IDENTIFICATION OF APPROPRIATE TRIBOMETER VALIDATION SURFACES

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ABSTRACT

For many years the direct comparison of various walkway tribometers data has been elusive in part because there has not been a precise method of validating tribometers as to ensure that they produce accurate and reproducible data. Also, different devices measure slip resistance in different ways and produce different results even when testing the same surface only to create uncertainty and confusion as to the surfaces “true” slip resistance value. Unlike other countries, The U.S. experiences a significantly high number of slip and fall lawsuits which tribometer data is often entered as evidence and can influence verdicts. Identifying a more consistent validation/calibration reference surface(s) will: (a.) allow tribometer users to validate that their device is functioning within the manufactures engineering guidelines/controls and, (b.) will permit a more precise means of direct comparison between various tribometer COF test results.

In an effort to identify a more suitable method of validating the accuracy and precision of tribometers, five (5) factory trained technicians (operators) measured the wet SCOF and DCOF of twenty (20) hard surface materials using five different (5) tribometers. Testing was performed per the ANSI/NFSI B101.1-2009 wet SCOF and ANSI/NFSI B101.3-2012 wet DCOF standards. Test surfaces included polymer-based sheet materials, engineered printed glass, and industry specified ceramic reference tiles.

Keywords: Tribometer, Validation, Calibration, Reference Surface,

Topic: Measurement Principles and Technology

Introduction:

The primary purpose of testing the Coefficient of Friction (COF) of a walkway is for the purpose of determining its level of safety. Currently the most widely used standards for measuring the safety of walkways are the ANSI/NFSI B101.1 and B101.3 wet SCOF and DCOF slip and fall prevention standards. However, for decades tribometer users and manufacturers have struggled to identify a scientifically reproducible reference surface which could be used to validate/calibrate device(s) as to ensure that they are operating within their designated engineering design parameters and that they produce accurate and reliable data. Three major variables including: (1.) test surface material consistency (i.e.: texture, micro-texture, micro-roughness, flatness, etc.), (2.) sensor liner preparation (i.e.: sand paper grit, sanding protocol, sanding residue removal, etc.), and: (3.) a specified standardized testing procedure (i.e.: nationally recognized test method/standard) have contributed to the problem. The purpose of the study was not to compare the prescribed tribometers to each other but rather to identify the most precise validation reference surface(s) to validate/calibrate a tribometers COF readings.
Tribometer calibration is generally performed under strict engineering controls in an environmentally conditioned laboratory by a trained engineer or technician. A validation surface and a prescribed test method can assist both tribometer manufacturers as well as device operators to assure them that the device is functioning within its designed measurement parameters and is accurate. Reference validation surfaces are used to ensure that the operator of the device is capable of measuring the known COF of a particular material as to ensure that its resulting data is precise, reproducible and without operator bias.

One current validation/calibration test procedure used in the U.S. is based on the ASTM F-2508-13 “Standard Practice for Validation, Calibration, and Certification of Walkway Tribometers Using Reference Surfaces.” The purpose of the ASTM practice is to provide a general ranking of four (4) individual floor tiles which include: RS-A-Polished Black Granite, RS-B-Porcelain Tile, RS-C Vinyl Composition Tile, and RS-D-Ceramic Tile. Each tile is selected from the manufacturers production line and produced to their prescribed level of quality control.

The ASTM F-2508 “self-certification” approach provides at best a cursory understanding of a particular devices ability to generally identify the slip resistance of four production quality floor tiles. The procedure claims to have been designed to validate or calibrate a tribometer to a specific “human gait-based reference system” based on a select population of pedestrians and establishes a generic slip resistance ranking system.

A second and more widely used procedure for validating and calibrating tribometers is via the use of a production quality glazed ceramic floor “reference” tile supplied by the Tile Council of North America (TCNA). The reference tiles wet and dry SCOF values are measured via the ASTM C-1028-06 “Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method” and is certified by the TCNA. According to the C-1028-06 standard the TCNA C-1028 “verification standard tiles” have a dry SCOF of approximately 0.71 and wet SCOF value of 0.47 which, according to the standard, were derived via a round robin hosted by the ASTM on April 2, 1987.

Validating a tribometer using a single reference surface with a single target COF level does not ensure the user that their device is providing accurate results on the entire COF spectrum. Having two validation materials one on either end of the COF spectrum (i.e. μ 0.0-1.0) would: (a.) improve the accuracy/precision of the device’s measurements, (b.) describe any potential user bias, and (c.) define the linear relationship, if any, of the measured COF along the entire COF spectrum (Figure 1.)

![Figure 1.](image-url)
The ANSI/NFSI B101.1 and B101.3 COF measuring standards define three unique COF Traction Ranges (Tables 1. and 2.) Each Traction-Range has been clinically associated with injury claims. High-Traction walkways present a low slip risk while Low Traction walkways present an elevated risk of a slip event.

Table 1. ANSI/NFSI B101.1-2009 (SCOF) (Distilled Water + Smithers Neolite ® Test Liner)

<table>
<thead>
<tr>
<th>µ</th>
<th>Traction Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥0.60</td>
<td>High-Traction</td>
</tr>
<tr>
<td>0.40 ≤ µ &lt;0.60</td>
<td>Moderate-Traction</td>
</tr>
<tr>
<td>µ &lt; 0.40</td>
<td>Low-Traction</td>
</tr>
</tbody>
</table>

Table 2. ANSI/NFSI B101.3-2012 (DCOF) (.1% SLS + German SBR Test Liner)

<table>
<thead>
<tr>
<th>µ</th>
<th>Traction Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.45 (inclines)  &gt;0.42 (level)</td>
<td>High-Traction</td>
</tr>
<tr>
<td>0.30 - 0.45 (inclines)</td>
<td>Moderate-Traction</td>
</tr>
<tr>
<td>0.30 - 0.42 (level)</td>
<td>Low-Traction</td>
</tr>
</tbody>
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Methods:

Four (4) different test sensor liner materials were used in the study including: Neolite® (Smithers Corp.), Neolite (Goodyear Corp.), German Styrene Butadiene Rubber (SBR) as specified in the ANSI/NFSI B101.3-2012 standard, and SBR (Black-Goodyear). Twenty (20) individual validation surfaces in three (3) categories were selected including: glazed ceramic reference tiles, extruded and or molded polymer sheets, and ceramic ink printed patterned engineered glass. Each material was tested using five (5) different tribometers including: Instron 3365 (Instron Corp.), BOT-3000 (TracScan) (MCS Mechanik UG), BOT-3000e (Regan Scientific Corporation), ASM-825A (American Slip Meter, Inc.), GS-1 (Johnson Labs) were used and operated by five (5) factory trained operators. With the exception of the ASM-825A which only measures SCOF, all other devices measured both SCOF and DCOF. Test sensors were prepared in compliance with the tribometer manufacturers procedure. Each tribometer has a sensor design unique to the device and close attention was paid in the preparation of the sensor liner per the manufacturer’s instructions as to ensure accurate readings. The validation surfaces were cleaned with distilled water and dried using a lint-free wiper prior to COF measurements.

Tribometer Operators: Each tribometer operator was trained by the manufacturer as to the proper use of their device and worked independently. Each operator rotated between twenty (20) different sections of the laboratory. Data was recorded and reported to an independent analyst who recorded and graphed each series of test results. The tribometer operators
included: Mr. Brent Johnson from Traction Auditing L.L.C. who operated the BOT-3000 (TracScan), Mr. Craig Stephenson from American Slip Meter who operated the ASM-825A, Mr. Bill King from Johnson Labs who operated the GS-1, Mr. Greg Cohen from Slip Doctors who operated the BOT-3000e and Mr. Russell Kendzior from the NFSI who operated the Instron 3365. The independent analyst was Mr. Steve Spencer of State Farm Insurance Company. COF testing was performed in compliance with the ANSI/NFSI B101.1 Wet SCOF and ANSI/NFSI B101.3 wet DCOF test methods. It should also be noted that each the specific tribometer’s validation/calibration procedure were followed before each round of testing.

Validation Surfaces

The twenty (20) validation reference surfaces used in the study were:

- 1. Engineered Glass-Checkerboard Pattern
- 2. Frosted Glass
- 3. Engineered Glass Geometric Pattern
- 4. Cast Nylon Polyamide (Nyloil®, Nylatron®)
- 5. Ultra-High Molecular Weight Polyethylene (UHMW)
- 6. Extruded Polypropylene Sheet
- 7. TCNA Glazed Ceramic Tile* #879
- 8. TCNA Glazed Ceramic Tile* #877
- 9. XL TCNA Glazed Ceramic Calibration Tile* #348
- 10. Acetal Polyoxymethylene POM® (Delrin)
- 11. Polytetrafluoroethylene (PTFE)
- 12. Polycarbonate
- 13. Polystyrene (Poly Pro) Sheet
- 14. Polyethylene Terephthalate Glycol Modified (PETG) Sheet
- 15. Extruded Nylon
- 16. XL TCNA Glazed Ceramic Calibration Tile* #349
- 17. XL TCNA Glazed Ceramic Calibration Tile* #548
- 18. TCNA Glazed Ceramic Tile* #878
- 19. TCNA Glazed Ceramic Tile* #876
- 20. Engineered Glass-Checkerboard Pattern

* - TCNA verification tiles #878 and #879 were laboratory tested per the ASTM C-1028 test method and certified by the TCNA to have dry SCOF values of 0.86 and wet SCOF values of 0.51. TCNA verification standard tiles #876 and #877 were tested via the Acutest® test method and certified by the TCNA to have wet DCOF values of 0.31. Based on the information provided by the TCNA, it was concluded that TCNA Tiles #878, #879 would be considered High-Traction surfaces per the ANSI/NFSI B101.1 and B101.3 standards while tiles #876 and #877 were certified as being Moderate Traction. The ANSI/NFSI B101.1 and B101.3 Traction Ranges are listed in Tables 1. and 2. Below.

Results:

Comparative analysis of the various test sensor liners on the twenty (20) validation surfaces revealed wide ranging COF results. The TCNA ceramic reference tiles had the highest range of COF variability (Figure 2.) The second most variable were the polymer-based materials (Figure 3. and Figure 4.) The checkerboard patterned engineered glass material had the least amount of COF variability (Figure 5.)
A clearer pattern emerged when the ANSI/NFSI B101.1 and B101.3 specified sensor liners were isolated (i.e.: Smithers Neolite® and German SBR). Comparative analysis of the two (2) sensor liner materials again revealed wide ranging DCOF results for the TCNA ceramic tile reference surfaces (Figure 6.) and with the exception of PTFE, the polymer-based materials also demonstrated a wide range of COF levels (Ex. Figure 7.) Both the checkerboard pattern engineered glass and PTFE demonstrated more tightly clustered and reproducible DCOF results (Figure 8. and Figure 9.)
Discussion and Conclusions:

The study found that various sensor liner materials produced a wide range of COF readings when used on the same test surfaces. This is particularly evident for the TCNA ceramic reference tiles which generated the largest variations in COF. Although the surface texture of ceramic tile appears to the naked eye to be uniformly textured and flat, they are not. The data revealed that the TCNA ceramic reference tiles have wide ranging COF variations most likely due to a combination of inconsistent surface texture, micro-textures, flatness, and inconsistent glazing materials and or manufacturing processes.

When testing the DCOF of the TCNA ceramic reference tiles using the prescribed German SBR sensor liner it was found that the wet DCOF of each of the TCNA ceramic reference tiles produced wide-ranging DCOF results spanning all three (3) traction ranges (Low, Moderate, and High). The TCNA ceramic reference tiles do not exhibit the rigorous quality control measures required for use as a scientific validation/calibration surface and although TCNA ceramic reference tiles have been used as a validation/calibration material for decades, its surface variability and lack of strict engineering controls makes them unsuitable as a tribometer calibration/validation surface.

The ideal tribometer validation surface is one which possess a uniform texture or surface pattern that remains consistent with repeated measurements and flat across its entire surface as not to change the contact area between the test sensor liner and the reference surface.
With the exception of PTFE, extruded or molded plastics substrates also demonstrated a wide range of COF variations most likely caused by the chemical-mechanical cross-linking (bonding) effect between the polymer-based sensor liners and the polymer-based test surfaces. (a/k/a Stiction effect). The study also found that when tested per the ANSI/NFSI B101.1 and B101.3 standards the checkerboard patterned engineered glass and PTFE materials generated the most reproducible and tightly clustered COF results all of which were within the same single traction range. It was concluded that the checkerboard patterned engineered glass and PTFE materials are well suited as tribometer validation/calibration surfaces.

It is noted that subsequent precision and bias information for tribometers should be established via an independent third-party Interlaboratory Study (ILS) like that developed by the NFSI. ([www.nfsi.org/ansinsfi-standards/b101-committee](http://www.nfsi.org/ansinsfi-standards/b101-committee)).

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