



Tribology: Prevention of Indoor Slips and Falls

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**What the heck is
Tribology!!**



Objectives

- Explain extent of slips and falls
- Describe causes and contributing factors that lead to slip and fall accidents
- Describe elements of a slip and fall prevention program
- Explain slip resistance measurement and types of slipmeters



Objectives

- Describe features and benefits of important prevention elements:
 - Analysis of injury and hazard data
 - Effective housekeeping programs
 - Floor surface selection guidelines
 - Floor surface treatment options
 - Mat systems
 - “Slip Resistant” footwear
- Use 3 slipmeters available in LP

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Significance of Slips and Falls

WC Claims	%\$	%#
Manual Materials Handling	34.8	36.7
Slips and Falls-Same Level	13.4	11.5
Slips and Falls-Elevation	10.0	5.0
Struck by/against/caught	8.8	16.7
Repeated Trauma	7.3	4.5
Motor Vehicle	6.2	1.9



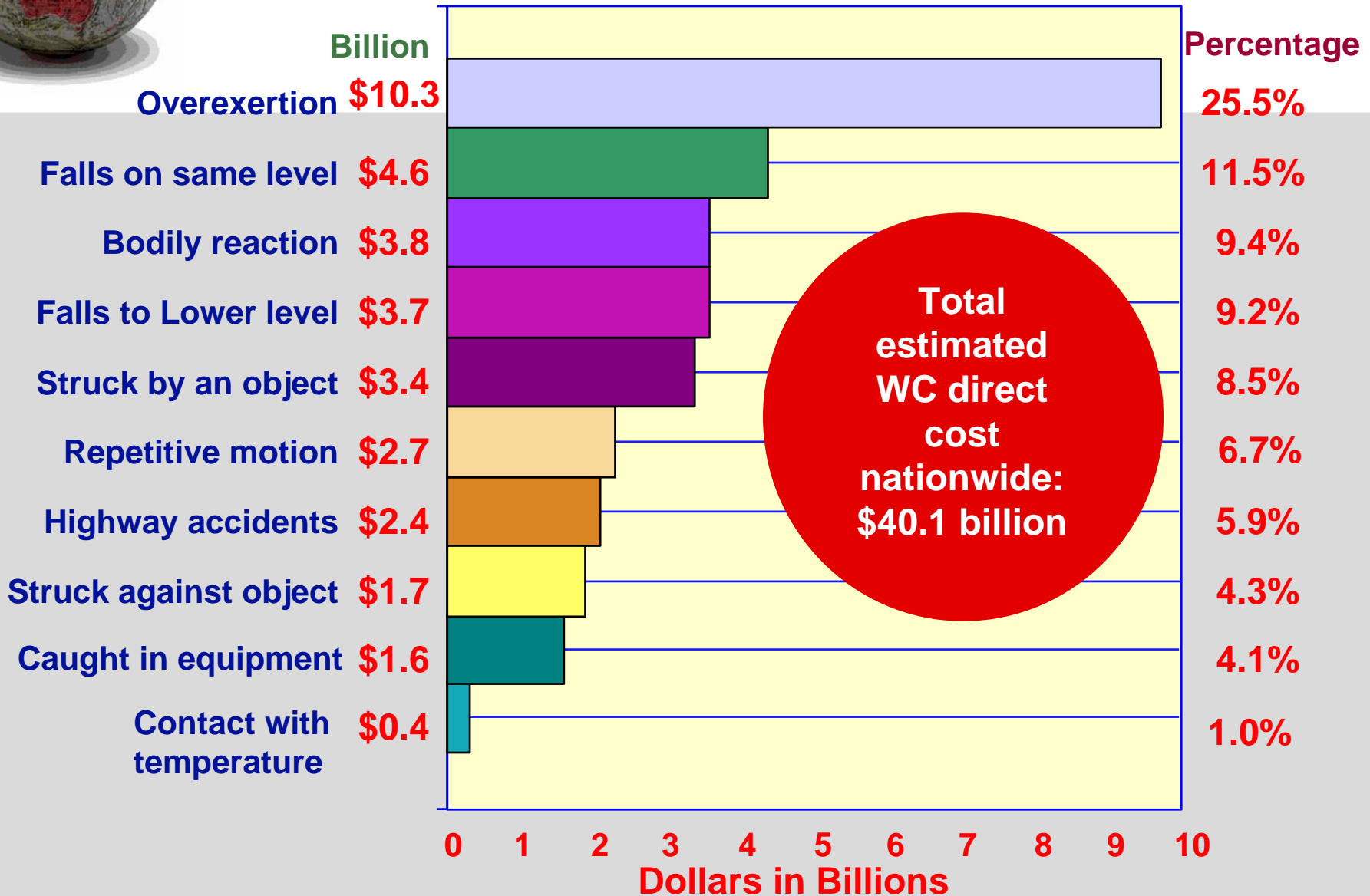
Significance of Slips and Falls

- 11% of low back pain (LBP) claims frequency and 12% of LBP claims cost attributed to slips and falls-same level

From Liberty Mutual Research Institute for Safety



Liberty Mutual Workplace Safety Index





Disciplines Involved In Slips and Falls

- Tribology
- Ergonomics
- Biomechanics
- Psychology
- Others



Video courtesy of Virginia Tech – Thurmon Lockhart, Ph.D

Slips and falls are complicated problems!



Tribology

- The study of the interaction of sliding surfaces
- It includes three subjects:
 - Friction
 - Lubrication
 - Wear



Tribology Issues in Slips and Falls

- Friction between shoe sole and floor
- Lubrication at interface (grease, water, soil etc.)
- Wear of shoe sole and floor surface

All these factors are interrelated!



What Is Friction?

- Friction: The resistance to movement of one body over another

$$F = \mu F_N$$

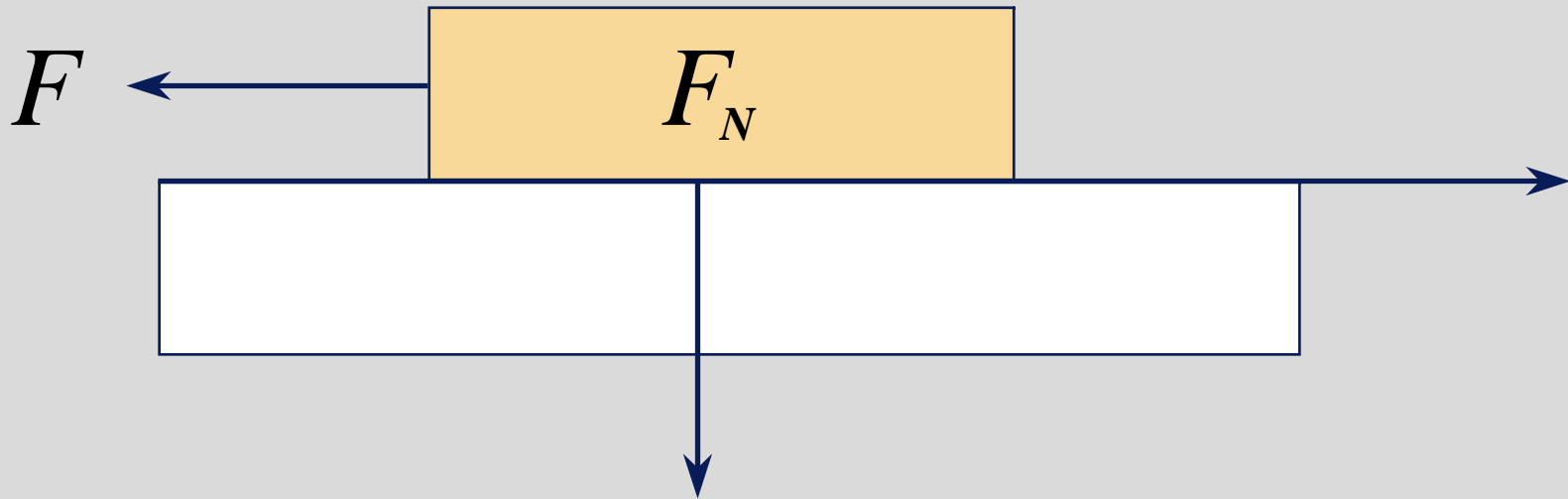
- Coefficient of Friction (COF): Ratio between the friction force (F) and the normal force (F_N)

$$\mu = \frac{F}{F_N}$$



Friction

Illustration of friction force F vs normal force F_N



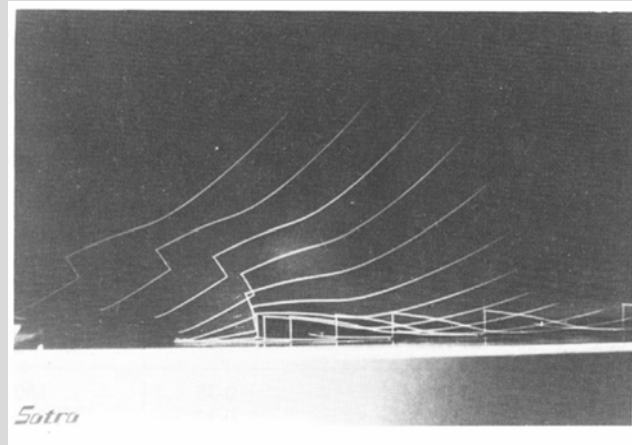


Static vs Dynamic Friction

- Static Friction (S): force required to initiate motion
 - SCOF: the ratio of the force required to move the object to its mass
- Dynamic Friction (D): force required to keep a sliding object in motion
 - DCOF: sensitive to velocity



Events in Human Walking Related to Slips and Falls



Multiple image photograph of a dangerous slip starting at peak 3

- **Heel strike — an impact phenomena**
- **Microslip (0–3cm) — undetected**
- **Slip (3–10cm) — aware of slipping and take corrective action**
- **Slide (> 10cm) — uncontrolled forward movement leads to falls**

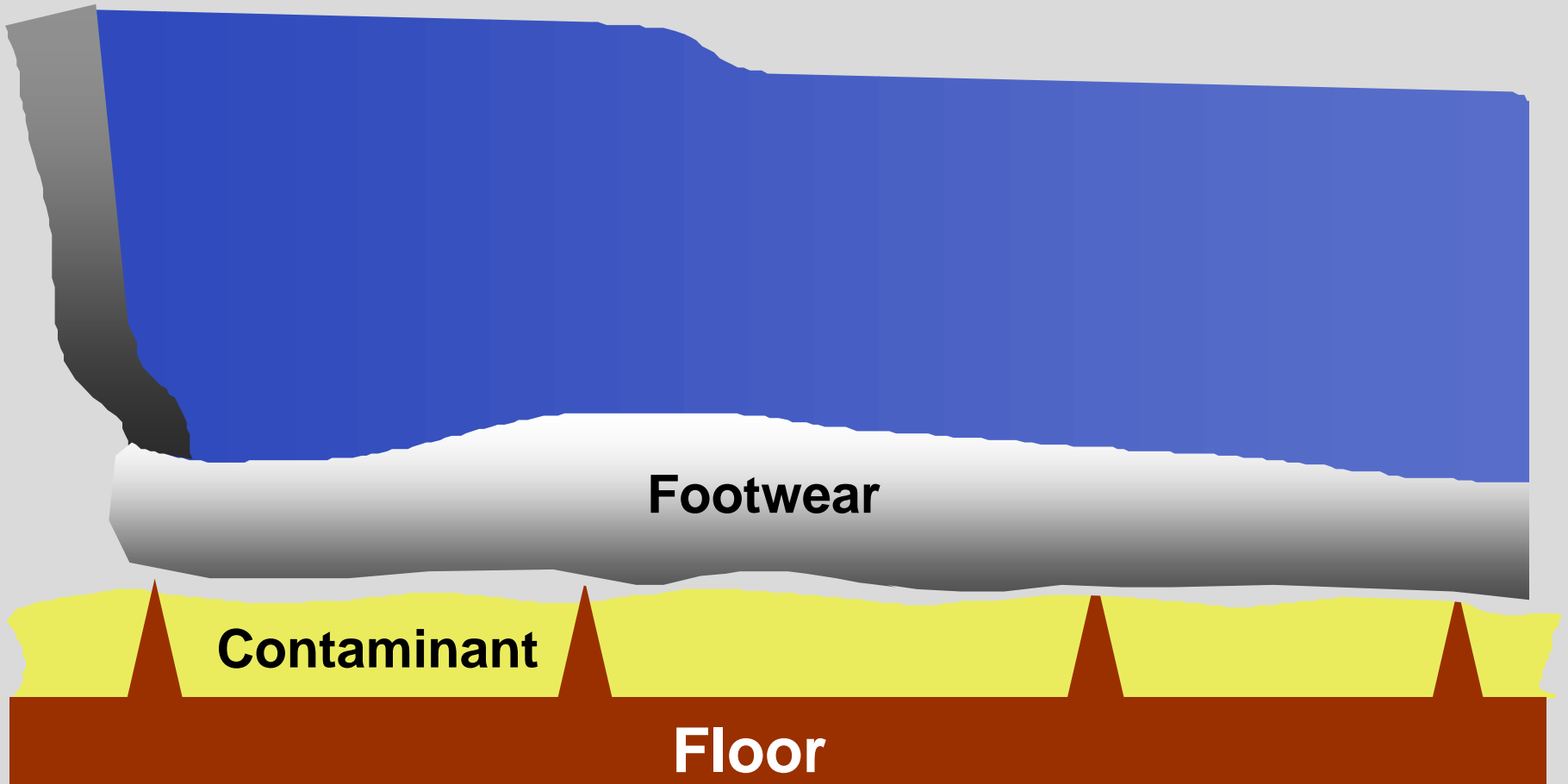


Same Level Falls

- Most inside falls are caused by slipperiness related to:
 - Faulty Housekeeping
 - Dirt, grease, or contamination on floors
 - Defects
 - Slippery floor dressing or finish
 - Inappropriate floor surface material
 - Surface wear
 - Uneven or damaged surface

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A Potentially More Slip Resistance Surface



Sharper and higher peaks could lead to a higher slip resistance

There exists an optimal high peak density that leads to a higher slip resistance



Falls from Stairs

- Slips and falls from stairs can be caused by:
 - Faulty Housekeeping
 - Objects, water, or grease on stairs or landings
 - Defects
 - No handrail
 - Handrail at improper height
 - Improper tread or riser dimensions
 - Tread surface material

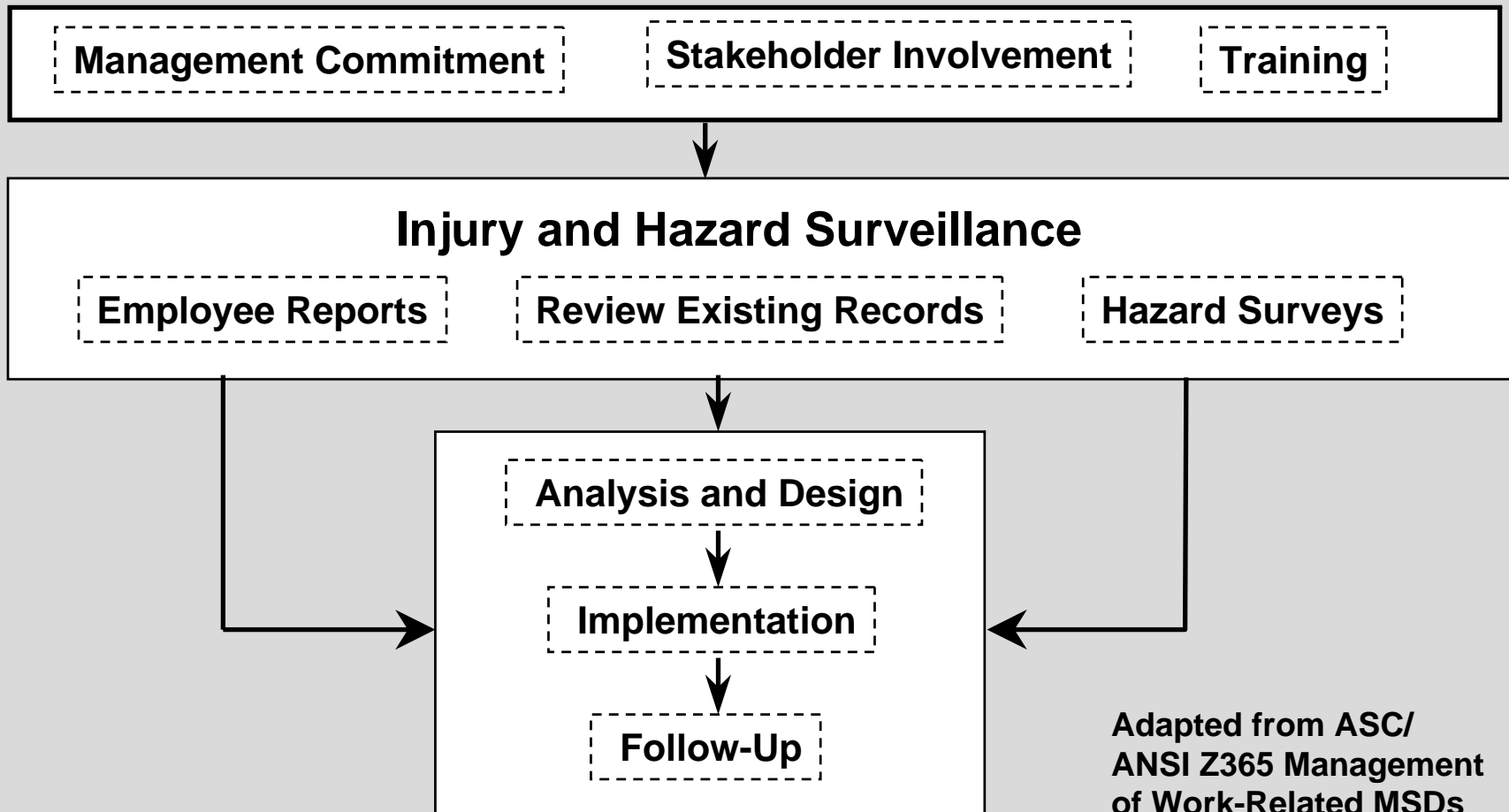


Other Major Causes

- Footwear traction
- Poor lighting
- Environment



Slips and Falls Prevention Process





Slips and Falls Prevention

- Risk assessment (slipperiness)
- Housekeeping
- Floor mats
- Floor surface materials
- Floor surface treatments
- Footwear



Measuring Slip Resistance

- Slipmeters
 - Horizontal Pull Slipmeter (HPS)
 - Brungraber Mark II (PIAST)
 - English XL Tribometer (VIT)
 - Others



HPS Slipmeter

- Use to test the slipperiness of clean, dry floors only
- Invented by Charles Irvine of Liberty Mutual Research Center
- ASTM F-609





HPS Slipmeter Readings

FLOORING	AVE. READING	RANGE
ASPHALT TILE	6.3	4.2 - 10.0
LINOLEUM	5.9	4.2 - 9.0
VINYL TILE	6.5	4.5 - 10.4
RUBBER TILE	5.6	4.0 - 8.1
TERRAZZO	5.0	4.1 - 6.2
WOOD	6.0	4.0 - 7.5
CONCRETE	7.8	5.6 - 9.4

>6: RELATIVELY NONSLIPPERY
5-6: GENERALLY ACCEPTABLE
<5: RELATIVELY SLIPPERY

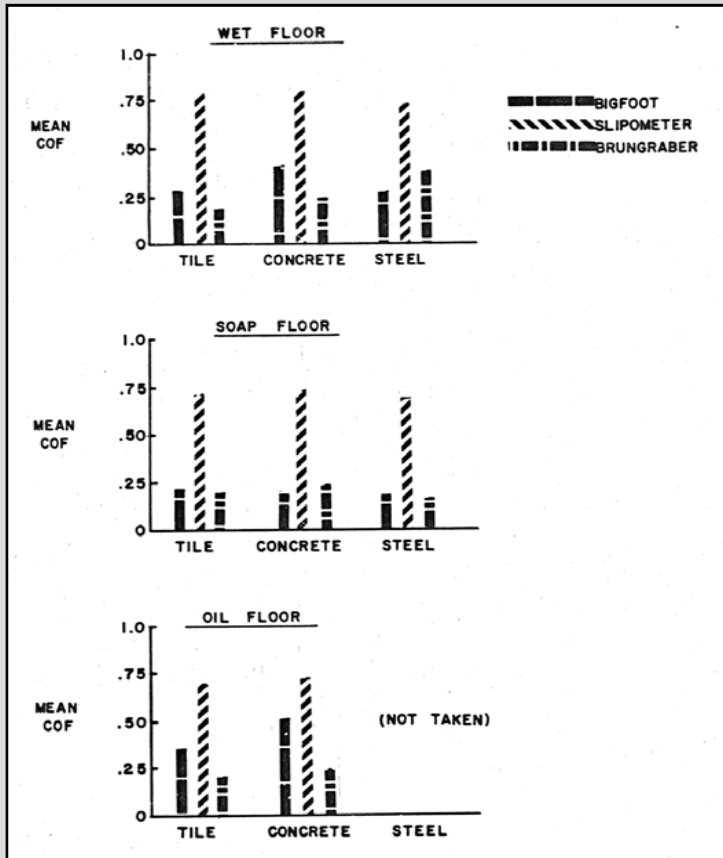


Brungraber Mark II (PIAST)

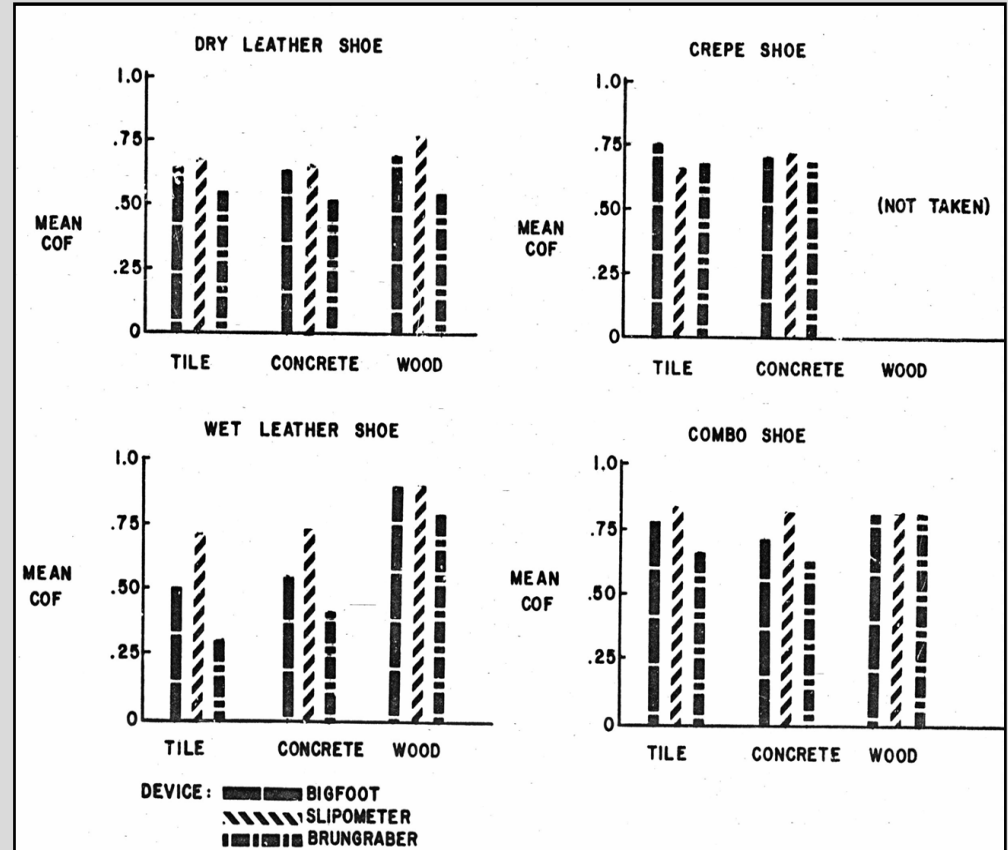
- Invented by Dr. Robert Brungraber
- Impact feature simulates heel strike and eliminates stiction
- ASTM F-1677



Brungraber vs. HPS



Mean static COF results for wet leather shoe on wet, oiled and soapy smooth flooring



Mean static COF results for different devices, shoe and floor materials over all floor-preparation conditions



English XL Tribometer (VIT)

- Invented by Mr. William English
- Impact feature simulates heel strike and eliminates stiction
- ASTM F-1679





Criteria for Slipperiness

- Cited criteria in the literature
 - James Machine - 0.5 for dry, clean and new floor finishes*
 - Penn State Univ. Studies - 0.6 for level surface
 - 0.8 for ramps

- Liberty Mutual guideline (HPS)
 - 6 or more: relatively non-slippery
 - 5-6: generally acceptable
 - 5 or less: relatively slippery

*ASTM D-2047 and UL 410-Slip Resistance of Floor Surface Materials



Criteria for Slipperiness

- ANSI/ASSE A1264.2 – 2001, *Standard for the Provision of Slip Resistance on Walking-Working Surfaces*
 - Cites a slip resistance guideline of 0.5 for walking surfaces in the workplace under dry conditions
- 1990 ADA (ADAAG)
 - SCOF of .6 or more for level floors and .8 or more for ramps
 - No mention of what instrument should be used to measure

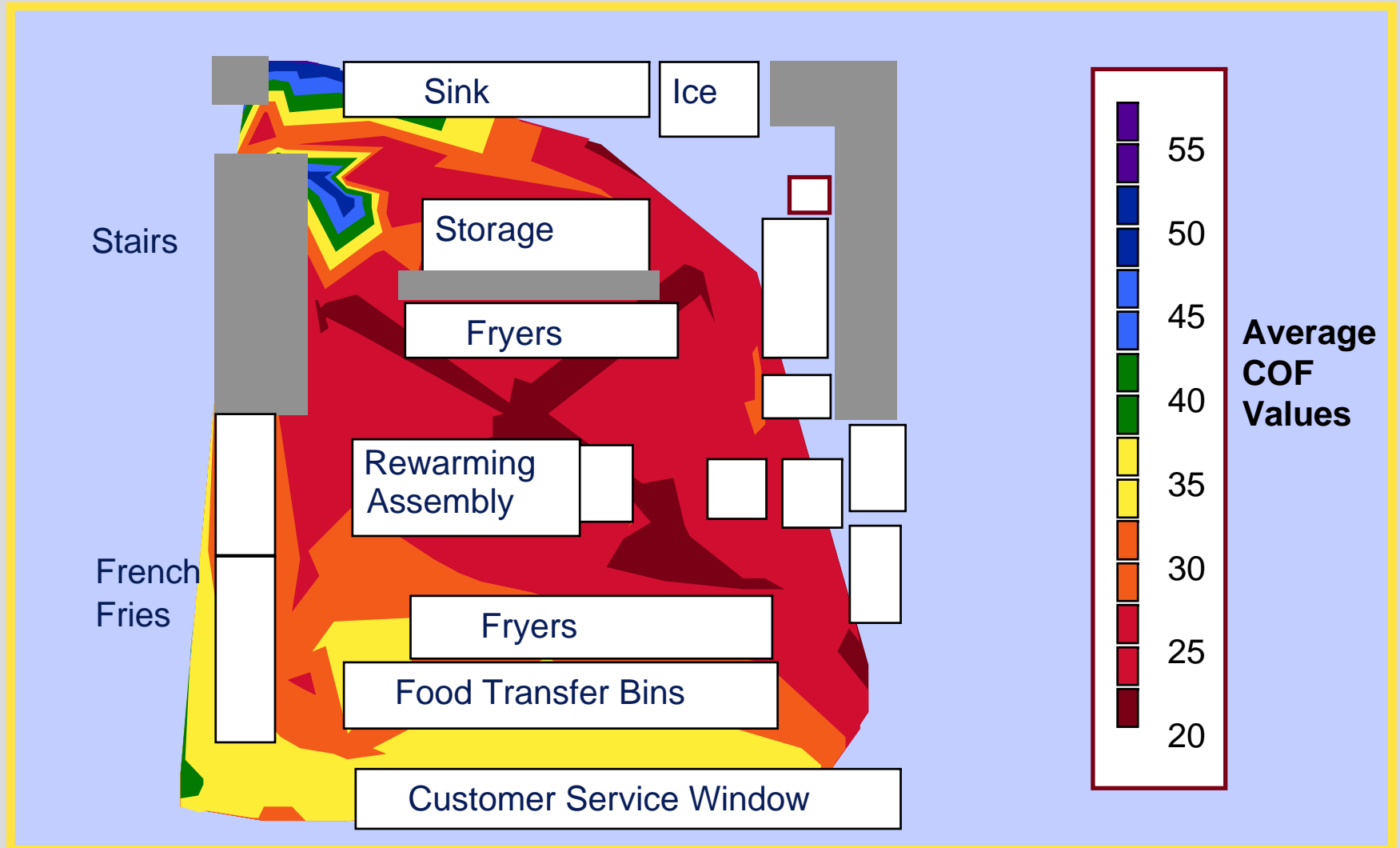
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Example Floor Topology Study

- Measured the slip resistance of kitchen floor in a fast food restaurant with a Brungraber Mk II device
- Divided the kitchen floor into small areas
- Measured the slip resistance of the selected tiles in four (4) directions and used the average of these four measurements

Where Are Falls Likely To Occur?





Potential Dangerous Spots

- Transition areas
- Unexpected changes in environment
- Distractions
- Contaminants
- Lighting and temperature
- Ramps



Housekeeping: Floor Cleaning

Cleaning Tools

Cleaning Chemicals

Floor cleaning protocols must be validated and tested

Proper Time and Frequency of Cleaning

What areas are most critical



Measuring Housekeeping

- Hold first line supervisors accountable for cleanliness in their departments
- Floor hazards must be periodically sampled, recorded, and information fed back to mgrs. (Unannounced inspections)
- Floor cleaning protocols must be tailored to the environment and floor material



Measuring Housekeeping

- Employees in best-performing departments should be publicly congratulated or recognized
- Measure hazards or cleanliness as these are much more reliable indicators and are earlier than measuring slip/fall accidents

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Housekeeping: Others

- Employee (Public) Awareness-**Signs**
- Enough trash containers and **Strategically** located close to points of generation of waste
- Enough cleaning implements and supplies accessible near points where needed
- Sweep Logs



Housekeeping: Others

- Training of employees
 - Keep main aisles clear and clean
 - If you drop it, pick it up
 - If you spill it, wipe it up
 - Go where you're looking, and look where you're going

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Floor Mats

- Benefits:
 - Use at entrances and in high contamination areas
 - Traps moisture and debris
 - Scrapes and absorbs moisture, snow, sand from footwear
 - Reduces floor maintenance costs by protecting the floor surface and finish



Floor Mats

- Need mats that both abrade and absorb
- Mats of sufficient running length and width
 - Snow: 10 - 12 walking steps
 - Rain: 8 - 10 walking steps
 - Dry: 6 - 8 walking steps
- Quick exchange of mats when wet or dirty
- Should be contrasting color to floor and affixed so as not to create another fall hazard

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Floor Treatments

■ Abrasive Floor Coatings

Grit Size

(Lower # = Larger Grit Size)

8 - 16	Ramps
16 - 30	General purpose
36 - 60	Food processing plants
60 - 80	Restaurants



Abrasive Floor Coatings

Grit Type (and Hardness)

Silicone Carbide

9.5

Al. Oxide

9.0

Quartz

7.0

Bonding Material

Epoxy Resin

Paint

Adhesive Sheets

Cost/Durability

High-----Low



Flooring and Grit Size Selection

- Type of business-FDA or local sanitary standards might be difficult to meet with abrasive floors. Some epoxies can be damaged by extremely hot water
- Abrasive floors should be avoided where floors are likely to be subject to crushing and turning forces associated with platform trucks and forklifts especially with steel wheels



Floor Treatments

- Chemical Etching
 - Ceramic tile, quarry tile, concrete
 - Higher coefficient of friction (COF)
 - When wet than dry
 - When more heavily etched

- Waxes, polishes
 - Limitations of COF data offered by manufacturers
 - Durability an issue

(continued)



Floor Surface Materials

- Concrete
- Tile
 - Ceramic
 - Quarry
 - Porcelain
 - Vinyl Composition Tile (VCT)
 - Marble
 - Others



Floor Tile Slip Resistance

- Glazed vs unglazed finish
- Wet vs dry environments
- Manufacturer COF Test Data
 - *ASTM C1028 Test method for determining the static coefficient of friction of ceramic tile and other like surfaces by the horizontal dynamometer pull-meter method*
 - Wet and dry SCOF given but only dry result is valid
- Surface roughness most important!!



Other Floor Surface Materials

- Carpeting
 - Inherently slip resistant
 - Aesthetically pleasing
 - Some carpets are “spill resistant”
 - Modular carpeting squares allow quick replacement in areas which can become soiled easily



When Choosing Flooring....

- What kinds of spills are likely?
- What are the sanitary requirements?
- Is noise a concern?
- Will the area have heavy traffic?
- Is it normally a wet environment?



When Choosing Flooring

- What equipment must the floor hold?
- How will the floor be cleaned?
- Are aesthetic effects a concern?

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“Slip Resistant” Footwear

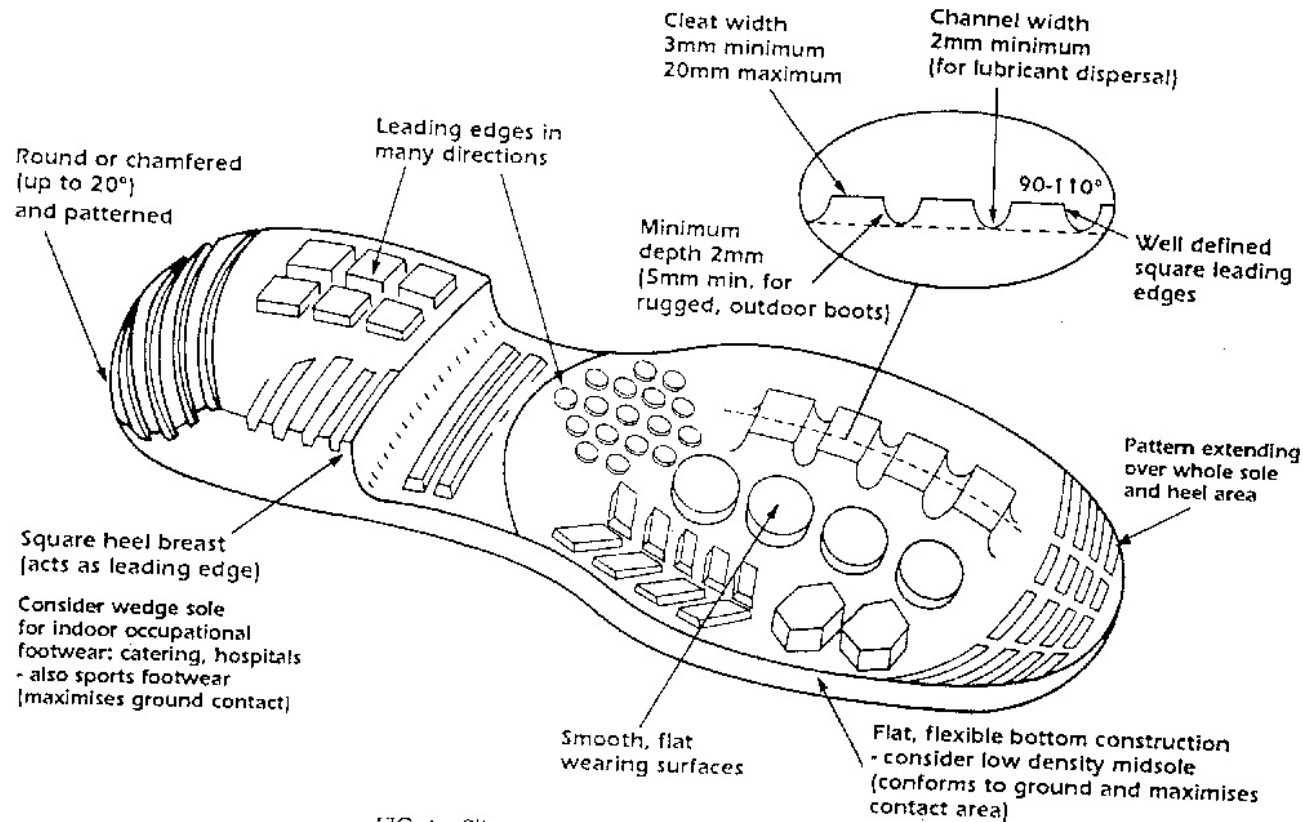


FIG. 4—Slip-resistant sole design—recommended features.



Other Footwear Issues

- Polyurethane microcellular sole material offers best slip resistant characteristics (Grönqvist)
- Some manufacturers have experience with slip testing of footwear
- Choose footwear appropriate to environmental conditions
- Like any PPE, hard to enforce use



Summary

- Slips and falls are a big problem
- Slip and fall accidents attributed to:
 - Faulty housekeeping
 - Defects
 - Lack of traction
 - Lighting
 - Overall, ineffective slip and fall safety process

(continued)



Summary

- Prevention needs to address all:
 - Knowledge of problem areas
 - Selection of floor surface material
 - Maintenance and housekeeping
 - Prompt removal of contaminants
 - Footwear
 - Selection and use of floor mats
 - Training and accountability!

(continued)



Slipmeter Workshop

- HPS
- Brungraber Mk II
- English XL