Standard Method for Conducting an Interlaboratory Study (ILS) to Establish Validity, Repeatability and Reproducibility of a Walkway Tribometer Measuring Wet Static Coefficient of Friction (SCOF) for a Common Hard-Surface Walkway

1.1 Scope

This method specifies the procedure for conducting an inter-laboratory study (ILS) for a walkway tribometer used to measure the wet static coefficient of friction (SCOF) of common hard-surface floor materials.

1.2. Purpose

This test method evaluates the validity, repeatability and reproducibility of instruments and methods employed to evaluate the wet SCOF of common hard-surface floor materials across a typical traction range.

1.3 Application

This ILS for evaluating test methods used to evaluate walkway traction does not apply to carpeting of any type, and addresses most common hard-surface flooring materials such as ceramic, porcelain, and polished stone tile, vinyl floor coverings, wood laminates, as well as coatings, polishes, etc.

Note: The ILS for evaluating test methods used to evaluate walkway traction does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. No express or implied representation or warranty is made regarding the accuracy or significance of any test results, for which instrument performance is evaluated by this ILS methodology set forth herein, in terms of slip resistance.

1.4 Exceptions

The ILS set forth herein does not pertain to methods employed for dry-surface testing.

Section 2: Reference to other Standards and Publications

ANSI/NFSI B101.1-2009 – Test Method for Measuring the Wet SCOF of Common Hard-Surface Floor Materials.

ASTM D297-93(2006) Standard Test Method for Rubber Products – Chemical Analysis

ASTM D2240-05 Standard Test Method for Rubber Property – Durometer Hardness

ASTM E691-92 Standard Practice for Conducting and Interlaboratory Study to Determine the Precision of a Test Method

ASTM F1469-11 Standard Guide for Conducting a Repeatability and Reproducibility Study on Test Equipment for Nondestructive Testing

ASTM F1646-03 Standard Terminology Relating to Safety and Traction of Footwear

Section 3: Definitions

3.1 Analysis of Variance (ANOVA). A statistical technique that separates systematic variation that is attributable to the operator and/or testing instrument from random variation.

3.2 Friction. Resistance to the relative motion of two solid objects in contact. This force is parallel to the plane of contact and is perpendicular to the normal force.

3.3 Gage Repeatability & Reproducibility (Gage R&R) - The amount of measurement variation introduced by a measurement system, which consists of the measuring instrument itself and the individuals using the instrument.

3.4 High Traction. The physical property of a floor or walkway that is designed to mitigate slipping during normal human ambulation by providing a reasonably sufficient level of available contact friction.

3.5 Interlaboratory Study (ILS). A controlled study designed to evaluate the consistency of two or more laboratories purporting to measure the same object or phenomenon.

3.6 Laboratory. A combination of instrument, method and person or persons used to evaluate the wet SCOF of a flooring material.

3.7 Low Traction. The physical property of a floor or walkway that provides a comparatively low level of available friction, thus increase the risk of slipping during normal human ambulation.

3.8 Moderate Traction. The physical property of a floor or walkway that provides a moderate level of available friction, thus creating a moderate risk of slipping during normal human ambulation.

3.9 Normally Trained Operator. A tribometer operator who has received normal training on the operation of the walkway tribometer under review, but who does not possess expert-level knowledge on tribology and/or the specific tribometer being evaluated by the ILS.

3.10 P-Value. A statistical term that, for the purpose of this standard, quantifies the likelihood that variability in SCOF readings can be attributed to the use of different examples of the same tribometer instruments and/or different normally trained operators. For this ILS, a p-value < 0.1. constitutes an unacceptable degree of user and/or instrument-related variation.

3.11 Repeatability. Or, test-re-test reliability, is the variation in measurements taken by a single person or instrument on the same item and under the same conditions. Repeatability conditions include the same measurement procedure, the same observer, the same measuring instrument, used under the same conditions, the same location and repetition over a short period of time.

3.12 Reproducibility. Refers to the ability of a test or experiment to be accurately reproduced, or replicated, by independent parties evaluating the same material(s) under the same conditions.

3.13 Slip Resistance. The property of a floor or walkway surface that acts in sufficient opposition to those forces and movements exerted by a pedestrian under normal conditions of human ambulation.

3.14 Static Coefficient of Friction (SCOF). The ratio of the horizontal component of force applied to a body that just overcomes the resistance to slipping to the vertical component of the weight of the object or force applied.

3.15 Static Friction. The resistance opposing the force required to start the movement of one surface over another.

3.16 Traction. The friction between the sole material of a shoe and the fixed surface it moves upon.

3.17 Validity. The degree to which a measurement accurately measures what it is intended to measure.

3.18 Walkway Tribometer. An instrument or device specifically designed to measure the available level of traction upon a floor or walkway.

Section 4: Procedure for the Inter-laboratory Study of a Walkway Tribometer Method

This method for conducting an inter-laboratory study may be utilized to evaluate the performance of any tribometer designed to measure the wet static coefficient of friction (SCOF) of a floor or walkway surface under the conditions specified herein.

4.1 Testing Location. All NFSI ILS qualification tests shall be conducted at the NFSI laboratories in South Lake, TX using NFSB101.1I standard reference materials.

4.2 The candidate walkway tribometer company shall provide the following:

- Three serialized walkway tribometer units of the same model or design, capable of testing reference materials that are approximately 12” X 12” in dimension.
- Two operators who are normally trained to operate the candidate walkway tribometer design.

4.3 Qualified Observer. A qualified observer is a supplier neutral, third-party observer who is trained and qualified on techniques of measurement for quality assurance - ideally possessing certification as a quality engineer (CQE), reliability engineer (CRE) or quality auditor (CQA) from the American Society for Quality (ASQ). Observer candidates must be approved by the NFSI and shall be required to sign an affidavit as an attest to their neutrality.

4.4 Create Laboratories. A laboratory shall be defined as the combination of one instrument and one user. ILS participants shall create six (06) unique laboratories by combining three (03) different measurement instruments and two (02) normally trained operators.

4.4.2 Select three normal production instruments and identify them as Tribometer A, Tribometer B and Tribometer C.

4.4.2 Calibrate the three walkway tribometers selected for the study.

4.4.3 Assign two operators who have been normally trained to operate the tribometer under evaluation and identify them as Operator 1 and Operator 2.

4.5 Data Collection. Each candidate for ILS validation by the NFSI shall collect data for each of the three (03) NFSI standard reference materials from each of the six (06) laboratories according to the following guidelines.

4.5.1 Each of the six laboratories shall collect eleven (11) observations on each of the three (03) standard materials utilizing standard wet SCOF measurement techniques set forth in the walkway tribometer supplier's operating manual, yielding a total of 66 observations for each surface (see table). So, for each tribometer/material combination, each operator shall perform 11 observations for a total of 22 for each tribometer/material/operator combination. One material shall be designated "low traction", one material shall be designated "moderate traction" and one material shall be designated "high traction." All standardized walkway surface materials shall be provided by the NFSI. All testing shall be conducted in conformance with ANSI/NFSI Standard B101.1-2009 – Test method for Measuring the Wet SCOF of Common Hard Surface Floor Materials.

		Tribometer A	**Tribometer B**	**Tribometer C**
Operator 1	NFSI Low Traction Material	11 Observations	11 Observations	11 Observations
	NFSI Moderate Traction Material	11 Observations	11 Observations	11 Observations
	NFSI High Traction Material	11 Observations	11 Observations	11 Observations
Operator 2	NFSI Low Traction Material	11 Observations	11 Observations	11 Observations
	NFSI Moderate Traction Material	11 Observations	11 Observations	11 Observations
	NFSI High Traction Material	11 Observations	11 Observations	11 Observations

4.5.2 Data shall be collected for a single tribometer testing the designated material while rotating the operator. Operator 1 shall conduct the first test, Operator two the second test, Operator 1 the third test and so forth. Operator 1 shall collect all of the odd data points between 1 and 22 for a tribometer/material combination and operator two shall collect all the even observation between 1 and 22.

4.5.3 The neutral third-party observer shall confirm that each laboratory is conducting measurements in accordance with the methodologies set forth in the walkway tribometer supplier's operating manual and in compliance with ANSI/NFSI Standard B101.1-2009.

4.5.4 The neutral third-party observer shall record all data on standard data collection forms provided by the NFSI.

4.5.5 The NFSI recognizes that mistakes can be made in measuring walkway traction. As such, the operator (without external coaching) may elect to exclude an observation prior to receiving visual or other sensory feedback about the measurement. Once the value from the observation is known to the user, the value may not be excluded from the data set. It is the responsibility of the third-party observer to decide when an observation may or may not be excluded.

4.5.6 A single data collection sheet shall be utilized for each of the three (03) standard surfaces. The neutral third-party observer shall sign each data collection sheet as an attest to the data collection process. Hard copies of the data collection sheets must be provided to the NFSI upon conclusion of the data collection.

Section 5: Method for Analyzing the Data Collected During a Walkway Tribometer Inter-laboratory Study

Upon receipt of data collection forms signed by the neutral third-party observer, NFSI's designated analyst shall evaluate the submitted data and render an official statement about the instrument/method's performance on the ILS.

5.1 Data Analysis Requirements. To qualify for NFSI recognition as a walkway tribometer, the instrument and method shall perform satisfactorily on the following three components of analysis:

- Validity and Repeatability Pass/Fail Evaluation
- Gage Repeatability and Reproducibility Evaluation
- Statistical analysis for Discriminant Validity Evaluation

5.2 Validity and Repeatability Pass/Fail Evaluation. The NFSI has set-forth a methodology by which the walkway tribometer's validity and repeatability in testing standard materials is evaluated using a Pass/Fail test.

5.2.1 Data Editing. For the pass/fail test, the data set of 66 observations from each of the three (03) materials provided by the NFSI, shall be edited to exclude the two (02) highest readings and the two (02) lowest readings, leaving a net total 62 observations for evaluation for the pass/fail evaluation for each surface material.

5.2.2 Pass/Fail Criteria. Pass/fail criteria have been set forth by the NFSI that are approximately +/- 0.06 SCOF basis points the known value for the tested material. The number was arrived at statistical analysis of empirical data, which revealed that the standard deviation is approximately 0.02 SCOF basis points for all surfaces, irrespective of the material's average SCOF value. This is due primarily to variations on the flooring surface material itself. For the SCOF pass fail test, all readings must fall within +/- three standard deviations from the reference point, which is the arithmetic mean, thus producing a confidence range that is >99%. For example, if the wet SCOF for a material is known to be 0.60, any reading that is between 0.54 and 0.66 shall be designated a "Pass." Any reading that falls outside of these bounds shall be designated a "Fail."

5.2.2.1 Required Confidence Level. The NFSI requires that the pass/fail test shall allow for a five percent (5%) likelihood of a false reading and be statistically accurate at the 95% confidence level.

5.2.3 Pass/Fail Judgment for a Material. A walkway tribometer shall be deemed to "Pass" in its ability to test a particular flooring material if all 62 observations of the wet SCOF for that material fall within the Pass/Fail criteria bounds set forth by the NFSI. The presence of any outlying observations in the edited data shall constitute a "Fail" for the tribometer in evaluating the material in question.

5.2.4 Pass/Fail Judgment for a Walkway Tribometer Methodology. A walkway tribometer method shall be deemed to "Pass" if all observations made by each of the six (06) laboratories on each of the three (03) standard designated flooring materials fall within the pass/fail criteria set forth by the NFSI. The presence of any outlying observations in the edited data set shall constitute a "Fail" for the tribometer methodology for the Pass/Fail evaluation.

5.3 Gage Repeatability and Reproducibility Analysis. Gage Repeatability and Reproducibility Analysis (Gage R&R) shall be conducted in accordance with ASTM F1469-11 – Standard Guide for Conducting a Repeatability and Reproducibility Study on Test Equipment for Nondestructive Testing, with the following modifications:

5.3.1 The standard is set up to test "N" number of standard parts by three (03) operators over two or more trials. For verifying the R&R of a walkway tribometer, the study is set-up to evaluate three (03) tribometers operated by two (02) operators to test each of the three (03) NFSI reference materials. For each tribometer/operator/material combination, "N" observations shall be made and N=11. Refer to appendix two for the Gage R&R test design.

5.3.2 ASTM F1469-11 sets forth Gage R&R limits not to exceed ten percent (10%). Due to the safety-oriented nature of walkway tribometry for auditing the slip-resistance of pedestrian walkways, Gage R&R requirements are set at five percent (05%) per the standard calculated method. Refer to appendix two for details pertaining to Gage R&R calculations. If the candidate walkway tribometer's calculated Gage R&R is >5%, the test is designated a "Pass," while failure to do so is designated a "Fail" for the Gage R&R test.

5.4 Statistical analysis for Discriminant Validity Evaluation

5.4.1 The candidate walkway tribometer shall prove its ability to discriminate between the three (03) reference tiles via statistical analysis of variance (ANOVA). A p-value < 0.05 shall constitute a pass (the lower the p-value the better). The ANOVA process is detailed in appendix three (03).

5.4.2 The candidate walkway tribometer shall prove its ability to discriminate between the three (03) reference materials per the statistical analysis methodology set forth in ASTM F2508-11 Standard Practice for Validation and Calibration of Walkway Tribometers Using Reference Surfaces, with the following modifications:

5.4.2.1 The test shall include three reference materials – one of which, the low traction material, is included in ASTM F2508-11. The midrange and high traction materials have been selected by the NFSI.

5.4.2.2 The test shall require 66 observations for each surface, not the 40 specified in ASTM F2508-11.

5.4.2.3 Testing shall be conducted using a lubricant specified in NFSI B101.1, which is distilled water.

5.4.2.4 Testing shall be conducted unidirectionally, not orthogonally as is specified in ASTM F2508-11. This is due to the often extreme degrees of directional bias observed in the reference surfaces, particularly in ASTM RS-D material.

5.5 Waiting Period for Reassessment. In the event that an instrument/method is unsuccessful in its attempt to achieve ILS validation from the NFSI, the supplier may attempt validation after a mandatory waiting period of six (06) months. There is no limit to the number of times ILS validation may be attempted.

Section 6: Report Generated Following Data Analysis for a Walkway Tribometer Inter-laboratory Study

For each instrument/method's submission, a confidential report shall be submitted to the sponsoring organization. The report shall serve to state whether or not the instrument/method passed or failed the NFSI ILS for a Walkway Tribometer. The report shall contain the following details and analysis.

1. A clear statement and summary of the overall Pass/Fail status for the walkway tribometer.
2. Details related to each of the following sections:
    a. Validity and Repeatability Pass/Fail Evaluation
    b. Gage Repeatability and Reproducibility Evaluation
    c. Statistical analysis for Discriminant Validity Evaluation
3. Observer recommendations for improving performance, whether the ILS is designated a "Pass" or "Fail."

Section 7: Term of Validation

7.1 Standard Term of Certification. If successfully validated by the NFSI inter-laboratory study method, the instrument/method's certification of ILS validation shall be valid for a period of five (05) years, after which to retain its certificate of validation, the instrument must be revalidated according to the then current methodology set forth by the NFSI.

7.2. Provision for Design Change. Any change in the design of a walkway tribometer instrument and/or method that materially alters the core method for measuring the wet SCOF of a walkway material invalidates the certification of ILS validation and the new instrument/method shall require revalidation.

Appendix 1 – Logic for Pass/Fail Analysis for Establishing Repeatability of a Walkway Tribometer

The NFSI opted to use a pass/fail test to establish repeatability of a walkway tribometer. To pass, each laboratory must produce 60 reading that fall within the range specified by the NFSI for a given tile. The logic for requiring 60 observations that fall within the specified range is based upon the following standard equation for determining the sample size of a pass/fail test.

$$n = \frac{\ln\left(1 - \frac{c\%}{100\%}\right)}{\ln\left(1 - p\right)}$$

Where:

n = The required number of observations without a "failure," which is an observation that falls outside of the specified parameters
ln = log normal
c% = The required confidence level, in our case 95%
p = Specified p-value – in our case, 0.05

For the pass/fail portion of the ILS for walkway tribometers, the equation is as follows:

$$n = \frac{\ln\left(1 - \frac{95\%}{100\%}\right)}{\ln\left(1 - 0.05\right)} = 58.40$$

The resultant value of 58.40 was rounded to 62 for the purpose of simplicity in the experimental design – a slightly more conservative requirement than that produced by the standard equation. To circumvent complications associated with data editing, it was decided to require a total number of 66 observations per laboratory per tile type. The highest two and lowest two readings are automatically excluded by the data analyst. If the remaining 62 observations fall within the parameters set forth by NFSI for the pass/fail test, the specified laboratory passes for the specified tile. If all laboratory/tile combinations pass, the walkway tribometer passes the pass/fail portion of the ILS to establish repeatability.

Appendix 2 – Gage R&R Analysis per ASTM F1469-11

Completion of the Gage R&R analysis shall be conducted per the following form, which includes example data and appropriate equations to compute age R&R. Each from summarizes the data collected for all the six designated laboratories. One form shall be completed for each surface.

NFSI ILS	Tribometer Under Evaluation					Observer: Drew D. Troyer, CRE					Date: April 4, 2010			
Reference Material:		**NFSI Low Traction**				Reference Value:			0.214					
	Tribometer A					**Tribometer B**					**Tribometer C**			
Sample	*Op 1*	*Op 2*		Range		*Op 1*	*Op 2*		Range		*Op 1*	*Op 2*		Range
1	0.22	0.22		0		0.21	0.21		0		0.22	0.21		0.01
2	0.21	0.21		0		0.21	0.2		0.01		0.22	0.21		0.01
3	0.21	0.21		0		0.2	0.2		0		0.2	0.2		0
4	0.21	0.2		0.01		0.2	0.2		0		0.21	0.2		0.01
5	0.21	0.22		0.01		0.2	0.2		0		0.2	0.2		0
6	0.21	0.2		0.01		0.19	0.2		0.01		0.19	0.19		0
7	0.21	0.2		0.01		0.2	0.19		0.01		0.2	0.19		0.01
8	0.21	0.2		0.01		0.19	0.19		0		0.2	0.19		0.01
9	0.2	0.21		0.01		0.19	0.19		0		0.19	0.18		0.01
10	0.2	0.2		0		0.19	0.18		0.01		0.19	0.19		0
11	0.2	0.2		0		0.19	0.18		0.01		0.19	0.18		0.01
ΣA1 =	2.29		Avg R, A =	0.005	ΣB1 =	2.17		Avg R, B =	0.005	ΣC1 =	2.21		Avg R, C =	0.006
ΣA2 =		2.27			ΣB2 =		2.14			ΣC2 =		2.14		
ΣA =	4.56				ΣB =	4.31				ΣC =	4.35			
Avg A =	0.207273				Avg B =	0.195909				Avg C =	0.197727			

Avg R, A =	0.005
Avg R, B =	0.005
Avg R, C =	0.006
Σ Avg R - A, B, C =	0.016
Overall Avg R =	0.005

Overall Avg R	x	**D-4 =**	**UCL-R**
0.005	x	3.27	0.018

Upper Limit =	0.182
Average =	0.200303
Upper Limit =	0.218

Avg, A =	0.207273
Avg, B =	0.195909
Avg, C =	0.197727
Overall Avg =	0.200303
Max Avg =	0.207273
Min Avg =	0.195909
Avg Dif =	0.011364

Gage R&R Results:

Operator Variation (O.V.) =	0.024873
Tribometer Variation (T.V.) =	0.03022
Repeatability and Reproducibility (R&R) =	0.03914
% O.V. =	0.50%
% T.V. =	0.60%
% R & R =	0.78%
Critical Value for % R&R <	5%

Status	Pass

Observer Signature:

Equations:

$$O.V. = (Overall\ Avg\ R \times 4.56)$$

$$T.V. = \sqrt{(Avg\ Dif \times 2.7)^2 - \left(\frac{(O.V.)^2}{22}\right)}$$

$$R\&R = \sqrt{(O.V.)^2 + (T.V.)^2}$$

$$\%\ O.V. = 100\left[\frac{O.V.}{5}\right]$$

$$\%\ T.V. = 100\left[\frac{T.V.}{5}\right]$$

$$\%\ R\&R = \sqrt{(\%\ O.V.)^2 + (\%\ T.V.)^2}$$

Appendix 3 – Analysis of Variance (ANOVA) to Establish Reproducibility for a Walkway Tribometer

Overview

Analysis of Variance, or ANOVA, is a statistical technique employed to differentiate and analyze the significance of systematic variation relative to random variation observed in a sample data set. For the purposes of validating a walkway tribometer under the NFSI Interlaboratory Study (ILS) method, our objective is to ensure that the walkway tribometer can differentiate between the three reference surfaces with a high degree of statistical significance.

Significance to Walkway Tribometer Measurement

If a walkway consistently reads high on the NFSI low traction material and consistently reads low on the NFSI medium traction material or the walkway tribometer produces inconsistent results, the possibility of a false positive or false negative decision is possible.

Method

ANOVA employs the Fisher Test, more commonly called the F-Test, which is based upon the Fisher Distribution first developed in the 1920s by Sir Ronald A. Fisher. The F-Test is the ratio of systematic variation to total variation. The result is reported as the p-value, which denotes the probability that the group responsible for systematic variation is the same as the larger sample population. As with most statistical techniques, the p-value penalized when the study includes a small number of observations. A larger sample size affords more "degrees of freedom" to the analysis. For the purpose of the walkway tribometer ILS to test the instrument's ability to differentiate between the three NFSI reference materials, a p-value > 0.05 represents a "Fail" condition for the test.

Example ANOVA

Groups	*Count*	*Sum*	*Average*	*Variance*
Low COF Surface	66	13.22	0.200303	0.000105
Medium COF Surface	66	25.55	0.387121	0.000101
High COF Surface	66	51.11	0.774394	0.000293

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11.31815	2	5.659077	34087.95	7.6E-249	0.695617
Within Groups	0.032373	195	0.000166			
Total	11.35053	197				

Appendix 4 – Determining Discriminant Validity per the Modified ASTM F 2508-11

ASTM F2508-11 requires a one-tailed t-test to verify that the tribometer can differentiate between reference materials at the 0.05 level of significance.

1. In a pairwise fashion, calculate the difference between each reading for the low traction material and the medium traction material and then for the medium traction material and the high traction material. For example, if the SCOF for observation one for the low traction material was 0.21 and reading one for observation one of the medium traction material is 0.38, then the difference for observation one equals 0.17.
2. Calculate the average of the differences (d_m) between the low and medium traction materials and for the medium and high traction materials.
3. Calculate the standard deviation for the both sets of differentials.
4. Calculate the t-statistic:

$$t = \frac{dm}{SD/\sqrt{N}}$$

Where:

d_m = the mean difference, that is, the sum of the differences of all data points (low coefficient measurement 1 – medium coefficient of measurement 1,….) divided by the number of pairs (66).

SD = The standard deviation of the differences between all the pairs.

N=The number of observations (66).