W (with a slip index value of .99 when dry), this relationship did not hold for the coated brick surface in department H. Although this surface had a high slip index value of .98 when dry, boot B showed its lowest uncontaminated COF values on this surface.

A significant result of the footwear tests is that the collected data supports the footwear recommendations delineated in ANSI/ASSE 1264.2-2001. This standard provides guidelines for the selection of slip resistant footwear that includes using footwear which provides leading edges in many directions, has a pattern extending over the entire surface of the sole, and provides channels for contaminant dispersal. Types of sole designs not recommended under the guidelines are raised, textured surfaces, large patternless areas, and the use of rigid sole materials (ANSI/ASSE 1264.2-2001). The variations in the coefficient of friction values between the tested boots, and their respective sole designs, provide evidence of these principles.

Boot A, the non-slip resistant boot, had a tread design consisting of a raised textured pattern (consisting of extremely small circles) that provided a large number of leading edges. This large number of edges provided boot A an advantage on the rough surfaces; the edges provided multiple sites for the boot to interlock with the flooring surface (it should be noted that this raised surface would be the first to be altered by wear, limiting the ability of this boot to provide long-term slip resistance). In contrast, boot B had a flat sole design with no raised tread pattern which allowed this boot to perform better on the smooth concrete surface due to greater contact area; this same characteristic was a liability on the rough surfaces due to the lack of available leading edges on the sole to interlock with the surface. Further evidence of this phenomenon was provided by the fact that boot A was observed to have higher traction properties on the contaminated rough surfaces in department W and H. The slightly raised pattern of boot A allowed the boot sole to penetrate the film of water to a greater degree than the smoother surface of boot B—an observation that also demonstrates the importance of having sufficient channels in the boot sole to disperse the contaminant film and allow for interlock with the flooring surface.

Cost/Benefit Analysis

A cost/benefit analysis to examine the feasibility of XYZ Company providing slip resistant footwear to its employees was conducted using the results of the loss records analysis. This analysis was used to evaluate the option of providing slip resistant footwear to XYZ Company employees as a means of controlling losses from slip, trips, and falls. Two scenarios were considered. The first option would involve purchasing new slip resistant footwear for all employees at XYZ Company. The second scenario in the analysis would provide the footwear only to the employees in departments D, W, and H. The cost of providing slip resistant boots for each employee was estimated at approximately $70.00 per pair. The cost of the footwear was evaluated against XYZ Company's loss records for the most recent period, fiscal year 2002. Table 6 contains the results of the cost/benefit analysis.

Table 6

Cost/Benefit Analysis of XYZ Company Slip Resistant Footwear Program Based on Fiscal 2002 Data

Scenario #1					
Number of Employees (Total)	**Cost of Footwear**	**Total Cost of Footwear**	**Losses from Slips, Trips, and Falls (fiscal 2002)**	**Difference (losses – cost of footwear)**	**Return on Investment (ROI)**
350	$70.00	$24,500.00	$18,738.00*	**-$5,762.00**	**- 23%**
Scenario #2					
Number of Employees in Dept. D, W, & H					
210	$70.00	$14,700.00	$18,738.00*	**$4,038.00**	**27%**

Note. Fiscal 2002 data was not complete at the time of this study. XYZ Company was only 7 months into the 2002 fiscal year. Based on the previous loss history concerning slip, trip, and fall injuries in fiscal 2000 and 1999, it was expected that losses for the entire year would be higher. This would impact the expected return on investment (ROI) positively. Calculated ROI percentages assume a reduction in STF injuries of the entire $18,738.00 occurs as a result of implementing the slip resistant footwear.

*This loss amount does not take into account the lost production time occurring in this period. XYZ Company had recorded 19 lost work days, and 7 days of restricted work. This loss amount also does not take into account the true cost as it relates to the three-year experience modification cycle used for calculating insurance premiums.

Using the option of providing slip resistant footwear to the entire workforce at XYZ Company, the calculated return on investment (ROI) resulted in a negative value of –23%. This was due to the fact that losses in fiscal 2002 had not yet exceeded the cost of providing the footwear to the employees, although the loss records analysis from prior years was indicative of an increasing trend in the cost of STF injuries. It appeared probable given the history of XYZ Company that losses for 2002 would be higher than the $18,738.00 value presented in Table 6. Fiscal 2002, seven months into the year, had already experienced a $6,000 claim in department D and a $10,138 claim in department H. Another significant claim of this magnitude occurring within the next 5 months of the fiscal year would result in a positive ROI value, indicating a financial benefit to XYZ Company of purchasing slip resistant footwear for all 350 employees. It is important to note that a negative ROI as calculated only indicates that a longer term is needed to realize a positive return for XYZ Company. It is probable given the loss history that a significant ROI would be realized in subsequent fiscal year periods.

A second cost/benefit analysis was conducted to determine the cost of providing slip resistant footwear only to the employees working in departments D, W, and H. The cost under this option was substantially less at $14,700.00 for the 210 employees in these departments. When this cost was subtracted from the total losses from STF injuries, the resulting ROI was 27%. As with the costs associated with the first scenario, this option also did not take into account the costs of lost production time or lost workdays resulting from STF injuries. As a control option, this alternative presents a definite advantage in that it provides a positive ROI much quicker than providing footwear for all employees at the facility.

Summary

This chapter detailed the results of the study in four key areas. Company XYZ's internal housekeeping policies were examined at the corporate and facility level to determine their scope and content. As an additional component of this analysis, the annual employee training program was also reviewed. Loss records for a three-year history were obtained from XYZ Company and examined to determine areas of the facility with patterns of high losses from STF injuries. Based on this analysis, slip resistance and footwear testing was conducted in high-risk areas both to determine the degree of risk present and to identify footwear appropriate for controlling the hazard. Lastly, a cost/benefit analysis was conducted to determine the financial cost to XYZ Company of providing slip resistant footwear to employees.

Chapter 5: Summary, Conclusions, and Recommendations

Restatement of the Problem

Losses from slips, trips, and falls have demonstrated an increasing trend over the last three years at XYZ Company. These injuries have resulted in not only the direct financial costs associated with worker's compensation claims, but also a significant loss of production time due to lost workdays and days of restricted work. These continued losses are indicative of deficiencies in the current control methods in place at XYZ Company to effectively prevent the occurrence of STF incidents. Without the development and implementation of alternative risk control approaches, it is likely that STF injuries will continue to increase at XYZ Company; these losses will continue to affect the profitability of the company in terms of direct financial costs and the loss of production time.

Methods and Procedures

To assess the scope of XYZ Company's ability to adequately address causes of slips, trips, and falls, an analysis was conducted of company housekeeping policy at the corporate and facility level. This review was performed by obtaining copies of the policies concerning housekeeping and analyzing them for their scope and content. This policy review also entailed an examination of the annual employee-training program, which was examined for its ability to provide comprehensive training to employees on the causes of STF's and methods to control them.

In order to ascertain the extent of the costs resulting from slips, trips, and falls at XYZ Company, loss records for a three-year history were examined. This analysis was conducted by entering the data obtained from the company into a Microsoft Excel spreadsheet; data was then classified by department and totaled to determine the highest areas of loss in the facility. The spreadsheet analysis was also used to determine the total losses from STF injuries for each fiscal year, as well as the percentage of STF injuries to the total incurred costs of all injuries. Indirect costs such as lost workdays and restricted work days were also tabulated by department and totaled for each year. This detailed examination of slip, trip, and fall losses at XYZ Company was subsequently used to identify areas of the facility in which to conduct slip resistance testing. These tests consisted of an evaluation of the slip resistant characteristics of the flooring surfaces, and testing to determine the most effective type of footwear for the facility's environments.

The slip resistant properties of three flooring surfaces identified from the loss records analysis were evaluated. The identified surfaces all had a recurring pattern of STF losses, and had the additional benefit of providing a good representation of the types of floor surfaces present at XYZ Company. Slip resistance readings were taken using an English XL Variable Incidence Tribometer. Floor readings were taken from the four compass directions and averaged to account for variations in surface wear, allowing for a measurement of the floor surface which would take into account any directionality of the surface. Slip resistance was measured under uncontaminated and contaminated conditions for each type of floor, and the results entered into a table format for comparison.

Footwear tests were carried out on the same three flooring surfaces to evaluate the most effective type of footwear to prevent slips at XYZ Company. Two different types of footwear, a non-slip resistant boot and a slip resistant boot, were evaluated for their ability to maintain traction with the floor surface under uncontaminated and contaminated conditions. These experiments used a force gauge to measure the horizontal force required to initiate motion between the boot and the floor. This value was then divided by the weight of the footwear to determine the coefficient of friction, which was used to compare the traction characteristics of the two types of boots in each environment.

Lastly, a cost/benefit analysis was developed to determine the financial cost to XYZ Company of providing slip resistant footwear for their employees. Two options were considered: purchasing footwear for all 350 employees, or limiting the footwear purchase to the 210 employees who work in the three tested areas. Each analysis considered the cost of the boots, the total STF losses to date, and used the difference (losses – cost of footwear) to calculate an expected return on investment value. This analysis was used to identify the most cost-effective option for XYZ Company.

Major Findings

Housekeeping program/policy. The internal housekeeping program/policy at XYZ Company was found to be limited in terms of its' ability to specifically address key areas pertaining to housekeeping as a means of controlling slips, trips, and falls. Limitations in the corporate policy included the lack of criteria addressing cleaning techniques/methods, slip resistant flooring standards, and the appropriate type of footwear for environments with recognized slip hazards. Facility level policy was also limited in scope; with no separate written policy governing housekeeping issues. Housekeeping concerns were briefly addressed under the fall prevention program, yet limitations were found to exist once again in the lack of floor surface standards and established guidelines for employee footwear to control slips. Although the corporate and facility policies were limited in addressing slips, trips, and falls, a review of the employee-training program revealed a fairly comprehensive program.

Elements of the employee training program included basic hazard recognition/awareness, establishing a proactive attitude towards the prompt clean up of hazards, and taking the appropriate actions necessary to remove an STF hazard from the work area. Training is required for all employees on an annual basis; materials used in the training session include a video and reading materials. Additionally, employees must pass a written component following completion of the training program. Although the employee training program did provide a fairly comprehensive overview of slips, trips, and falls, including the use of slip resistant footwear in hazardous areas, no mention was made of the effects of wear in influencing the traction characteristics of the footwear.

Loss records analysis. Losses from slips, trips, and falls demonstrated a significantly increasing trend at XYZ Company. An analysis of the company's loss records for fiscal 2000, 2001, and 2002 revealed that although the number of incidents had declined, the costs associated with STF injuries had dramatically increased. This comparison was even more apparent when STF injuries were analyzed as a percentage of the total incurred worker's compensation cost. For the three-year period surveyed, the percentage of STF injuries increased from 2.5% in 2000 to 63% in fiscal 2002.

The loss records analysis indicated the presence of a significant and persistent loss area at XYZ Company, a loss driver which was resulting in increasing financial costs as well as the loss of production time due to lost or restricted work days. For example, in fiscal 2000 there were a total of 95 days recorded as restricted work. In 2001, this number increased sharply to 185 days. This year also had 33 lost days. Only seven months into fiscal 2002, XYZ Company had recorded a total of 19 restricted workdays and 7 lost days—it was probable that this number would continue to increase through the end of the fiscal year. Several departments were identified as areas of recurring losses due to slips, trips, and falls; this data was subsequently used as the criteria for the selection of flooring surfaces for the slip resistance and footwear tests. Areas chosen for the slip resistance and footwear tests were departments D, W, and H--these areas also provided a representative sample of the different types of flooring surfaces present at the facility.

Slip resistance testing. The results of the slip resistance testing indicated the smooth concrete surface present in department D to be the least slip resistant of the tested surfaces when uncontaminated. When evaluated under clean conditions this surface had a measured slip index value of .53, a reading close to the recommended threshold of safety (ANSI/ASSE A1264.2-2001). When contaminated with a powdered product common to the work area, the slip index of the concrete dropped to .26, the lowest measurement recorded during the floor testing.

In contrast to the smooth concrete surface, department W had a rough coated surface which exhibited the highest slip index values. Readings under dry conditions were .99, a significant measurement given the fact that the scale on the instrument only records slip resistance as high as 1.0. When contaminated with water the value dropped only slightly to .85, still a significantly high measurement.

The coated brick surface evaluated in department H also achieved high slip resistance under dry conditions with a slip index of .98, yet this value did not hold when the brick was contaminated with water. When wet, the slip index decreased to .64—a substantially larger decrease than the rough coated surface in department W showed. Although this surface decreased in slip resistance markedly when contaminated, the slip index value of .64 was still higher than the recommended threshold of .50 (ANSI/ASSE A1264.2-2001). It was significant, however, that when the surface was contaminated with a gelatin-based product found in the work area, the slip index measurement dropped to .41—a level representing a large reduction in slip resistance.

Footwear testing. Testing of the non-slip resistant (boot A) and slip resistant (boot B) boots showed significant variations in the coefficient of friction (COF) values for the different surfaces and conditions. Boot B performed better on the smooth concrete in department D, with COF values of .91 and .80 for the respective trials. Boot A readings were much lower for this surface at .53 and .57. When loose powder was present on the surface, boot B retained its' performance advantage with measurements of .39 for both of the experiments. Boot A values were lower under contaminated conditions as well, with readings of .27 and .31 after loose powder was applied to the surface.

On the rough coated surface tested in department W, the non-slip resistant boot (boot A) demonstrated a large improvement in traction. Under dry conditions boot A recorded COF values of .93 and .99, while boot B measurements were only slightly lower at .84 and .96. In contrast to the values observed in uncontaminated conditions, a large difference in the boots was observed under wet conditions. Boot A performed significantly better than boot B in water, an unexpected finding given the slip resistant designation of boot B. Boot A COF values were .94 and .87; readings for boot B were .64 and .67 with the water present.

Similar findings were recorded on the coated brick surface found in department H. High COF measurements were observed for boot A under both dry and contaminated conditions, while substantially lower values were recorded for boot B. Uncontaminated readings for boot A were .90 and .83, while for boot B these values were .57 and .68. This difference continued under contaminated conditions as well, with boot A demonstrating COF measurements of .73 and .80. In comparison, boot B measurements were .54 and .46. It was noteworthy that values for both of the boots declined in respect to the readings obtained for the rough coated surface in department W, a finding which may have been due to differences in the peak heights of the surface features.

Differences between the two types of footwear were also observed in terms of repeatability between the experimental trials. Boot A exhibited less of a change between trials for all of the measurements taken under dry, uncontaminated conditions. For example, the average difference between the trials for boot A on an uncontaminated surface was .06. For boot B this average difference was .11. In contrast, when the floor surface was tested under contaminated conditions this difference in repeatability decreased for boot B with an average of .04. The average difference for boot A remained the same at .06. It was not determined what variables were responsible for this difference in repeatability, although the variations may be due to differences in wear patterns between the boots.

The coefficient of friction differences between the tested footwear were significant in that the data supports recommendations regarding the selection of slip resistant footwear provided in ANSI/ASSE 1264.2-2001. This standard provides guidelines for the use of slip resistant footwear which includes choosing footwear with many leading edges in different directions, with a pattern over the entire sole, and footwear with sufficient channels for contaminant dispersal. Sole designs which are not recommended include raised textured surfaces, large areas with no pattern, and the use of rigid sole materials (ANSI/ASSE 1264.2-2001). The design characteristics of the boots, as well as the recorded test data, provide evidence of the principles of footwear selection described in these guidelines.

The non-slip resistant boot, boot A, had a tread design with a raised, textured pattern (consisting of small circles) that provided a large number of leading edges which interlocked with the rough flooring surfaces to produce higher COF measurements under these conditions (it is worth noting that this raised texture would also be the first to wear down, resulting in a limited ability of boot A to provide slip resistance over an extended period). Yet boot A performed significantly worse on the smooth concrete, due to the reduced contact area caused by the textured pattern. In contrast the slip resistant boot, boot B, had a tread pattern designed with a smoother surface. Although this smoother surface provided boot B a significant performance advantage on the smooth concrete surface due to the greater contact area, this characteristic was a limitation on the rougher surfaces—the smooth sole provided few leading edges to interlock with the rough surface features. Further evidence of this explanation was provided by the fact that boot A exhibited greater traction on the contaminated surfaces in departments W and H. The raised, textured pattern of this boot allowed the sole to penetrate the film of water present on the surface to a greater extent than boot B. This observation also demonstrated the importance of having sufficient channels in the boot sole to disperse the contaminant film and allow the boot to interlock with the flooring surface.

Cost/benefit analysis. The cost/benefit analysis that evaluated the financial cost to XYZ Company of providing slip resistant footwear to employees considered two options. Both alternatives used the fiscal 2002 loss data for calculations. Under the first option, slip resistant footwear would be provided to all of the employees at the facility. The total cost of this option was determined to be $24,500.00 based on a cost of $70.00 per pair of boots. When this cost was evaluated against the total amount of incurred STF losses for fiscal 2002, the calculated return on investment resulted in a negative value, -23%. In contrast, when the option of providing footwear only to the employees working in departments D, W, and H was evaluated the expected ROI was a positive 27%. The cost/benefit analysis was limited, however, due to the fact that losses from fiscal 2002 were only current for the first seven months of the year. It was probable that actual losses from STF injuries would be higher. This analysis also did not take into account the financial cost of lost production time due to restricted or lost workdays.

Conclusions

The analysis of XYZ Company's housekeeping program/policy revealed limitations in the company's efforts regarding housekeeping. At the corporate level, policy provides a minimum starting point for facilities to structure their own program. Although corporate policy addresses many basic housekeeping issues such as maintaining order and cleanliness, proper storage of tools, and prompt cleanup of spills, these guidelines are limited in scope. For example, although the guidelines state that non-slip materials should be used on wet surface areas, no criteria is established in terms of the materials to be used or what degree of slip resistance must be maintained in these environments. Slip hazards which occur under dry conditions (such as the loose powder evaluated in this study) are not addressed at all. Additionally, no standards are established by this policy to address proper cleaning methods or the use of slip resistant footwear in hazardous environments. Lastly, corporate policy guidelines do not require that facilities develop comprehensive written programs that focus solely on housekeeping; this does not allow for corporate level control over the development of a systematic plan to effectively control the causes of slips, trips, and falls at the facility level.

Housekeeping policy at the facility was limited. No written housekeeping program was in place at XYZ Company; the only mention of housekeeping was a brief paragraph within the text of the fall prevention program. This lack of a written program to specifically address the many aspects of housekeeping issues does not allow for effective control of the numerous causes of slips, trips, and falls at XYZ Company. A comprehensive written housekeeping program is needed to address such elements as the appropriate cleaning methods for the facility, the use and type of slip resistant surfaces in work areas, criteria for determining the slip resistance of surfaces, and the types of footwear appropriate for use in the facility's environments.

The annual employee training program on slips, trips, and falls provides for fairly comprehensive coverage of the causes of STF's and how to recognize and prevent them. The use of the video and written materials, coupled with the lecture component and quiz, provided generally adequate training on slips, trips, and falls to employees at XYZ Company. The training was found to be limited, however, in providing instruction to employees on the use of slip resistant footwear. Training materials did not address the different types of slip resistant footwear, the appropriate footwear for their work environment, or the expected longevity of the footwear and how to recognize the effects of wear. This was a significant gap in the current STF training conducted at XYZ Company.

The findings of the slip resistance tests conducted with the English XL slipmeter indicated the smooth concrete surface to be the most slippery surface, even under uncontaminated conditions. When clean, the slip index on this floor was .53--a value significantly close to the recommended threshold of .50. With the loose powder present, this surface became extremely slippery with a slip index value of .26. The coated surfaces tested in departments W and H provided much higher levels of slip resistance, even when the surfaces were contaminated with water. These findings indicate that, with the exception of the smooth concrete, the flooring surfaces at XYZ Company are able to provide an adequate level of slip resistance. These results lead to the conclusion that the footwear currently being used at this facility is inadequate to provide traction on these surfaces.

The results of the footwear tests demonstrated limitations in both the non-slip resistant and slip resistant boots. Neither boot performed well on all three floor surfaces. The findings support footwear guidelines stated in ANSI/ASSE 1264.2-2001, which describes features of slip resistant soles that are able to provide a high degree of traction. Although the recommendations caution that no boot will be superior under all conditions, the test data indicates that slip resistant footwear with the following characteristics would be effective at XYZ Company:

1) Footwear that provides maximum contact with the floor surface
2) Footwear that has numerous leading edges for interlock with rough surfaces

3) Footwear with sufficient channels in the sole for dispersal of contaminant films

Slip resistant footwear designed with the criteria listed above are available from various manufacturers. The design of these shoes typically takes the form of a grid-like pattern which covers the entire bottom of the sole (Shoes for Crews, 1999).

A slip resistant footwear program limited to the employees in departments D, W, and H would cost $14,700.00 compared to $24,500.00 for plant-wide implementation. The more limited distribution of the footwear provides three advantages for XYZ Company. First, the footwear is provided to the high-loss areas—limiting the hazard exposure. Second, this allows for the use of the footwear on a trial basis; the results achieved by providing the footwear can be used to evaluate the feasibility of implementing a facility wide program in the future. Lastly, the expected ROI for this option is significantly higher in the short term—allowing more immediate financial benefits to XYZ Company.

Sources of Error

Potential sources of errors in the test data were inherent in the design of the footwear test protocol. The method used to evaluate the two boots contained potential sources of error in the data due to the following:

1) Differences in wear between the boots. Although the study attempted to compensate for the difference by abrading the surface of the new boot with sandpaper, the degree of wear may not have accurately simulated wear due to environmental conditions at XYZ Company.
2) Variations in the application of the contaminants. Although care was taken to

provide a consistent layer on the surface, no procedure was known which would control for this variable.

3) The weight placed inside the boots to simulate the downward force of the human foot may not have correctly represented the force of an actual person's step.

4) Inconsistencies in pulling the force gauge forward to initiate motion between the boot and the floor surface. Although effort was made to hold the instrument parallel to the surface for each reading, no controls were in place to ensure this.

5) The influence of residence time, adhesion and sticktion on the measurements taken with the force gauge.

Recommendations of the Study

Based on the findings of this study, the following recommendations should be implemented to reduce losses associated with slips, trips, and falls:

1) Modify the corporate guidelines on housekeeping to include criteria for evaluating the slip resistance of wet and dry surfaces, guidelines directing the use of proper cleaning techniques, when slip resistant footwear is to be used, and directing facilities to develop comprehensive written housekeeping programs. These changes would provide a consistent level of performance in the way facilities, including XYZ Company, implement controls to manage STF losses.

2) Develop and implement a comprehensive written housekeeping program at XYZ Company in accordance with ANSI/ASSE 1264.2-2001. Elements of

the program which should be developed under this standard are specific descriptions of the materials, methods, scheduling, equipment, and training of personnel responsible for housekeeping at the facility. The development of a housekeeping program will provide a comprehensive internal standard of performance at the facility. Such a standard will provide benefits in performance measurement and establishing accountability for housekeeping procedures. Additionally, this program should also address the use of slip resistant footwear to include the appropriate types, when the footwear is to be used, and the limitations and longevity of the footwear. This will serve to provide a high level of control over the types of slip resistant footwear worn at XYZ Company.

3) Add an additional component to the existing employee training program on slips, trips, and falls to include instruction on slip resistant footwear. This training should include the appropriate types, when the footwear is required, limitations of the footwear, and how to recognize signs of wear. The primary benefits of this added element of training is that it will ensure that employees understand company policy on the use of slip resistant footwear, particularly regarding when the effects of wear necessitates replacement of the footwear.

4) Investigate alternatives to improve the slip resistance of the smooth concrete surfaces. At a minimum, abrasive applications should be installed in high traffic areas of this surface to increase the slip resistance.

5) Provide slip resistant footwear to the employees in departments D, W, and

H. Selection of the footwear should consider the following:

a. maximum contact with the floor surface

b. numerous leading edges to interlock with rough surfaces

c. sufficient channels for the dispersal of contaminant films

Advantages of providing the footwear to the 210 employees in the three departments are that it allows management to control the type of footwear worn, provides slip resistant footwear in the areas of recurring losses, and allows for a trial period to consider facility-wide implementation of the program. Costs of this limited program are approximately $14,700.00, compared to $24,500.00 for full implementation. Footwear designed with the slip resistant features detailed above are available from various manufacturers, and typically involve a grid-like pattern over the entire sole bottom (Shoes for Crews, 1999)

Recommendations for Further Research

The findings of this research identified several areas related to slip, trips, and falls which require additional research, yet were outside the scope of this study. As such, the following are recommendations for continued research into the causes of slips, trips, and falls:

1) More research is needed to understand the effects of wear on the slip resistance of footwear. Although Chiou, Bhattacharya, and Succop (1996) have collected data which indicates improved slip resistance for worn shoes, it is not clear when this would cease to provide an advantage in terms of slip resistance.

2) Additional research is needed to determine the influence of floor roughness on the coefficient of friction. Further research comparing COF measurements and the height of floor surface features would provide much insight into this relationship, as well as aid in the selection and design of slip resistant flooring surfaces.

3) The effects of the water film as it interacted with the sole of the footwear requires additional study. Research into the effects of residence time, adhesion, and sticktion would provide greater insight into how these elements act to influence the slip resistant characteristics of footwear.

4) Further study is needed at XYZ Company to determine the degree of conformance to internal housekeeping standards. Such research would further identify factors contributing to losses from slips, trips, and falls at this facility.

5) Additional research at XYZ Company should include the use of a more sophisticated model for analyzing cost/benefit scenarios. A more detailed analysis which takes into account the time value of money (such as the double-discount method) would provide additional insight into the financial aspects of providing slip resistant footwear.

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