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Repeatability of Friction Measurement Devices in Self-Wetting Mode

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MFT
Mobility Friction Technology AS

CDRM Inc
1911 East College Avenue
P.O. Box 1277
State College, Pennsylvania, 16804, USA

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by

Arild Andresen

MFT AS

and

Dr. James C. Wambold

Dr. J. J. Henry

CDRM, Inc

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Project Team

Arild Andresen, Consultant, MFT Mobility Friction Technology AS
Dr. John J. Henry, PhD., Consultant, CDRM Inc
Dr. James C. Wambold, PhD., Consultant, CDRM Inc

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16. Abstract

A series of tests to establish repeatability values for several friction measurement devices was conducted at the 8th Annual Tire/Runway Friction Workshop at NASA Wallops Flight Facility in May 2001. The study determined average reported friction values, standard deviation, standard error, coefficient of variation and range of variation for nine friction measurement devices in self-wetting mode on 12 different runway and taxiway surfaces.

The results of this study show that repeatability statistics depend on the friction pair: the friction measurement device and surface. An overall average coefficient of variation of 5 percent was determined for the participating devices and the surfaces measured. For all wetted pavement surfaces measured, a standard deviation of 0.027 of mixed units of friction measurements was achieved.

Harmonization to a common unit of friction measurement, such as the International Friction Index, is suggested before calculating repeatability statistics on wet pavement.

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CDRM Inc.
P.O. Box 1277
State College, PA
USA 16804

MFT Mobility Friction Technology
Oberst Rodes Vei 896
1165 Oslo
Norway

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16. Résumé

Plusieurs instruments de mesure du coefficient de frottement ont été soumis à une série des tests visant à déterminer leur répétabilité, à l'occasion du 8e atelier annuel de la NASA sur le frottement des pistes, au Centre de vols spatiaux des îles Wallops (NASA), en mai 2001. L'étude visait à déterminer les coefficients moyens de frottement, l'écart type, l'erreur type, le coefficient de variation ainsi que la plage de variation observés sur neuf appareils de mesure du frottement utilisés en mode d'arrosage automatique sur 12 pistes et voies de roulement différentes.

Selon les résultats de l'étude, les statistiques de répétabilité sont fonction du couple de mesure que constituent l'appareil de mesure et la surface de la piste. Un coefficient de variation moyen global de 5 p. cent a été établi pour les appareils utilisés et les surfaces mesurées. Pour toutes les surfaces mouillées soumises aux mesures, on a réalisé un écart type de 0,027 des unités de mesure du frottement.

Avant de procéder au calcul de statistiques de répétabilité dans le cas des mesures des chaussées mouillées, il est recommandé d'adopter une unité commune harmonisée de mesure du frottement, par exemple l'Indice international de la glissance des pistes (IRFI).

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EXECUTIVE SUMMARY

Measuring the capability of a runway surface to provide aircraft wheel-braking action is fundamental to airport aviation safety, especially during winter conditions. The different seasons, mainly winter, result in the possibility of the runway having contaminants of varying natures and qualities that contribute significantly to reduced braking friction capabilities. Because the operational window for aircraft movement can change quite rapidly in the wintertime, a service is warranted for measurement of surface friction.

Measurements of friction were not calibrated to a common scale in the past. Also, being a non-dimensional ratio of forces (some coming from a fore transducer and some coming from a torque transducer), they were never associated with units of a scale, which could be another reason for the resulting differences. Ultimately, dynamic friction measurement results in the best accuracy, but the procedure has been limited to machine component calibrations. Research over the past four years has made significant advances to ward solving these problems. Methods of measurement and correlation of equipment are being improved to increase measurement quality and remove the uncertainties.

This study was part of a government/industry project called the Joint Winter Runway Friction Measurement Program (JWRFMP), led by Transport Canada and the U.S. National Aeronautics and Space Administration (NASA). Support was received from National Research Council Canada, the U.S. Federal Aviation Administration, the Norwegian Civil Aviation Authority and France's Direction générale de l'aviation civile. Organizations and equipment manufacturers from Austria, Canada, France, Germany, Norway, Scotland, Sweden, Switzerland, and the United States also participated.

The field tests and data for this study were provided by the participants of the 8th annual NASA Tire/Runway Friction Workshop, which took place at NASA Wallops Flight Facility in May 2001. The repeatability findings are therefore linked to the condition of the surfaces of the NASA Wallops Flight Facility at Chincoteague, Virginia, USA, at the time of testing.

As friction measurements have no fundamental calibration reference, the repeatability parameters are associated with the friction measurement device/surface pair. The repeatability findings of a device for one surface do not apply for another surface. Many surfaces must therefore be measured by a friction measurement device to obtain a better view of repeatability for the device. This study obtained practical values of repeatability for reported friction values on several runway and taxiway surface types for each participating friction measurement device.

It was generally found that the repeatability of the participating friction measurement devices in self-wet mode yielded an average repeatability expressed as a standard deviation of 0.027 friction units as a coefficient of variation of 5 percent.

Significant differences of repeatability statistics were found between different friction measurement devices for the same surfaces. To a large extent this is explained by the different units of friction measurement that the devices report to. One indication of this is the wide range of average friction values each device produced for a surface. As a rule of thumb, the range was found to be two thirds of the averaged friction value of the group of devices. If the average friction value for a surface by the group of devices was 0.60, the difference between a device reporting the lowest average friction value and a device reporting the highest average friction value for a surface would be 0.40. For a normal distribution, this translates to a group variance of ±33 percent.

Harmonization to a common unit of friction measurement, such as the International Friction Index, is suggested before calculating repeatability statistics for friction measurement devices on wet pavement. Repeatability values would then be more comparable between devices and the range of variability between different devices would become smaller.

If a device were chosen as a physical reference for friction measurement units, the statistics of repeatability as found for different surfaces for that device would apply as a measure of quality of the reference friction measure.

SOMMAIRE

Connaître l'adhérence des pneus d'un avion au freinage est essentiel à la sécurité des opérations aériennes sur les aéroports. En hiver, principalement, les pistes peuvent présenter des contaminants de natures diverses qui réduisent l'adhérence à divers degrés. Les conditions de décollage/atterrissage en hiver peuvent changer très rapidement, et à une fréquence telle que la constitution d'un service aéroportuaire de mesurage de la glissance des pistes est amplement justifiée.

Jusqu'à maintenant, la mesure du frottement n'était pas effectuée de manière uniforme. De plus, les valeurs de frottement n'étant pas exprimées par un ratio dimensionnel de forces (mesurées par un transducteur de force et un transducteur de couple), elles n'ont jamais été associées à des unités figurant sur une échelle, ce qui peut aussi expliquer les différences. À terme, la mesure du frottement dynamique donne une bonne précision, mais la procédure a été limitée à l'étalonnage des composants de la machine. La recherche effectuée au cours des quatre dernières années a cependant accompli des progrès significatifs pour régler ces problèmes. Les méthodes de mesure et la corrélation du matériel sont perfectionnées dans le but d'améliorer la qualité des résultats et d'éliminer les incertitudes.

L'étude faisait partie de l'initiative conjointe gouvernement-industrie appelée Programme conjoint de recherche sur la glissance des chaussées aéronautiques l'hiver (PCRGCAH), sous la conduite de Transports Canada (TC) et de la National Aeronautics and Space Administration (NASA) des États-Unis. Le projet a reçu l'appui du Conseil national de recherches du Canada, de l'U.S. Federal Aviation Administration (FAA), de la Norwegian Civil Aviation Authority et de la Direction générale de l'aviation civile, en France. Ont également participé des organisations et des fabricants de matériel de plusieurs pays : Autriche, Canada, France, Allemagne, Norvège, Écosse, Suède, Suisse, États-Unis.

Les résultats des essais en vraie grandeur ainsi que les données recueillies ont été fournis par les participants au 8e atelier annuel de la NASA sur le frottement des pistes, qui s'est tenu au Centre de vols spatiaux des îles Wallops (NASA), en mai 2001. Les constatations sont reliées aux états de surface des pistes des installations des îles Wallops, à Chincoteague, Virginie, É.-U., au moment des essais.

Comme les mesures du frottement ne sont comparées à aucune valeur de référence de base, les paramètres de répétabilité sont associés au couple appareil de mesure-surface de mesure. Les valeurs de répétabilité obtenues pour un couple donné, c'est-à-dire pour un appareil et la surface contrôlée, ne peuvent pas s'appliquer à une autre surface. Il faut par conséquent mesurer un bon nombre de surfaces avec le même appareil pour obtenir une valeur exacte de sa répétabilité. La présente étude a permis de calculer des valeurs pratiques de répétabilité des mesures de frottement obtenues avec plusieurs types de surfaces de pistes et de voies de circulation pour chaque appareil de mesure évalué.

Il a été généralement constaté que les appareils de mesure du frottement en mode d'arrosage automatique avaient une répétabilité moyenne exprimée comme l'écart type à 0,027 unité de frottement, soit un coefficient de variation de 5 p. cent.

Pour les mêmes surfaces, on a constaté des différences significatives de répétabilité par suite de l'utilisation d'appareils de mesure différents. Cette constatation s'explique en majeure partie par les unités de mesure différentes affichées par les appareils, et elle est confirmée entre autres par la grande plage de valeurs moyennes de frottement obtenue par chaque appareil pour une surface donnée. En règle générale, cette plage englobait les deux tiers de la valeur de frottement moyenne obtenue pour l'ensemble des appareils. Si la valeur moyenne pour une surface donnée était de 0,60, l'écart entre la valeur moyenne la plus basse et la valeur moyenne la plus élevée, pour une même surface, serait de 0,40. En comparaison d'une distribution normale, on obtient, pour le groupe, une variance de ±33 p. cent.

Avant de procéder au calcul de statistiques de répétabilité dans le cas des mesures des chaussées mouillées, il est recommandé d'adopter une unité commune harmonisée de mesure du frottement, par exemple l'Indice international de la glissance des pistes (IRFI). Les valeurs de répétabilité seraient plus comparables entre appareils et on observerait, entre différents appareils, une plage de variabilité plus étroite.

En désignant un appareil donné comme référence matérielle ou étalon des unités de mesure du frottement, les valeurs de répétabilité obtenues avec ce même appareil pour des surfaces différentes seraient considérées comme une mesure de la qualité de la mesure de frottement de référence.

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DEFINITIONS AND NOMENCLATURE

Acronyms

ASTM	ASTM International
CV	Coefficient of Variation
E274	A locked-wheel mode friction measurement device manufactured to and operated per ASTM standard E-274
FAA	Federal Aviation Administration, USA
GRT	GripTester, Findlay Irvine, Scotland
IMAG	Instrument de Mesure Automatique de Glissance
IRFI	International Runway Friction Index
IRV	International Reference Vehicle. A dedicated IMAG device serving as the IRFI reference device for the JWRFMP.
JWRFMP	Joint Winter Runway Friction Measurement Program
NASA	National Aeronautics and Space Administration, USA
NRC	National Research Council Canada
PADOT	Pennsylvania Department of Transportation
RFT	Runway Friction Tester
SFT	Surface Friction Tester
TC	Transport Canada
USAF	United States Air Force
VADOT	Virginia Department of Transportation

Definitions

average friction coefficient, **n.** - The sum of individual friction measurements, μ_i, divided by the number of measurements, *n*. Mathematically expressed as

$$\mu_{avg} = \frac{1}{n} \Sigma(\mu_i)$$

coefficient of variation, **n.** - an adaptation of the standard deviation used to express the variability of a set of numbers on a relative scale rather than on an absolute scale. Mathematically expressed as

$$CV = \frac{StdDev}{\mu_{avg}} \cdot 100\%$$

friction measure, **n.** - the unit of measure of a friction measurement.

friction measurement, **n.** - the measured, processed and reported value of the ratio of braking slip friction force in the tire-surface contact plane to the tire load force acting through the test wheel axis and normal to the contact plane. Mathematically expressed as

$$\mu = \frac{F_{brakingslip}}{F_{normaltireload}}$$

friction measurement device configuration, **n.** - a term used to designate the entire test system as used for any friction measurement. It includes, but not is limited to, type of device (force or torque measurements), tire type, size and inflation pressure, slip ratio, normal load and braking system control mode.

harmonization, **n.** - the transformation of the measured outputs of different devices used for measurement of a specific phenomenon so that all devices report similar values.

IRFI reference device, **n.** - a particular friction measurement device selected as a benchmark or reference. It is used to calibrate other friction devices to permit their measurements to be converted to IRFI values.

repeatability, **n.** - the ability of a measurement device to produce the same measured value when measurement runs are repeated on the same surface under the same conditions.

standard deviation, **n.** - a measure of dispersion about a mean value, calculated as the square root of the squared sum of the difference of each measured friction value relative to the arithmetic mean friction value, divided by the number of measurements less one. Mathematically expressed as

$$StdDev = \sqrt{\frac{\sum_{i=1}^{n} (\mu_i - \mu_{avg})^2}{n-1}}$$

standard error, **n.** - the standard deviation divided by the square root of the number of samples. Mathematically expressed as

$$StdErr = \frac{StdDev}{\sqrt{n}}$$

1 INTRODUCTION

Measuring the capability of a runway surface to provide aircraft tire braking action is fundamental to airport aviation safety, especially under winter conditions. The different seasons, mainly winter, result in the possibility of the runway having contaminants of varying natures and qualities that contribute significantly to reduced braking friction capabilities. In addition, because the operational window for aircraft movement can change quite rapidly and frequently in the winter, a service is warranted for the measurement of surface friction. The measured results of such services have had serious deficiencies, which have been acknowledged by experts worldwide.

The equipment used and procedures followed in measuring winter surfaces report noncalibrated values with respect to a common unit of measure of surface friction. A value from one type of device at one airport does not provide the same information as a value from another device operated at another airport, even if the two devices are of the same type. In general, a simple transformation of measured values from one device to another has not been possible in the past.

In 1996, a multi-year government/industry study, called the Joint Winter Runway Friction Measurement Program (JWRFMP), was initiated by Transport Canada (TC) and the U.S. National Aeronautics and Space Administration (NASA), with support from National Research Council Canada (NRC), the U.S. Federal Aviation Administration (FAA), the Norwegian Civil Aviation Authority,[1] and the French Civil Aviation Administration.[2] Also participating were organizations and equipment manufacturers from Austria, Canada, France, Germany, Norway, Scotland, Sweden, Switzerland, and the United States. The primary objective is to perform instrumented aircraft and ground vehicle tests aimed at improving the safety of aircraft ground operations. With this goal in mind, related studies were conducted to look at the harmonization of ground vehicle friction measurement. Harmonization will enable friction data to be reported to a unified common index worldwide, which will then be used to predict aircraft braking performance. This report addresses the repeatability of some of the ground friction measurement equipment.

It is expected that dissemination, acceptance, and implementation of the ASTM E 2100 test method throughout the aviation community will be facilitated by several organizations. These include the International Civil Aviation Organization, ASTM International (ASTM), the Joint Aviation Authority, the International Federation of Air Line Pilots Association, the Air Line Pilots Association, the Air Transport Association, and Airports Council International.

[1] Luftfartsverket, Hovedadministrasjonen, Oslo, Norway
[2] Direction générale de l'aviation civile (DGAC), Paris, France

2 PROGRAM OBJECTIVE AND STUDY OBJECTIVE

In cooperation with other researchers from TC, NRC, NASA, and the FAA, the objective is to establish a method to allow airports, countries, regions and manufacturers to correlate their equipment and thus harmonize all ground friction measurements so that the common values can be reported and used by airports around the world.

The study objective is to establish repeatability statistics for several continuous friction measurement devices in self-wetting mode that participated in the 8th annual NASA Wallops Workshop.

3 SCOPE OF THE STUDY

3.1 The Understanding of Repeatability

The ability of a friction measurement device to produce the same measured value of the same surface, when measurement runs are repeated under the same conditions, is called the repeatability of the device. This ability is also known as precision.

Methods of comparing devices with respect to their different units of measurements and correlating them to report nearly the same value are called harmonization methods.

The ability of several different devices of the same brand, type and configuration to report the same friction value for the same surface is called reproducibility.

Within the JWRFMP, harmonization and reproducibility are addressed in several reports. Other work by the authors of this report on these topics can be found in [1] and [2].

The units of friction measurement are unique for a device and generally there is no fundamental calibration reference for friction measures. A deviation from a calibration reference is called bias. With no calibration reference available, bias cannot be established for friction measurement devices. Either a given device needs to be accepted as the reference or in some cases the average of many devices is used as the reference. In this report friction values are friction coefficients, a decimal notation with two significant figures after the decimal point.

Repeatability is device specific. The repeatability measures may be used to compare the performances of different devices or to evaluate the performance history of a device.

One should always keep in mind that a friction measurement is a product of a tire-surface interaction. The reported friction value is an indicator of the interaction process, not of the surface or the device alone. The repeatability findings of a device for one surface may not apply for another surface. By studying repeatability of a device for several kinds of surfaces, one may obtain typical reference measures of repeatability, but care must be exercised in using such reference values for other device-surface pairs.

When friction measurement devices make repeated runs of the same surface segment following the same wheel track as closely as possible, the average reported friction values for that segment for all runs are compared. The measure of variance across all repeated runs for a surface segment is called repeatability.

For a friction measurement device, any repeatability measurements will include some variance stemming from surface texture and surface material. This surface variance comes from the fact that the surface is not completely uniform and is subjected to wear from use and/or weathering. Also, different wheel tracks may be measured and in some cases the measurement changes the surface.

No attempt has been made to separate the surface variance from the device variance, as there is no method or standardized procedure available for that.

A repeatability value of a friction measurement device is obtained for one surface at a time. The repeatability value is specific for that surface. To get a more general appreciation of repeatability for a device, one must obtain repeatability measures for several different surfaces.

3.2 Field Tests

3.2.1 Field Test Data from 8th Annual Tire/Runway Friction Workshop

The data for this study has been provided by the participants of the NASA sponsored 8th Annual Tire/Runway Friction Workshop, which took place at NASA Wallops Flight Facility in May 2001.

The database comprises measures from eight different friction measurement devices operated in self-wetting mode as listed in Table 1. The surfaces measured included surfaces A through F and S-6 on runway 04/22, surfaces L and M-2 on taxiway 04/22, and surfaces K0 and K on taxiway 10/28. In addition, a string of aluminium plates, temporarily mounted on taxiway 04/22, was measured. Schematics of the surface locations and geometries are given in Appendix D. All devices used their self-wetting and each ran a separate track, rather then all running the same track. This was done to avoid water buildup on the surfaces. All devices made each run in a group, following each other with one minute between devices. All runs were made in one direction only and then the entire group returned to start another run. This was done to avoid the affect of texture on direction and to allow time between runs to prevent water buildup. In addition, the surfaces were washed with a water truck before runs were started to minimize the effect of any change of starting from a dry pavement and the effect of washing with each run. Texture measurements were measured by several devices before the surfaces were wetted. They reported mean texture depth, mean profile depth and outflow time. Values are reported in the NASA database and in the NASA Wallops Workshop reports.

The data used in this study was extracted from the computerized NASA Contractor JWRFMP Field Test Friction database available as an MS Access[3] database type.

Table 1 - Participating friction measurement devices

Device Description	Tire Type and Inflation Pressure	Device Code
IRFI-International Reference Vehicle (IRV) (15% slip)	PIARC Smooth Tread 150 kPa (22 psi)	IMAG-IRV-PIARC-22
GripTester operated by NASA (12% slip)	ASTM E-1844 138 kPa (20 psi)	GRT-211-E1844-20
Surface Friction Tester operated by TC (15% slip)	ASTM E-1551 690 kPa (100 psi)	SFT-TC85-E1551-100
GripTester operated by USAF (12% slip)	ASTM E-1844 138 kPa (20 psi)	GRT-033-E1844-20
Runway Friction Tester operated by FAA (15% slip)	ASTM E-1551 690 kPa (100 psi)	RFT-FAA-E1551-100
Skiddometer BV-11 operated by FAA (15% slip)	ASTM E-1551 690 kPa (100psi)	BV11-196-E1551-100
Surface Friction Tester operated by FAA (15% slip)	ASTM E-1551 690 kPa (100 psi)	SFT-212-E1551-100
ASTM E-274 trailer operated by VA DOT (100% slip)	ASTM E-524 165 kPa (24 psi)	E274-VDOT-E524-24
ASTM E-274 trailer operated by PA DOT (100% slip)	ASTM E-524 165 kPa (24 psi)	E274-PDOT-E524-24

[3] Trademark of Microsoft Corporation

3.2.2 Field Test Procedures

Each device conducted a minimum of five repeat runs, and in most cases ten repeat runs, over each surface segment at target speeds of 65 km/h (40 mph) and 100 km/h (65 mph).

The ASTM E 1551 test tire has a standard operating inflation pressure of 207 kPa (30 psi). For an improved contact pressure distribution on surfaces with non-rigid contaminants, the E 1551 tires were inflated to 690 kPa (100 psi) in conformance with the standard practice of the JWRFMP.

3.2.2.1 A note on device codes

The device code should be read as the device type abbreviation, followed by its manufacturer's serial number when known, or an abbreviation for the current owner, followed by the test tire type, and lastly, the test tire inflation pressure in psi. For example, E274-PDOT-E524-24 is an ASTM E-274 trailer owned by the Pennsylvania Department of Transportation using an ASTM E-524 test tire at an inflation pressure of 24 psi.

The devices were operated at their standard settings, except for inflation pressures of the SFT and RFT, where the pressure had been increased from 30 psi to 100 psi.

3.2.2.2 A note on surface codes

The surfaces at the NASA Wallops Flight Facility are designated with letters and numbers. Each letter implies a unique surface material. Texture gradation within a surface material may vary and is often designated with a number. Wide runway surfaces are subdivided laterally into four parts. A number designates each lateral position. The numbering starts from east with 1. Compass direction of the direction of measurement is indicated as the last number suffix of the surface segment code. For example, on runway 04/22 a suffix – 04 means that the surface was measured in the 04 direction (going north).

Schematics of surface locations, designations and geometries are given in Appendix D.

4 DATA AND ANALYSIS

4.1 Calculated Repeatability Statistics

As measures of repeatability, a group of common descriptive statistics may be employed. A brief overview of these statistical terms is given in the following sections.

4.1.1 Standard Deviation

The standard deviation expresses how much the repeated friction values deviate from the arithmetical mean, or average, of all the measurements. The unit of measure is the friction units of the friction measurement device. It is designated as StdDev in this report. The standard deviation is a function of the average value. The average value and standard deviation are often given as companion values and are the basis for the calculations of coefficient of variation and standard error.

4.1.2 Coefficient of Variation

The coefficient of variation (CV) is the standard deviation divided by the average friction value. It is a measure of friction variability per friction unit; therefore, it depends on the average friction value or friction level. The CV value per friction unit is multiplied by 100 to express it in percent. It is designated CV % in this report.

4.1.3 Standard Error of Measurements

The standard error is the standard deviation divided by the square root of the number of friction measurements. It is a measure of friction variability per number of repeated measurements. With the square root function, however, the effect of the number of runs is disproportional and diminishing with increasing number of repeated measurements. It is designated as StdErr in this report.

4.1.4 Range of Variability

The difference between the maximum and minimum measured values is called the range of variation. It is expressed in the device units of friction. It is designated *r* in this report.

4.2 A Case of Descriptive Statistics for Repeatability

This section demonstrates the repeatability statistics of one surface segment as computed and analyzed in this report.

Since friction measurement devices have unique units of measurement, the reported values will be different by different devices for the same surface. These differences are caused by differences in design of the devices, different mechanical and instrumental states (wear of parts, lubrication, instrumentation set-up, self-wetting dispensing and control) and variability of the field test (different tow vehicles, different operators, different surface tracks, ambient environment changes).

A sample illustration of the differences among devices with respect to friction measures are shown in Figure 1. The highest average friction value was 0.38 and the lowest average friction value was 0.15, giving a range of variability equal to 0.23 friction units. The averages per device were calculated from 10 repeated measurement runs across the surface. The average friction value of all devices was 0.28.

In Figure 1, the devices are sorted by descending average friction value from left to right. The position of each device on the category axis is kept the same for all subsequent statistics charts related to the same surface segment.

Surface segment K-10 is a medium texture surface and therefore the higher slip devices, such as the E-274 locked-wheel trailer, would be expected to read lower than the others.

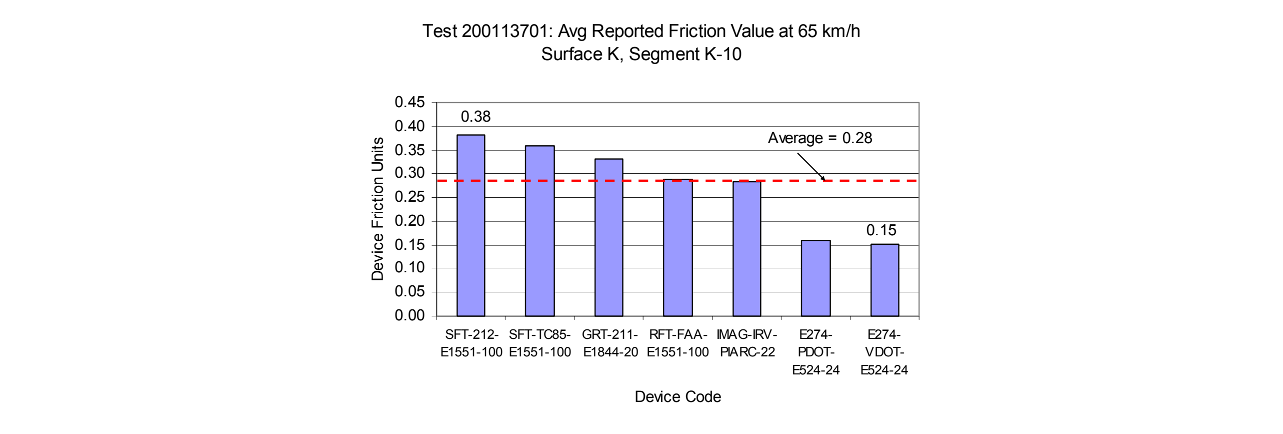


Figure 1 - Reported friction values for the same surface by seven different devices

The corresponding chart of standard deviations for the case depicted in Figure 1 is shown in Figure 2. The highest standard deviation was 0.039 and the lowest was 0.008. The average for all devices was 0.020.

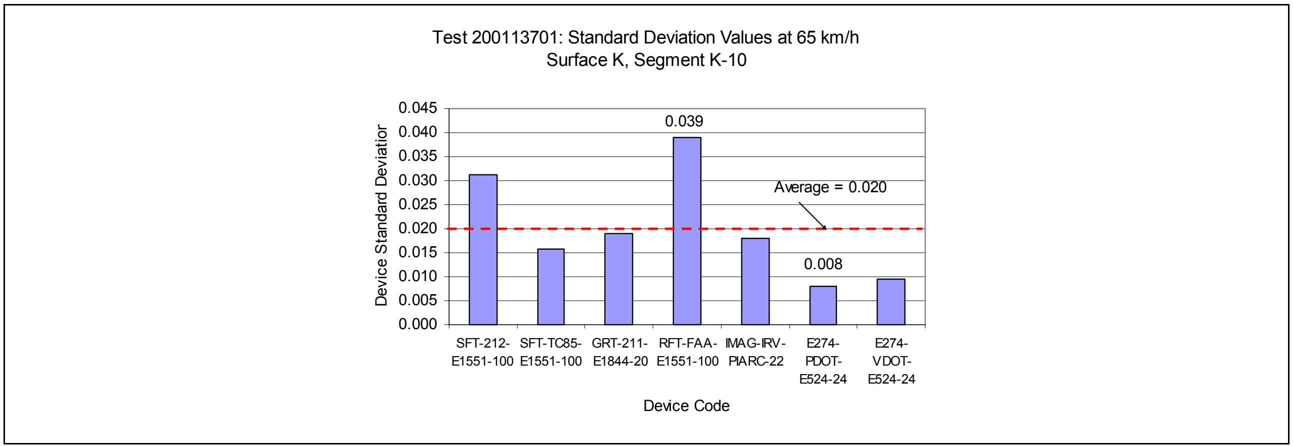


Figure 2 - Standard deviations for the measurements of Figure 1

The coefficients of variation for the same case are shown in the bar chart of Figure 3. The CV ranges from a high of 13.5 percent to a low of 4.4 percent with an average of 7.1 percent. It should be noted that the CV values for the devices that had the lowest average friction values have moved up relative to those that had the highest friction values reported.

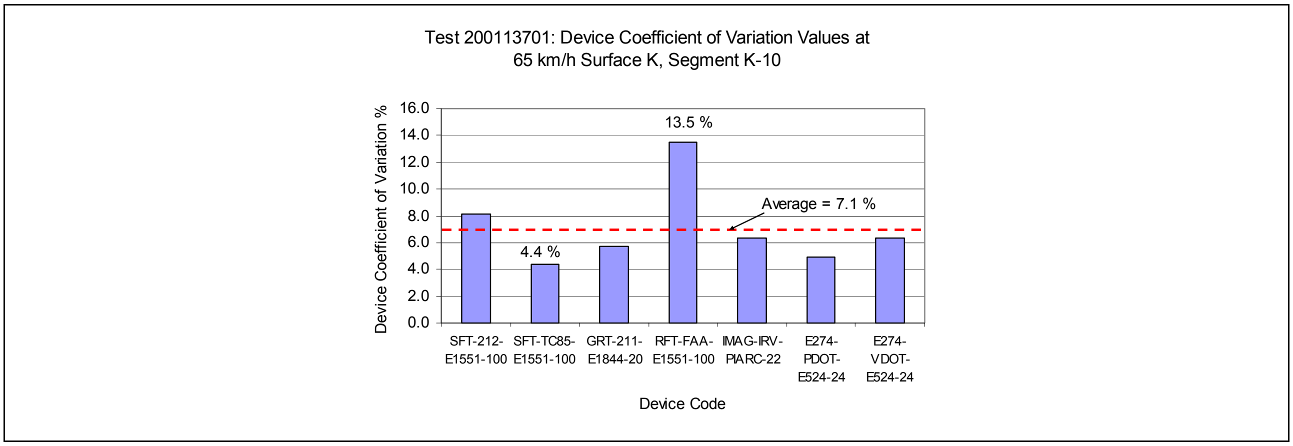


Figure 3 - Coefficients of variation for the measurements of Figure 1

The standard error for each device of the sample case is shown in Figure 4. The standard error ranges from a high 0.017 value to a low 0.0035 value. The average standard error across the devices was 0.010.

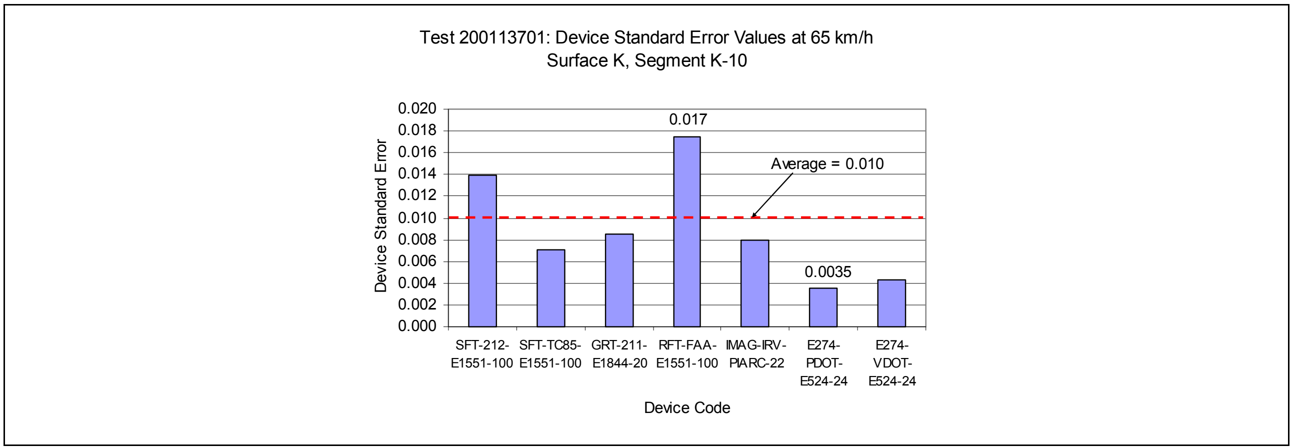


Figure 4 - Standard errors for the measurements of Figure 1

The variability range for each device is shown in Figure 5. The smallest range was 0.02 device friction units and the largest range was 0.08 device friction units.

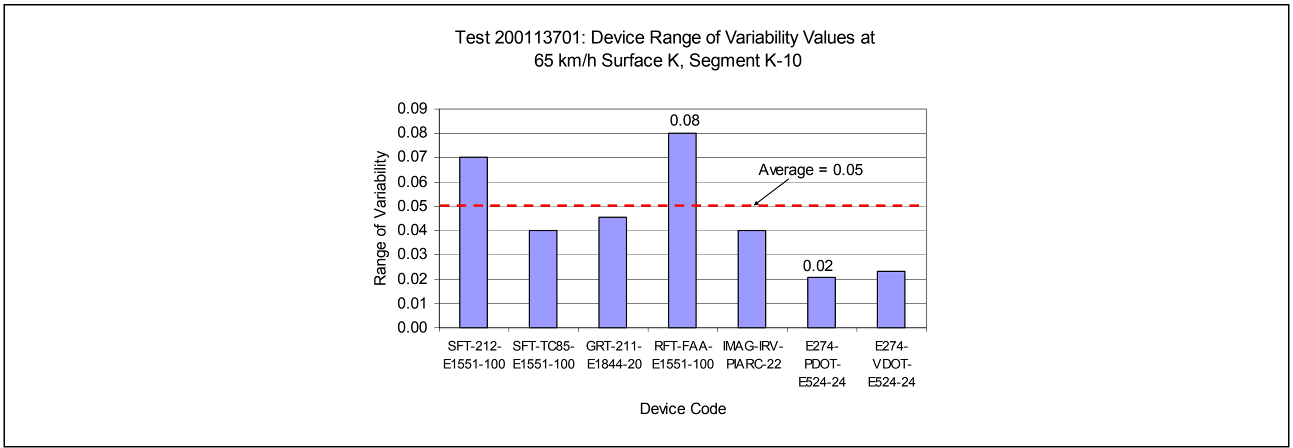


Figure 5 - Variability range for the measurements of Figure 1

4.2.1 The Utility of Each Statistic of Repeatability

The standard deviation is in absolute friction units of the device. It is not a function of the friction level being measured. This is an adequate statistic when evaluating one surface object at a time.

To evaluate the interactions with several surface objects, the coefficient of variation offers a normalized measure per unit of friction reported by the device. The CV is therefore better suited for a general repeatability characteristic across different surfaces and measuring speeds. Reported friction values decrease with increasing speed on wet pavement (i.e., different friction levels are reported at different speeds for the same surface object).

The standard error is a transformation of the standard deviation to reflect the number of repeated measurements. Trends of device stability may be observed, because the number of runs also implies elapsed time due to the manner in which the field tests were executed. The standard error is also helpful in comparing different cases, which have different numbers of repeat runs.

The variability range shows the range of variability between the extreme values measured in device friction units.

It is always beneficial to include an average result of the group of devices when evaluating several devices in order to determine whether device performance is above or below average. The average for a group of devices may be a yardstick for comparisons, but since this average is based on a mix of friction units, caution must be exercised in interpreting the average value for a group. A more useful group average will be obtained if the reported friction values by each device are transformed to a common unit of friction measurement. The group averages of repeatability statistics in this report are useful for demonstrating the need for common units of friction measurements.

Common for all the statistics is that small values indicate better performance than larger values.

4.3 Discussion of Workshop Results

4.3.1 Computed Repeatability Statistics

Results from the 8th NASA Tire/Runway Friction Workshop 2001 are included in tabulated form in Appendix A. The results are illustrated in bar charts organized for each surface segment in Appendix B. The reader may interpret these charts as demonstrated in section 4.2.

Figures 6 to 12 are summary charts by each device code for all surface segments the device measured. Data for the runway surfaces of the IMAG-IRV device has been excluded in these charts, since the test time and field test procedures deviated from the time and procedures of the other devices. Tests were made on three different tracks and therefore there is a large variation due to the surfaces that is not representative of the device (all IMAG-IRV data is included in the attachments).

4.3.2 Summary Charts for Surface Groups Measured by Device

Figure 6 shows the standard deviations for surfaces on runway 04/22 measured at 65 km/h. All devices did not measure all surfaces, but the average, as indicated by a dotted line, is nevertheless a useful yardstick to differentiate well-performing devices from devices with a potential for improvement.

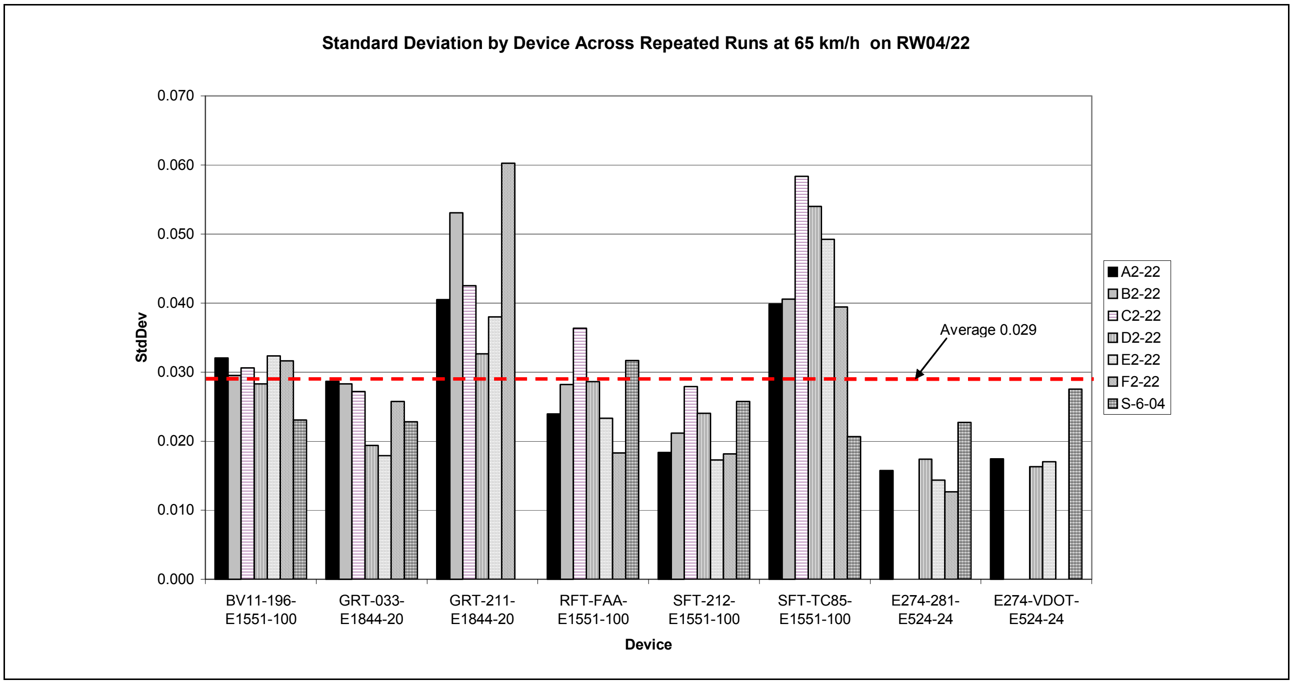


Figure 6 - Standard deviations for all runs at 65 km/h on the surface segments of runway 04/22

Figure 7 shows the coefficients of variation for the same set of runway runs as Figure 6. The average CV value of the group of devices was 4.7 percent. The best device, SFT-212, achieved 3.2 percent.

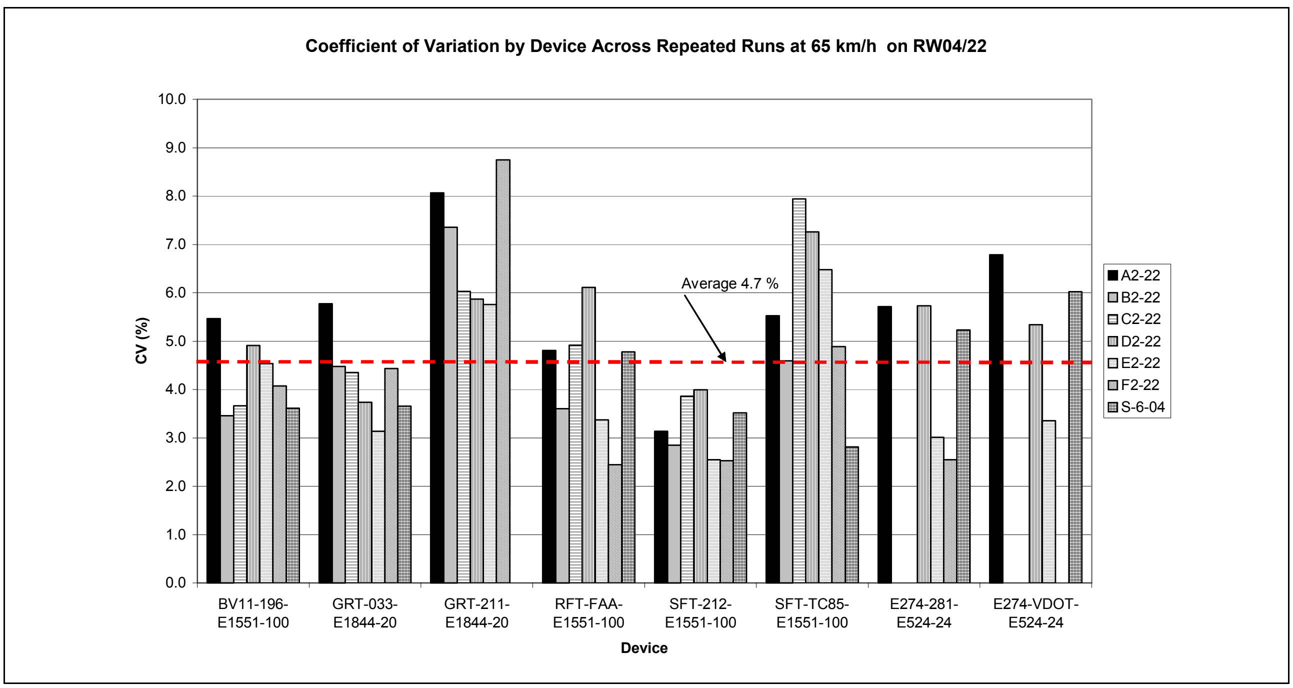


Figure 7 - CVs for all runs at 65 km/h on the surface segments of runway 04/22

The runway surfaces were measured at target speeds of 65 km/h and 100 km/h. The set of high-speed runs was less comprehensive than the low-speed set. Figure 8 shows the standard deviations produced at 100 km/h and Figure 9 shows the corresponding CV values. A comparison of the bulk figures is less meaningful due to the dissimilarity of the data sets. Instead, the reader should consider consulting Appendix B for plots by surface segment.

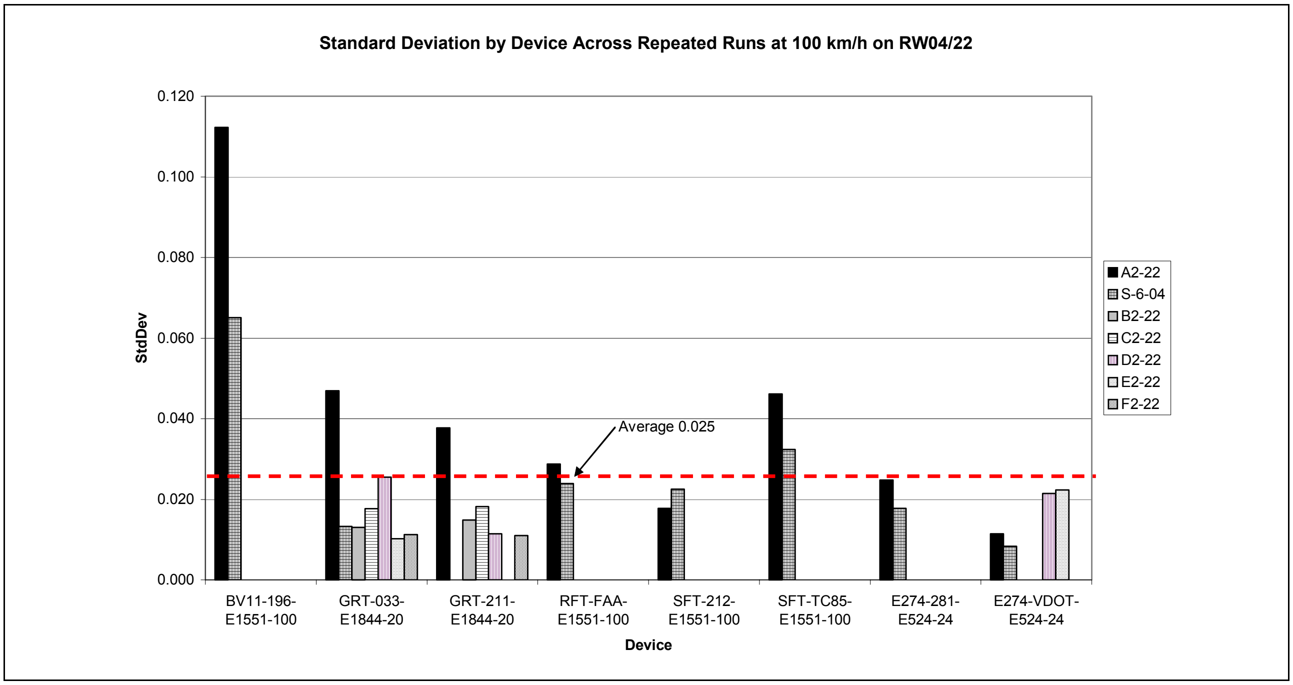


Figure 8 - Standard deviations for all runs at 100 km/h on the surface segments of runway 04/22

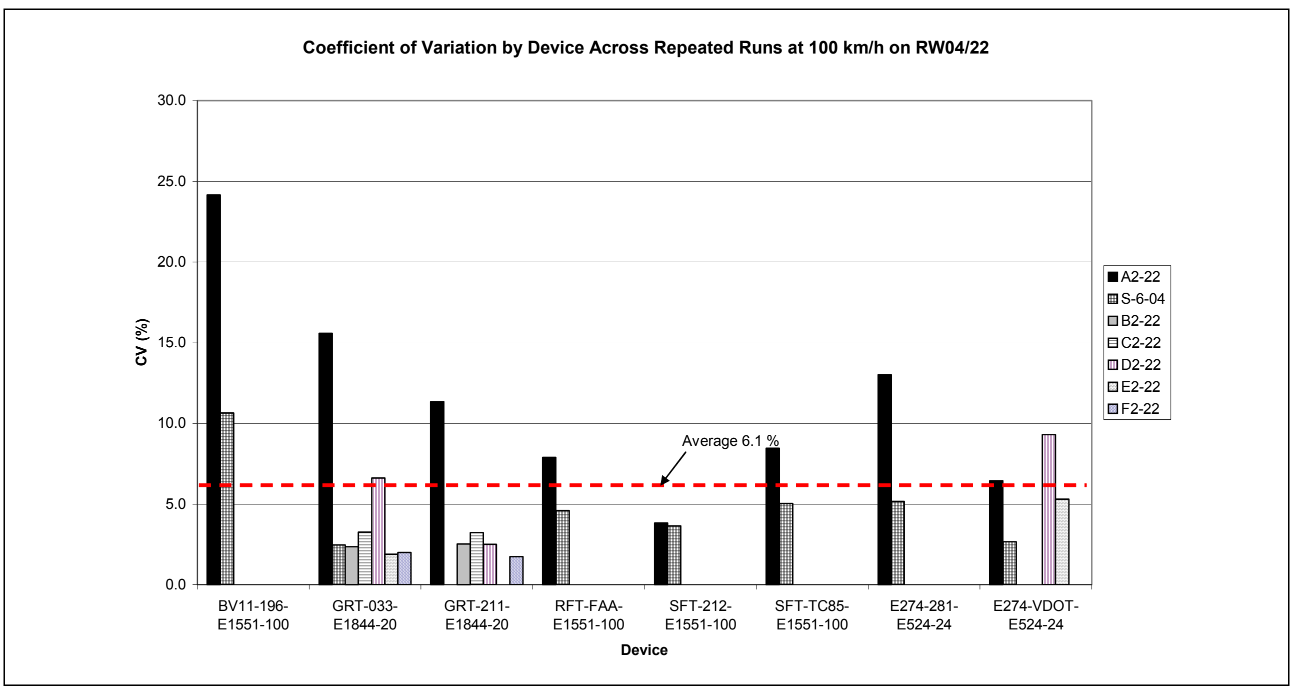


Figure 9 - CVs for all runs at 100 km/h on the surface segments of runway 04/22

Runs were also made on five taxiway surfaces. The standard deviations and CVs are shown in Figure 10 and Figure 11. The taxiway surfaces included aluminium panels that exhibited pronounced high values for standard deviation and CVs. The aluminium panels, having minimal texture for preventing hydroplaning, may have resulted in non-continuous tire-surface interaction, yielding friction measurements of poor quality.

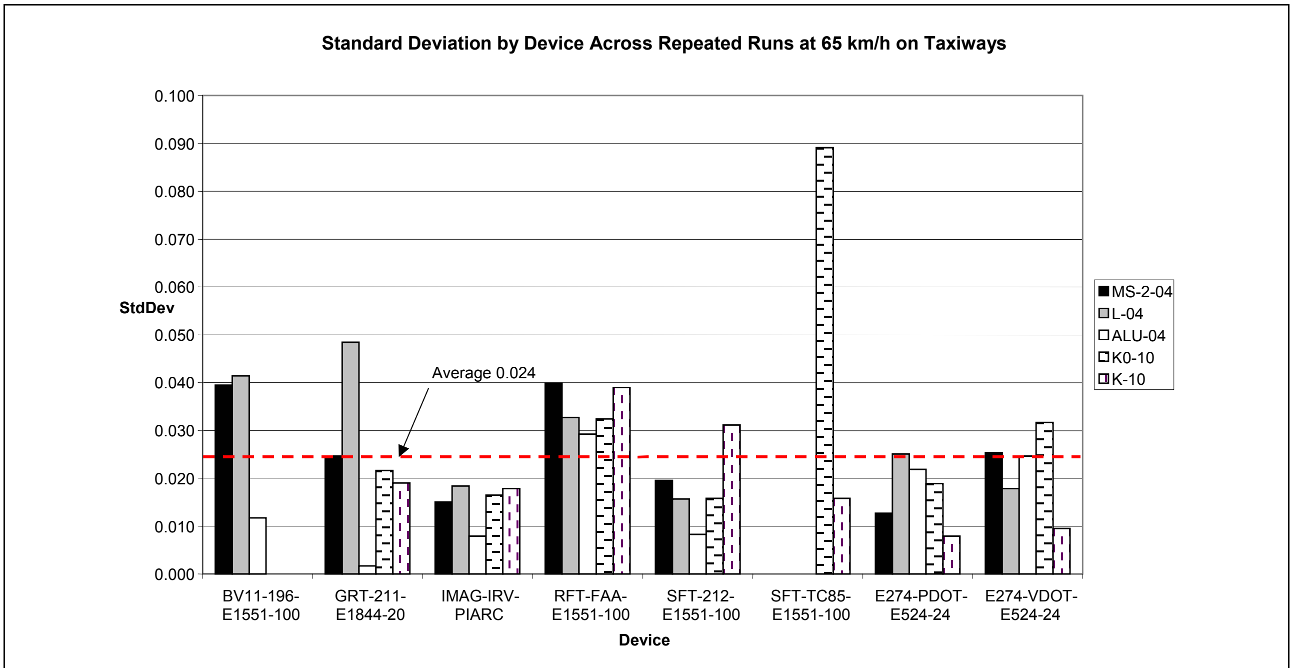


Figure 10 - Standard deviations for all runs at 65 km/h on the surface segments of taxiways

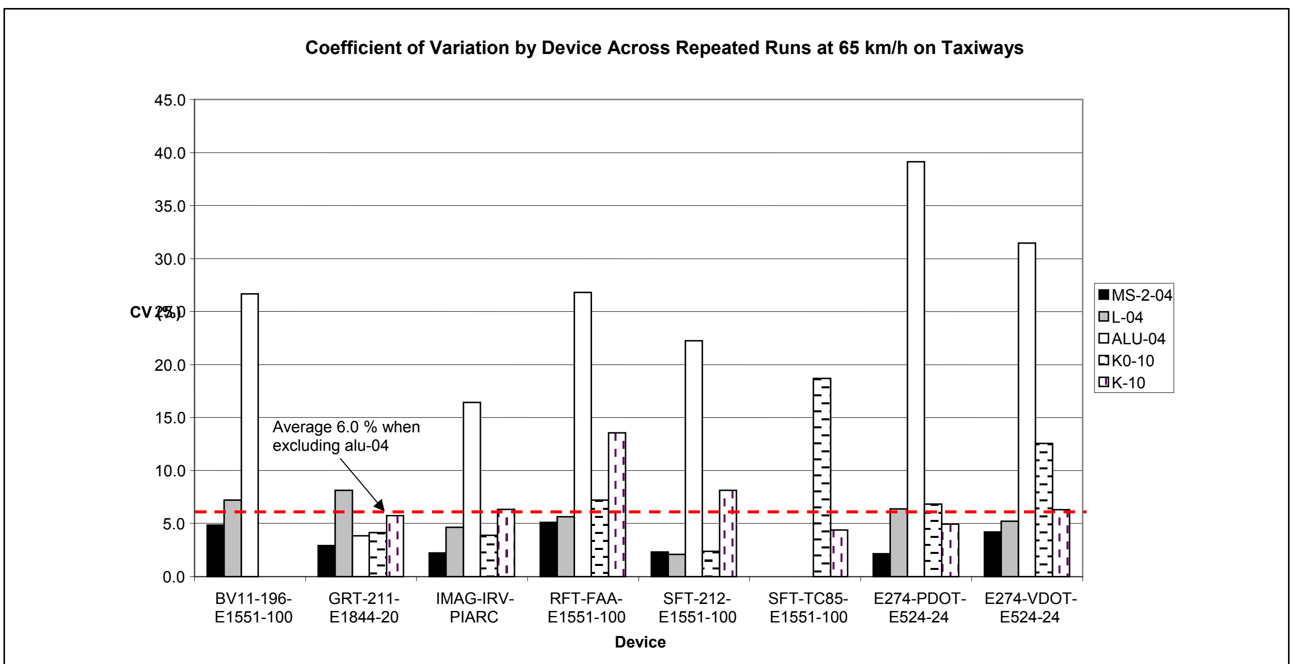


Figure 11 - CVs for all runs at 65 km/h on the surface segments of taxiways

The set of runs for taxiways included five repeat runs for some devices and ten repeat runs for others. As opposed to the runway run set, it is observable in the taxiway run set that the standard error is influenced by the different number of repeat runs, when comparing the chart of standard deviations and the chart of standard errors in Figure 12.

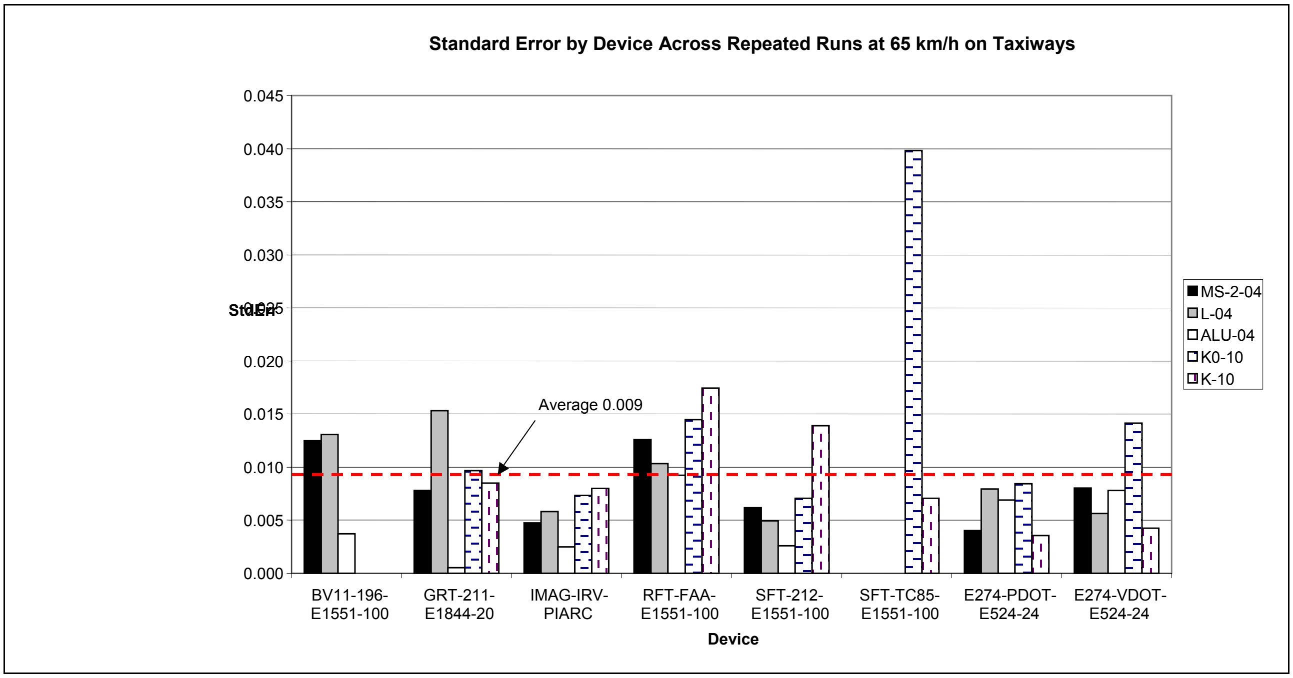


Figure 12 - Device standard errors for all runs at 65 km/h on the surface segments of taxiways

Figure 13 establishes a group reference of coefficient of variation for each device when including all runs on all surfaces at each speed. Since the run sets for each surface were dissimilar for some devices, and all devices did not measure all surfaces, caution must be exercised in interpreting the displayed composition.

The group average reference CV value for the devices participating in the workshop was of the order of 6 percent. The trend of the CV for most of the devices was a small decrease in CV with increasing measuring speed. This should be expected, since the friction level decreases with increasing speed and the CV is a function of the friction level.

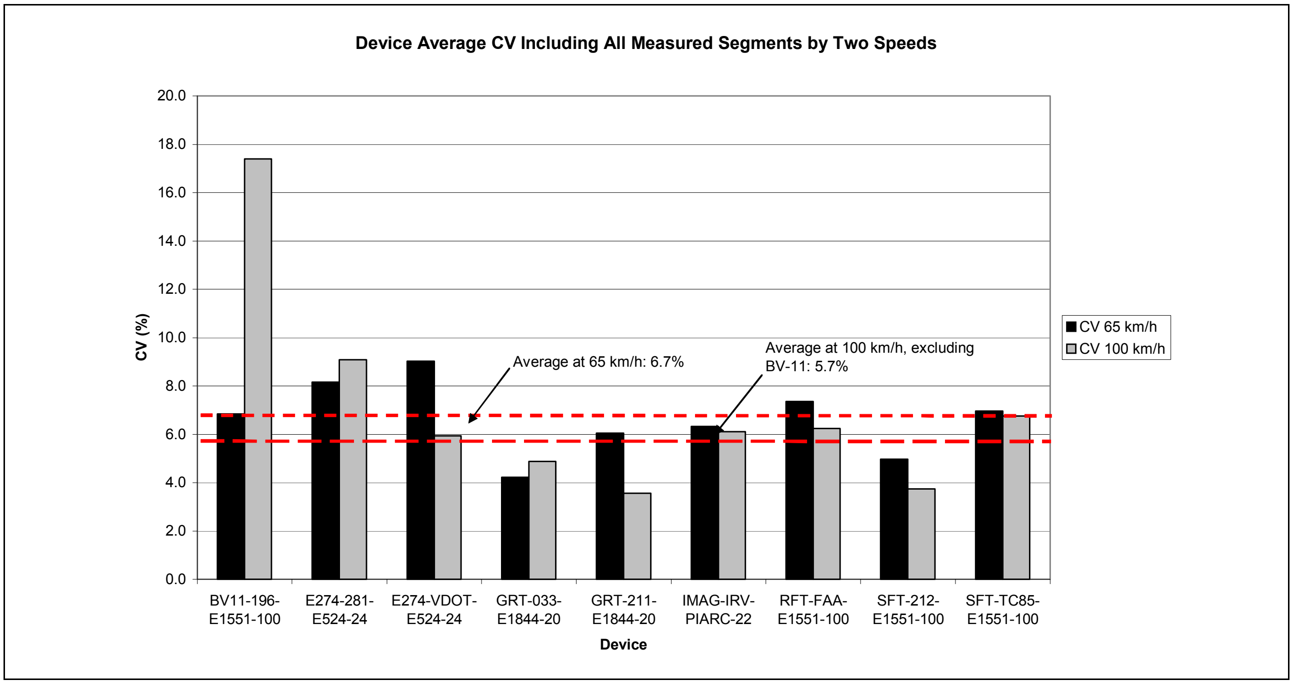


Figure 13 - Average CVs for all surfaces at two speeds

4.3.3 Correlation of Standard Deviation and Coefficient of Variation with Friction Level

No correlation has been found between standard deviation and reported friction values for any of the devices. There is, however, a general trend that the standard deviation increases with friction level as shown in Figure 14, when combining all data for all devices at 65 km/h. The average standard deviation of this data set is 0.027. However, as can be seen from the charts for each device in Appendix C, each device does not exhibit the same consistent trend.

From Figure 15 it can be seen that the coefficient of variation for all devices at 65 km/h has a high value in the low friction region (approximately 0.20) and then stabilizes around an average of 5 percent within a range of ±3 percent points for higher friction values. Overall, the CV has a trend of slightly decreasing values with increasing friction.

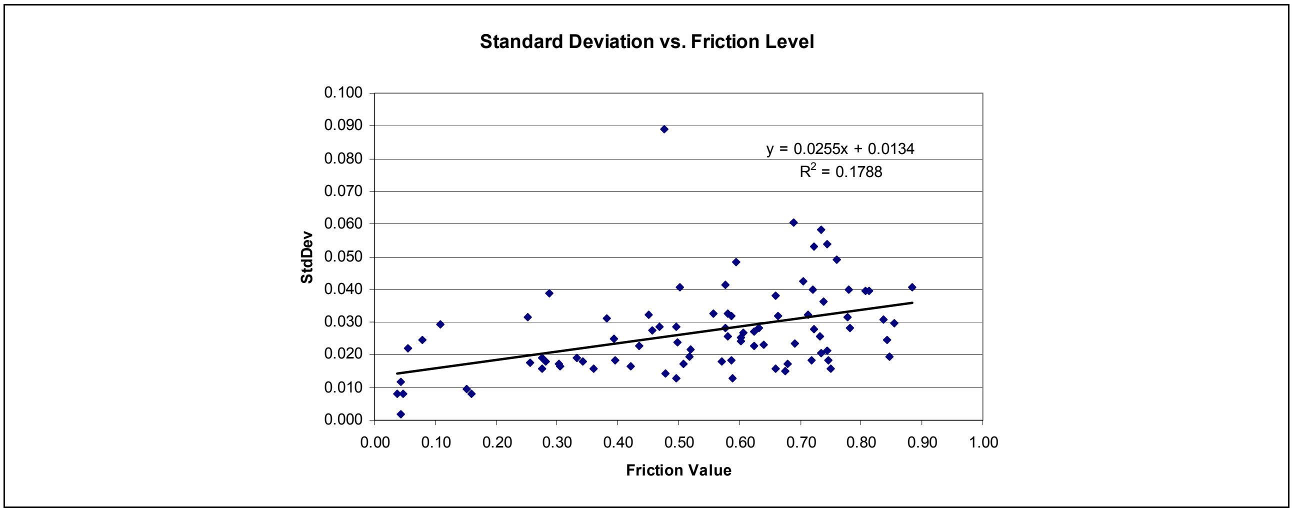


Figure 14 - Standard deviation vs. friction level for all devices and all surfaces at 65 km/h

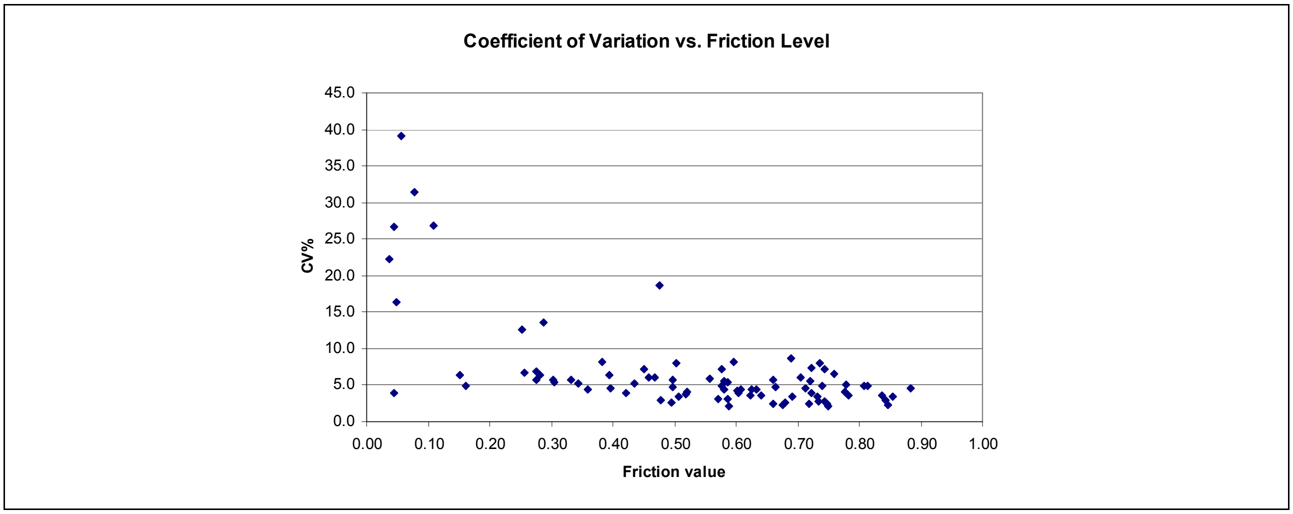


Figure 15 - Coefficient of variation vs. friction level for all devices and all surfaces at 65 km/h

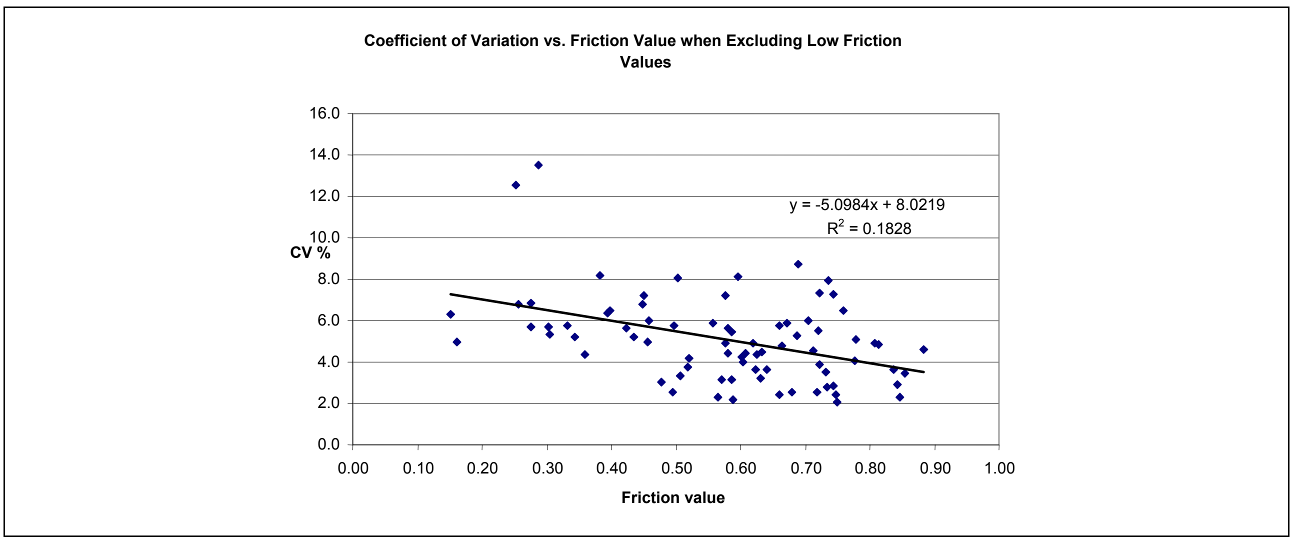


Figure 16 - Coefficient of variation vs. friction level for all devices and all surfaces at 65 km/h when excluding low friction values

4.4 Variation of Device Friction Measures

Since the friction measurement devices report friction values in units of friction measurements that are different by design and set-up, a comparison of repeatability statistics across devices has limited value.

Figure 17 shows the group variability range (i.e., average friction of the device that measured the maximum average friction minus the average friction of the device that measured the minimum average friction) for each surface segment at 65 km/h. Next to the variability range, the average friction value for all devices is shown for reference.

The ranges of variability across surfaces are large; for half of the surfaces the variability range value is nearly the same as the average friction value. As shown in Figure 18, the average variability per surface segment is 66 percent. In other words, as a rule of thumb, the range of average device friction values per surface constitutes two-thirds of the average friction value for all devices per surface.

The figures should be interpreted with caution, as the participation and number of runs of each device differed for each surface segment.

The two figures clearly document the need for common units of friction measurements.

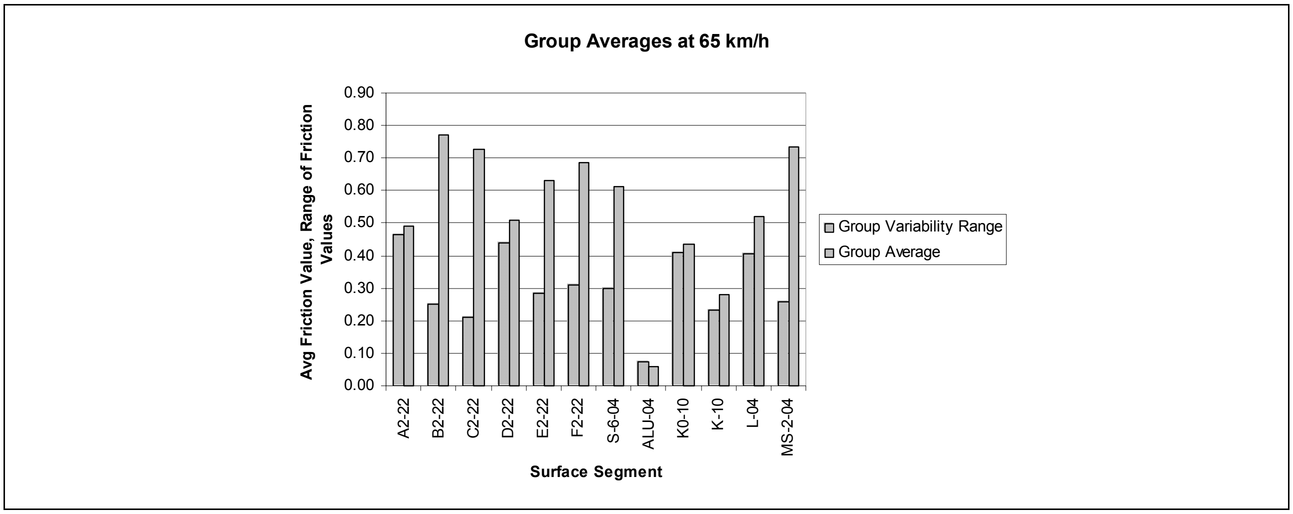


Figure 17 - Variability range of device friction averages and group friction averages for each surface segment

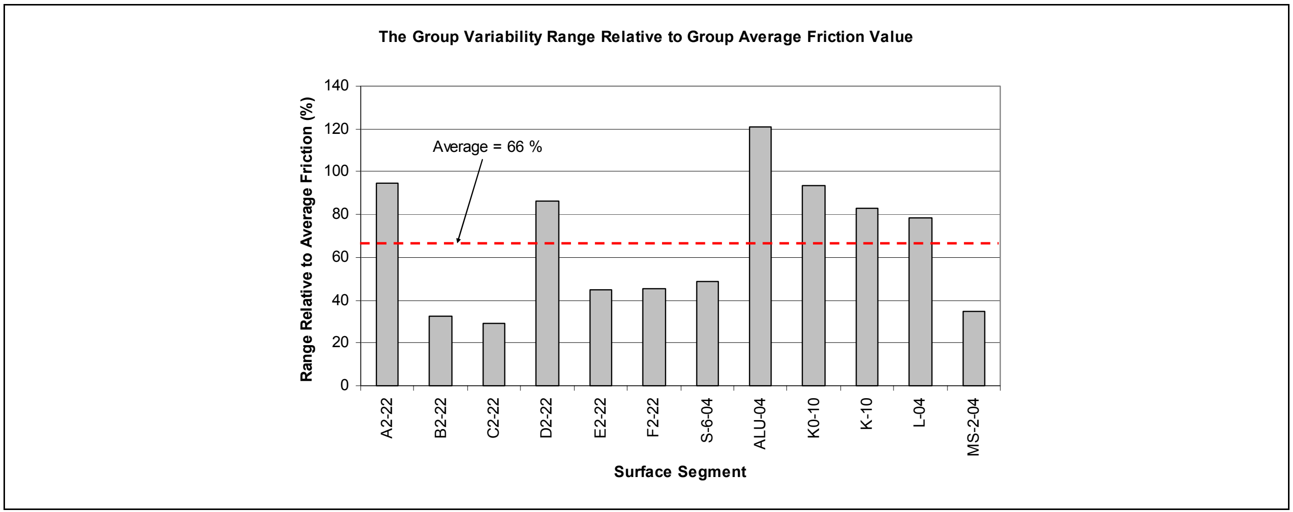


Figure 18 - Group variability range as percentage of group averages for each surface segment

5 CONCLUSIONS AND RECOMMENDATIONS

A fundamental basis for evaluating bias or precision does not exist for friction measurement devices. This makes it impossible to evaluate precision relative to fixed references. The use of data from a comprehensive field test can only make up, to some extent, for the lack of a fixed reference. Such field tests produce benchmarks for each surface type included, but prediction of performance from such benchmarks for similar surfaces may not achieve a required confidence.

A first step towards a basis for evaluating precision, in general, of friction measurement devices can be the harmonization of the reported friction values to the International Friction Index. Then the descriptive statistics for repeatability are computed on the basis of adjusted IFI friction values to a selected reference slip speed.

The difference between the maximum average friction value achieved for any device on a surface and the minimum average friction value for any device was found to be 66 percent of the average friction value for all devices. In other words, if a surface was measured by all the devices and the average friction value for all the devices was 0.60, the range within which the devices reported average friction values was 0.40. Assuming a normal distribution, this translates to 0.60 plus/minus 0.20 mixed friction units or plus/minus 33 percent. The large extent to which the reported friction values differed from the average, clearly documents the need for a common scale of friction measurement.

The devices and surfaces included in this study produced an average repeatability value expressed in a standard deviation equal to 0.027 at 65 km/h. Because each device measured different average friction values for each surface segment, such an average value can be misleading when evaluating a particular single surface and device pair.

Relating the variability with the friction level by using the coefficient of variation may be a more useful indication of general repeatability for friction values higher than 0.20. The average CV for all devices and surfaces combined at 65 km/h was 6.4 percent. When excluding the aluminium plates (i.e., friction values less than 0.15) the CV had an average of 5.0 percent with a decreasing trend with higher friction values. The variability of the CV was then found to be +/- 3 percentage points.

If a device were chosen as a physical reference for friction measurement units, the statistics of repeatability as found for different surfaces for that device would apply as a measure of quality of the reference friction measure. The statistics of repeatability of each device is useful for evaluation of possible reference devices.

References

(1) A. Andresen and J.C. Wambold, “Friction Fundamentals, Concepts and Methodology”, Transport Canada publication no. TP 13837E, October 1999.

(2) J.C. Wambold, C.E. Antle, J.J. Henry, and Z. Rado, “International PIARC Experiment to Compare and Harmonize Texture and Skid Resistance Measurements”, World Road Association (PIARC), publication no. AIPCR-01.04.T-1995.

Appendix A. Tabulated Results

Table A-1 - Tabulated results at 65 km/h sorted by surface segment

Device code (type-serial-tire-inflation)	Segment	Average reported friction value of all runs	Standard Deviation	Number of runs	Maximum friction value	Minimum friction value	Range (Maximum-minimum)	Coefficient of Variation	Standard Error
BV11-196-E1551-100	A2-22	0.59	0.032	10	0.65	0.54	0.11	5.5	0.010
E274-PDOT-E524-24	A2-22	0.28	0.016	10	0.30	0.25	0.05	5.7	0.005
E274-VDOT-E524-24	A2-22	0.26	0.017	10	0.29	0.23	0.06	6.8	0.006
GRT-033-E1844-20	A2-22	0.50	0.029	10	0.54	0.46	0.09	5.8	0.009
GRT-211-E1844-20	A2-22	0.50	0.040	10	0.55	0.43	0.12	8.1	0.013
IMAG-IRV-PIARC-22	A2-22	0.45	0.030	10	0.51	0.41	0.10	6.8	0.010
IMAG-IRV-PIARC-22*	A2-22	0.40	0.026	12	0.45	0.36	0.09	6.5	0.007
RFT-FAA-E1551-100	A2-22	0.50	0.024	10	0.54	0.47	0.07	4.8	0.008
SFT-212-E1551-100	A2-22	0.59	0.018	10	0.63	0.57	0.06	3.1	0.006
SFT-TC85-E1551-100	A2-22	0.72	0.040	10	0.81	0.67	0.14	5.5	0.013
BV11-196-E1551-100	ALU-04	0.04	0.012	10	0.07	0.03	0.04	26.7	0.004
E274-PDOT-E524-24	ALU-04	0.06	0.022	10	0.10	0.04	0.07	39.1	0.007
E274-VDOT-E524-24	ALU-04	0.08	0.025	10	0.13	0.05	0.07	31.5	0.008
GRT-211-E1844-20	ALU-04	0.04	0.002	10	0.05	0.04	0.01	3.9	0.001
IMAG-IRV-PIARC	ALU-04	0.05	0.008	10	0.06	0.04	0.02	16.4	0.002
RFT-FAA-E1551-100	ALU-04	0.11	0.029	10	0.17	0.07	0.10	26.8	0.009
SFT-212-E1551-100	ALU-04	0.04	0.008	10	0.05	0.03	0.02	22.3	0.003
BV11-196-E1551-100	B2-22	0.85	0.030	10	0.90	0.79	0.11	3.5	0.009
GRT-033-E1844-20	B2-22	0.63	0.028	10	0.65	0.56	0.10	4.5	0.009
GRT-211-E1844-20	B2-22	0.72	0.053	10	0.79	0.61	0.18	7.4	0.017
IMAG-IRV-PIARC-22	B2-22	0.69	0.036	10	0.74	0.65	0.09	5.3	0.011
IMAG-IRV-PIARC-22*	B2-22	0.63	0.020	12	0.66	0.60	0.06	3.2	0.006
RFT-FAA-E1551-100	B2-22	0.78	0.028	10	0.83	0.76	0.07	3.6	0.009
SFT-212-E1551-100	B2-22	0.74	0.021	10	0.79	0.72	0.07	2.8	0.007
SFT-TC85-E1551-100	B2-22	0.88	0.041	10	0.94	0.81	0.13	4.6	0.013
BV11-196-E1551-100	C2-22	0.84	0.031	10	0.88	0.77	0.11	3.7	0.010
GRT-033-E1844-20	C2-22	0.62	0.027	10	0.66	0.56	0.10	4.4	0.009
GRT-211-E1844-20	C2-22	0.70	0.042	10	0.75	0.63	0.12	6.0	0.013
IMAG-IRV-PIARC-22	C2-22	0.67	0.040	10	0.72	0.62	0.10	5.9	0.013
IMAG-IRV-PIARC-22*	C2-22	0.62	0.030	12	0.66	0.57	0.09	4.9	0.009
RFT-FAA-E1551-100	C2-22	0.74	0.036	10	0.80	0.70	0.10	4.9	0.011
SFT-212-E1551-100	C2-22	0.72	0.028	10	0.77	0.69	0.08	3.9	0.009
SFT-TC85-E1551-100	C2-22	0.74	0.058	10	0.81	0.65	0.16	7.9	0.018
BV11-196-E1551-100	D2-22	0.58	0.028	10	0.63	0.54	0.09	4.9	0.009
E274-PDOT-E524-24	D2-22	0.30	0.017	10	0.34	0.28	0.06	5.7	0.005

E274-VDOT-E524-24	D2-22	0.31	0.016	10	0.34	0.29	0.05	5.3	0.005
GRT-033-E1844-20	D2-22	0.52	0.019	10	0.54	0.48	0.07	3.7	0.006
GRT-211-E1844-20	D2-22	0.56	0.033	10	0.59	0.49	0.10	5.9	0.010
IMAG-IRV-PIARC-22	D2-22	0.46	0.023	10	0.50	0.42	0.08	5.0	0.007
IMAG-IRV-PIARC-22*	D2-22	0.42	0.024	12	0.48	0.40	0.08	5.6	0.007
RFT-FAA-E1551-100	D2-22	0.47	0.029	10	0.52	0.42	0.10	6.1	0.009
SFT-212-E1551-100	D2-22	0.60	0.024	10	0.64	0.58	0.06	4.0	0.008
SFT-TC85-E1551-100	D2-22	0.74	0.054	10	0.85	0.64	0.21	7.3	0.017
BV11-196-E1551-100	E2-22	0.71	0.032	10	0.79	0.67	0.12	4.5	0.010
E274-PDOT-E524-24	E2-22	0.48	0.014	10	0.50	0.46	0.04	3.0	0.005
E274-VDOT-E524-24	E2-22	0.51	0.017	10	0.53	0.47	0.05	3.4	0.005
GRT-033-E1844-20	E2-22	0.57	0.018	10	0.60	0.55	0.06	3.1	0.006
GRT-211-E1844-20	E2-22	0.66	0.038	10	0.70	0.59	0.11	5.8	0.012
IMAG-IRV-PIARC-22	E2-22	0.63	0.044	10	0.69	0.57	0.12	7.1	0.014
IMAG-IRV-PIARC-22*	E2-22	0.56	0.013	12	0.59	0.54	0.05	2.3	0.004
RFT-FAA-E1551-100	E2-22	0.69	0.023	10	0.73	0.65	0.08	3.4	0.007
SFT-212-E1551-100	E2-22	0.68	0.017	10	0.71	0.66	0.05	2.5	0.005
SFT-TC85-E1551-100	E2-22	0.76	0.049	10	0.88	0.71	0.17	6.5	0.016
BV11-196-E1551-100	F2-22	0.78	0.032	10	0.84	0.74	0.10	4.1	0.010
E274-PDOT-E524-24	F2-22	0.50	0.013	10	0.52	0.48	0.04	2.5	0.004
GRT-033-E1844-20	F2-22	0.58	0.026	10	0.64	0.55	0.08	4.4	0.008
GRT-211-E1844-20	F2-22	0.69	0.060	10	0.77	0.59	0.18	8.7	0.019
IMAG-IRV-PIARC-22	F2-22	0.67	0.058	10	0.75	0.60	0.15	8.7	0.018
IMAG-IRV-PIARC-22*	F2-22	0.61	0.010	12	0.62	0.59	0.03	1.7	0.003
RFT-FAA-E1551-100	F2-22	0.75	0.018	10	0.77	0.71	0.06	2.4	0.006
SFT-212-E1551-100	F2-22	0.72	0.018	10	0.75	0.69	0.06	2.5	0.006
SFT-TC85-E1551-100	F2-22	0.81	0.039	10	0.89	0.74	0.15	4.9	0.012
E274-PDOT-E524-24	K0-10	0.28	0.019	5	0.31	0.26	0.05	6.8	0.008
E274-VDOT-E524-24	K0-10	0.25	0.032	5	0.30	0.22	0.08	12.6	0.014
GRT-211-E1844-20	K0-10	0.52	0.022	5	0.55	0.50	0.06	4.2	0.010
IMAG-IRV-PIARC-22	K0-10	0.42	0.016	5	0.44	0.41	0.03	3.9	0.007
RFT-FAA-E1551-100	K0-10	0.45	0.032	5	0.50	0.41	0.09	7.2	0.014
SFT-212-E1551-100	K0-10	0.66	0.016	5	0.68	0.64	0.04	2.4	0.007
SFT-TC85-E1551-100	K0-10	0.48	0.089	5	0.60	0.35	0.25	18.7	0.040
E274-PDOT-E524-24	K-10	0.16	0.008	5	0.17	0.15	0.02	4.9	0.004
E274-VDOT-E524-24	K-10	0.15	0.010	5	0.16	0.14	0.02	6.3	0.004
GRT-211-E1844-20	K-10	0.33	0.019	5	0.36	0.32	0.05	5.7	0.009
IMAG-IRV-PIARC-22	K-10	0.28	0.018	5	0.30	0.26	0.04	6.3	0.008
RFT-FAA-E1551-100	K-10	0.29	0.039	5	0.34	0.26	0.08	13.5	0.017
SFT-212-E1551-100	K-10	0.38	0.031	5	0.42	0.35	0.07	8.2	0.014
SFT-TC85-E1551-100	K-10	0.36	0.016	5	0.38	0.34	0.04	4.4	0.007
BV11-196-E1551-100	L-04	0.58	0.041	10	0.68	0.54	0.14	7.2	0.013
E274-PDOT-E524-24	L-04	0.39	0.025	10	0.41	0.34	0.07	6.4	0.008
E274-VDOT-E524-24	L-04	0.34	0.018	10	0.36	0.31	0.05	5.2	0.006
GRT-211-E1844-20	L-04	0.60	0.048	10	0.69	0.56	0.13	8.1	0.015
IMAG-IRV-PIARC-22	L-04	0.40	0.018	10	0.42	0.37	0.05	4.6	0.006
RFT-FAA-E1551-100	L-04	0.58	0.033	10	0.64	0.52	0.12	5.6	0.010
SFT-212-E1551-100	L-04	0.75	0.016	10	0.78	0.73	0.05	2.1	0.005

BV11-196-E1551-100	MS-2-04	0.81	0.039	10	0.90	0.76	0.14	4.9	0.012
E274-PDOT-E524-24	MS-2-04	0.59	0.013	10	0.61	0.57	0.04	2.2	0.004
E274-VDOT-E524-24	MS-2-04	0.60	0.025	10	0.64	0.56	0.08	4.2	0.008
GRT-211-E1844-20	MS-2-04	0.84	0.025	10	0.88	0.81	0.07	2.9	0.008
IMAG-IRV-PIARC	MS-2-04	0.68	0.015	10	0.69	0.65	0.04	2.2	0.005
RFT-FAA-E1551-100	MS-2-04	0.78	0.040	10	0.87	0.74	0.13	5.1	0.013
SFT-212-E1551-100	MS-2-04	0.85	0.020	10	0.88	0.83	0.05	2.3	0.006
BV11-196-E1551-100	S-6-04	0.64	0.023	10	0.68	0.60	0.08	3.6	0.007
E274-PDOT-E524-24	S-6-04	0.43	0.023	10	0.48	0.40	0.08	5.2	0.007
E274-VDOT-E524-24	S-6-04	0.46	0.028	10	0.51	0.43	0.08	6.0	0.009
GRT-033-E1844-20	S-6-04	0.62	0.023	10	0.67	0.59	0.08	3.7	0.007
IMAG-IRV-PIARC-22	S-6-04	0.61	0.027	10	0.67	0.58	0.09	4.4	0.008
IMAG-IRV-PIARC-22*	S-6-04	0.59	0.015	11	0.60	0.56	0.04	2.6	0.005
RFT-FAA-E1551-100	S-6-04	0.66	0.032	10	0.73	0.62	0.11	4.8	0.010
SFT-212-E1551-100	S-6-04	0.73	0.026	10	0.76	0.69	0.07	3.5	0.008
SFT-TC85-E1551-100	S-6-04	0.73	0.021	10	0.76	0.70	0.06	2.8	0.007

Note: IMAG-IRV-PIARC-22* refers to a second series of repeatability runs.

Table A-2 - Tabulated results at 65 km/h sorted by device

Device code (type-serial-tire-inflation)	Segment	Average reported friction value of all runs	Standard Deviation	Number of runs	Maximum friction value	Minimum friction value	Range (Maximum-minimum)	Coefficient of Variation	Standard Error
BV11-196-E1551-100	A2-22	0.59	0.032	10	0.65	0.54	0.11	5.5	0.010
BV11-196-E1551-100	B2-22	0.85	0.030	10	0.90	0.79	0.11	3.5	0.009
BV11-196-E1551-100	C2-22	0.84	0.031	10	0.88	0.77	0.11	3.7	0.010
BV11-196-E1551-100	D2-22	0.58	0.028	10	0.63	0.54	0.09	4.9	0.009
BV11-196-E1551-100	E2-22	0.71	0.032	10	0.79	0.67	0.12	4.5	0.010
BV11-196-E1551-100	F2-22	0.78	0.032	10	0.84	0.74	0.10	4.1	0.010
BV11-196-E1551-100	L-04	0.58	0.041	10	0.68	0.54	0.14	7.2	0.013
BV11-196-E1551-100	MS-2-04	0.81	0.039	10	0.90	0.76	0.14	4.9	0.012
BV11-196-E1551-100	ALU-04	0.04	0.012	10	0.07	0.03	0.04	26.7	0.004
BV11-196-E1551-100	S-6-04	0.64	0.023	10	0.68	0.60	0.08	3.6	0.007
E274-281-E524-24	A2-22	0.28	0.016	10	0.30	0.25	0.05	5.7	0.005
E274-281-E524-24	D2-22	0.30	0.017	10	0.34	0.28	0.06	5.7	0.005
E274-281-E524-24	E2-22	0.48	0.014	10	0.50	0.46	0.04	3.0	0.005
E274-281-E524-24	F2-22	0.50	0.013	10	0.52	0.48	0.04	2.5	0.004
E274-281-E524-24	K0-10	0.28	0.019	5	0.31	0.26	0.05	6.8	0.008
E274-281-E524-24	K-10	0.16	0.008	5	0.17	0.15	0.02	4.9	0.004
E274-281-E524-24	L-04	0.39	0.025	10	0.41	0.34	0.07	6.4	0.008
E274-281-E524-24	MS-2-04	0.59	0.013	10	0.61	0.57	0.04	2.2	0.004
E274-281-E524-24	ALU-04	0.06	0.022	10	0.10	0.04	0.07	39.1	0.007
E274-281-E524-24	S-6-04	0.43	0.023	10	0.48	0.40	0.08	5.2	0.007
E274-VDOT-E524-24	A2-22	0.26	0.017	10	0.29	0.23	0.06	6.8	0.006
E274-VDOT-E524-24	D2-22	0.31	0.016	10	0.34	0.29	0.05	5.3	0.005
E274-VDOT-E524-24	E2-22	0.51	0.017	10	0.53	0.47	0.05	3.4	0.005
E274-VDOT-E524-24	K0-10	0.25	0.032	5	0.30	0.22	0.08	12.6	0.014
E274-VDOT-E524-24	K-10	0.15	0.010	5	0.16	0.14	0.02	6.3	0.004
E274-VDOT-E524-24	L-04	0.34	0.018	10	0.36	0.31	0.05	5.2	0.006
E274-VDOT-E524-24	MS-2-04	0.60	0.025	10	0.64	0.56	0.08	4.2	0.008
E274-VDOT-E524-24	ALU-04	0.08	0.025	10	0.13	0.05	0.07	31.5	0.008
E274-VDOT-E524-24	S-6-04	0.46	0.028	10	0.51	0.43	0.08	6.0	0.009
GRT-033-E1844-20	A2-22	0.50	0.029	10	0.54	0.46	0.09	5.8	0.009
GRT-033-E1844-20	B2-22	0.63	0.028	10	0.65	0.56	0.10	4.5	0.009
GRT-033-E1844-20	C2-22	0.62	0.027	10	0.66	0.56	0.10	4.4	0.009
GRT-033-E1844-20	D2-22	0.52	0.019	10	0.54	0.48	0.07	3.7	0.006
GRT-033-E1844-20	E2-22	0.57	0.018	10	0.60	0.55	0.06	3.1	0.006
GRT-033-E1844-20	F2-22	0.58	0.026	10	0.64	0.55	0.08	4.4	0.008
GRT-033-E1844-20	S-6-04	0.62	0.023	10	0.67	0.59	0.08	3.7	0.007
GRT-211-E1844-20	A2-22	0.50	0.040	10	0.55	0.43	0.12	8.1	0.013

GRT-211-E1844-20	B2-22	0.72	0.053	10	0.79	0.61	0.18	7.4	0.017
GRT-211-E1844-20	C2-22	0.70	0.042	10	0.75	0.63	0.12	6.0	0.013
GRT-211-E1844-20	D2-22	0.56	0.033	10	0.59	0.49	0.10	5.9	0.010
GRT-211-E1844-20	E2-22	0.66	0.038	10	0.70	0.59	0.11	5.8	0.012
GRT-211-E1844-20	F2-22	0.69	0.060	10	0.77	0.59	0.18	8.7	0.019
GRT-211-E1844-20	K0-10	0.52	0.022	5	0.55	0.50	0.06	4.2	0.010
GRT-211-E1844-20	K-10	0.33	0.019	5	0.36	0.32	0.05	5.7	0.009
GRT-211-E1844-20	L-04	0.60	0.048	10	0.69	0.56	0.13	8.1	0.015
GRT-211-E1844-20	MS-2-04	0.84	0.025	10	0.88	0.81	0.07	2.9	0.008
GRT-211-E1844-20	ALU-04	0.04	0.002	10	0.05	0.04	0.01	3.9	0.001
IMAG-IRV-PIARC-22	A2-22	0.45	0.030	10	0.51	0.41	0.10	6.8	0.010
IMAG-IRV-PIARC-22	B2-22	0.69	0.036	10	0.74	0.65	0.09	5.3	0.011
IMAG-IRV-PIARC-22	C2-22	0.67	0.040	10	0.72	0.62	0.10	5.9	0.013
IMAG-IRV-PIARC-22	D2-22	0.46	0.023	10	0.50	0.42	0.08	5.0	0.007
IMAG-IRV-PIARC-22	E2-22	0.63	0.044	10	0.69	0.57	0.12	7.1	0.014
IMAG-IRV-PIARC-22	F2-22	0.67	0.058	10	0.75	0.60	0.15	8.7	0.018
IMAG-IRV-PIARC-22	K0-10	0.42	0.016	5	0.44	0.41	0.03	3.9	0.007
IMAG-IRV-PIARC-22	K-10	0.28	0.018	5	0.30	0.26	0.04	6.3	0.008
IMAG-IRV-PIARC-22	L-04	0.40	0.018	10	0.42	0.37	0.05	4.6	0.006
IMAG-IRV-PIARC-22	MS-2-04	0.68	0.015	10	0.69	0.65	0.04	2.2	0.005
IMAG-IRV-PIARC-22	ALU-04	0.05	0.008	10	0.06	0.04	0.02	16.4	0.002
IMAG-IRV-PIARC-22	S-6-04	0.61	0.027	10	0.67	0.58	0.09	4.4	0.008
IMAG-IRV-PIARC-22*	A2-22	0.40	0.026	12	0.45	0.36	0.09	6.5	0.007
IMAG-IRV-PIARC-22*	B2-22	0.63	0.020	12	0.66	0.60	0.06	3.2	0.006
IMAG-IRV-PIARC-22*	C2-22	0.62	0.030	12	0.66	0.57	0.09	4.9	0.009
IMAG-IRV-PIARC-22*	D2-22	0.42	0.024	12	0.48	0.40	0.08	5.6	0.007
IMAG-IRV-PIARC-22*	E2-22	0.56	0.013	12	0.59	0.54	0.05	2.3	0.004
IMAG-IRV-PIARC-22*	F2-22	0.61	0.010	12	0.62	0.59	0.03	1.7	0.003
IMAG-IRV-PIARC-22*	S-6-04	0.59	0.015	11	0.60	0.56	0.04	2.6	0.005
RFT-FAA-E1551-100	A2-22	0.50	0.024	10	0.54	0.47	0.07	4.8	0.008
RFT-FAA-E1551-100	B2-22	0.78	0.028	10	0.83	0.76	0.07	3.6	0.009
RFT-FAA-E1551-100	C2-22	0.74	0.036	10	0.80	0.70	0.10	4.9	0.011
RFT-FAA-E1551-100	D2-22	0.47	0.029	10	0.52	0.42	0.10	6.1	0.009
RFT-FAA-E1551-100	E2-22	0.69	0.023	10	0.73	0.65	0.08	3.4	0.007
RFT-FAA-E1551-100	F2-22	0.75	0.018	10	0.77	0.71	0.06	2.4	0.006
RFT-FAA-E1551-100	K0-10	0.45	0.032	5	0.50	0.41	0.09	7.2	0.014
RFT-FAA-E1551-100	K-10	0.29	0.039	5	0.34	0.26	0.08	13.5	0.017
RFT-FAA-E1551-100	L-04	0.58	0.033	10	0.64	0.52	0.12	5.6	0.010
RFT-FAA-E1551-100	MS-2-04	0.78	0.040	10	0.87	0.74	0.13	5.1	0.013
RFT-FAA-E1551-100	ALU-04	0.11	0.029	10	0.17	0.07	0.10	26.8	0.009
RFT-FAA-E1551-100	S-6-04	0.66	0.032	10	0.73	0.62	0.11	4.8	0.010
SFT-212-E1551-100	A2-22	0.59	0.018	10	0.63	0.57	0.06	3.1	0.006
SFT-212-E1551-100	B2-22	0.74	0.021	10	0.79	0.72	0.07	2.8	0.007
SFT-212-E1551-100	C2-22	0.72	0.028	10	0.77	0.69	0.08	3.9	0.009
SFT-212-E1551-100	D2-22	0.60	0.024	10	0.64	0.58	0.06	4.0	0.008
SFT-212-E1551-100	E2-22	0.68	0.017	10	0.71	0.66	0.05	2.5	0.005
SFT-212-E1551-100	F2-22	0.72	0.018	10	0.75	0.69	0.06	2.5	0.006
SFT-212-E1551-100	K0-10	0.66	0.016	5	0.68	0.64	0.04	2.4	0.007

SFT-212-E1551-100	K-10	0.38	0.031	5	0.42	0.35	0.07	8.2	0.014
SFT-212-E1551-100	L-04	0.75	0.016	10	0.78	0.73	0.05	2.1	0.005
SFT-212-E1551-100	MS-2-04	0.85	0.020	10	0.88	0.83	0.05	2.3	0.006
SFT-212-E1551-100	ALU-04	0.04	0.008	10	0.05	0.03	0.02	22.3	0.003
SFT-212-E1551-100	S-6-04	0.73	0.026	10	0.76	0.69	0.07	3.5	0.008
SFT-TC85-E1551-100	A2-22	0.72	0.040	10	0.81	0.67	0.14	5.5	0.013
SFT-TC85-E1551-100	B2-22	0.88	0.041	10	0.94	0.81	0.13	4.6	0.013
SFT-TC85-E1551-100	C2-22	0.74	0.058	10	0.81	0.65	0.16	7.9	0.018
SFT-TC85-E1551-100	D2-22	0.74	0.054	10	0.85	0.64	0.21	7.3	0.017
SFT-TC85-E1551-100	E2-22	0.76	0.049	10	0.88	0.71	0.17	6.5	0.016
SFT-TC85-E1551-100	F2-22	0.81	0.039	10	0.89	0.74	0.15	4.9	0.012
SFT-TC85-E1551-100	K0-10	0.48	0.089	5	0.60	0.35	0.25	18.7	0.040
SFT-TC85-E1551-100	K-10	0.36	0.016	5	0.38	0.34	0.04	4.4	0.007
SFT-TC85-E1551-100	S-6-04	0.73	0.021	10	0.76	0.70	0.06	2.8	0.007

Note: IMAG-IRV-PIARC-22* refers to a second series of repeatability runs.

Note: For the SFT-TC85-E1551-100 there is a very large range of friction values for some test sections. Normally the repeatability of this device is much better. Perhaps the device was not working correctly or not operated correctly?

Table A-3 - Tabulated results at 100 km/h sorted by segment

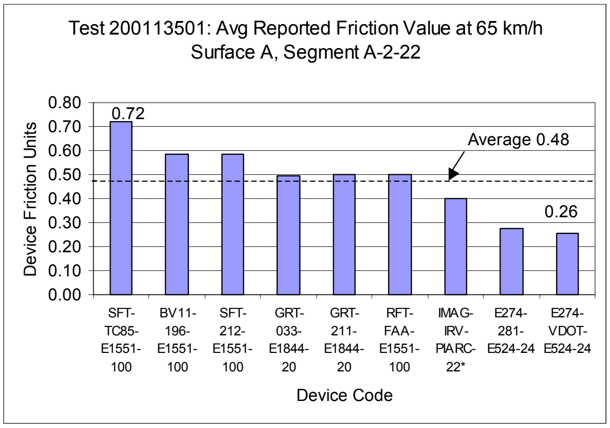
Device code (type-serial-tire-inflation)	Segment	Average reported friction value of all runs	Standard Deviation	Number of runs	Maximum friction value	Minimum friction value	Range (Maximum-minimum)	Coefficient of Variation	Standard Error
BV11-196-E1551-100	A2-22	0.47	0.112	10	0.71	0.35	0.36	24.1	0.036
E274-281-E524-24	A2-22	0.19	0.025	10	0.24	0.16	0.08	13.0	0.008
E274-VDOT-E524-24	A2-22	0.18	0.011	10	0.20	0.17	0.03	6.5	0.004
GRT-033-E1844-20	A2-22	0.30	0.047	10	0.38	0.23	0.15	15.6	0.015
GRT-211-E1844-20	A2-22	0.33	0.038	5	0.37	0.27	0.10	11.4	0.017
IMAG-IRV-PIARC-22	A2-22	0.25	0.050	10	0.32	0.20	0.12	19.7	0.016
RFT-FAA-E1551-100	A2-22	0.37	0.029	10	0.42	0.33	0.09	7.9	0.009
SFT-212-E1551-100	A2-22	0.47	0.018	10	0.50	0.44	0.06	3.8	0.006
SFT-TC85-E1551-100	A2-22	0.54	0.046	10	0.62	0.50	0.12	8.5	0.015
GRT-033-E1844-20	B2-22	0.55	0.013	10	0.57	0.53	0.04	2.4	0.004
GRT-211-E1844-20	B2-22	0.59	0.015	5	0.61	0.57	0.04	2.5	0.007
IMAG-IRV-PIARC	B2-22	0.63	0.013	11	0.64	0.60	0.04	2.1	0.004
GRT-033-E1844-20	C2-22	0.54	0.018	10	0.57	0.51	0.06	3.3	0.006
GRT-211-E1844-20	C2-22	0.56	0.018	5	0.58	0.54	0.04	3.2	0.008
IMAG-IRV-PIARC	C2-22	0.60	0.008	11	0.61	0.59	0.02	1.3	0.002
E274-VDOT-E524-24	D2-22	0.23	0.021	10	0.27	0.19	0.07	9.3	0.007
GRT-033-E1844-20	D2-22	0.39	0.026	10	0.43	0.36	0.08	6.6	0.008
GRT-211-E1844-20	D2-22	0.46	0.011	5	0.47	0.44	0.03	2.5	0.005
IMAG-IRV-PIARC	D2-22	0.32	0.021	10	0.34	0.28	0.06	6.5	0.007
E274-VDOT-E524-24	E2-22	0.42	0.022	10	0.47	0.38	0.08	5.3	0.007
GRT-033-E1844-20	E2-22	0.54	0.010	10	0.55	0.51	0.03	1.9	0.003
GRT-211-E1844-20	E2-22	0.63	0.000	5	0.63	0.63	0.00	0.0	0.000
IMAG-IRV-PIARC	E2-22	0.57	0.017	11	0.60	0.54	0.06	3.0	0.005
GRT-033-E1844-20	F2-22	0.56	0.011	10	0.58	0.54	0.03	2.0	0.004
GRT-211-E1844-20	F2-22	0.63	0.011	5	0.64	0.62	0.02	1.7	0.005
IMAG-IRV-PIARC	F2-22	0.61	0.013	11	0.64	0.60	0.04	2.0	0.004
BV11-196-E1551-100	S-6-04	0.61	0.065	10	0.72	0.54	0.18	10.6	0.021
E274-PDOT-E524-24	S-6-04	0.34	0.018	10	0.38	0.32	0.06	5.2	0.006
E274-VDOT-E524-24	S-6-04	0.31	0.008	10	0.33	0.30	0.03	2.7	0.003
GRT-033-E1844-20	S-6-04	0.54	0.013	10	0.56	0.52	0.04	2.5	0.004
IMAG-IRV-PIARC	S-6-04	0.55	0.045	10	0.60	0.49	0.11	8.3	0.014
RFT-FAA-E1551-100	S-6-04	0.52	0.024	10	0.55	0.48	0.07	4.6	0.008
SFT-212-E1551-100	S-6-04	0.62	0.023	10	0.64	0.57	0.07	3.6	0.007
SFT-TC85-E1551-100	S-6-04	0.64	0.032	10	0.69	0.59	0.10	5.0	0.010

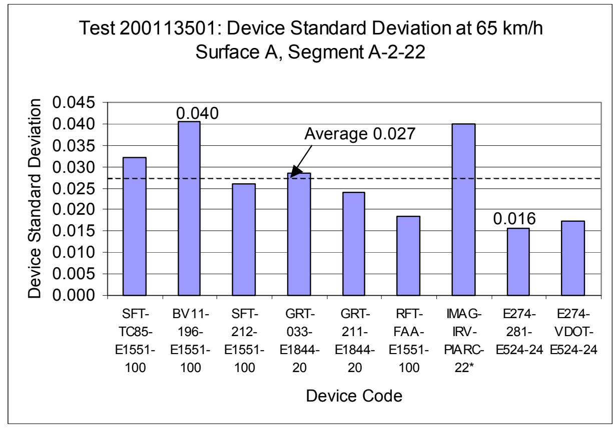
Table A-4 - Tabulated results at 100 km/h sorted by device

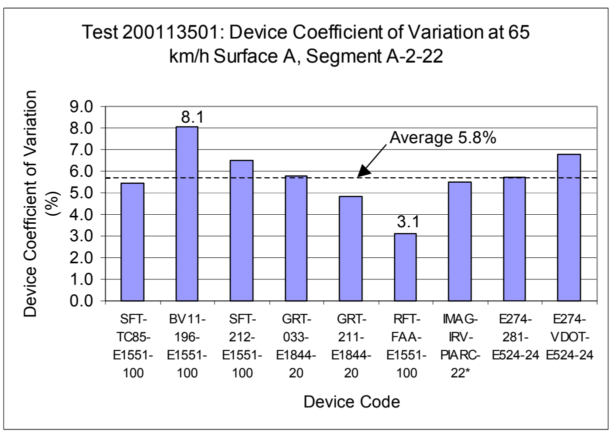
Device code (type-serial-tire-inflation)	Segment	Average reported friction value of all runs	Standard Deviation	Number of runs	Maximum friction value	Minimum friction value	Range (Maximum-minimum)	Coefficient of Variation	Standard Error
BV11-196-E1551-100	A2-22	0.47	0.112	10	0.71	0.35	0.36	24.1	0.036
BV11-196-E1551-100	S-6-04	0.61	0.065	10	0.72	0.54	0.18	10.6	0.021
E274-281-E524-24	A2-22	0.19	0.025	10	0.24	0.16	0.08	13.0	0.008
E274-PDOT-E524-24	S-6-04	0.34	0.018	10	0.38	0.32	0.06	5.2	0.006
E274-VDOT-E524-24	A2-22	0.18	0.011	10	0.20	0.17	0.03	6.5	0.004
E274-VDOT-E524-24	D2-22	0.23	0.021	10	0.27	0.19	0.07	9.3	0.007
E274-VDOT-E524-24	E2-22	0.42	0.022	10	0.47	0.38	0.08	5.3	0.007
E274-VDOT-E524-24	S-6-04	0.31	0.008	10	0.33	0.30	0.03	2.7	0.003
GRT-033-E1844-20	A2-22	0.30	0.047	10	0.38	0.23	0.15	15.6	0.015
GRT-033-E1844-20	B2-22	0.55	0.013	10	0.57	0.53	0.04	2.4	0.004
GRT-033-E1844-20	C2-22	0.54	0.018	10	0.57	0.51	0.06	3.3	0.006
GRT-033-E1844-20	D2-22	0.39	0.026	10	0.43	0.36	0.08	6.6	0.008
GRT-033-E1844-20	E2-22	0.54	0.010	10	0.55	0.51	0.03	1.9	0.003
GRT-033-E1844-20	F2-22	0.56	0.011	10	0.58	0.54	0.03	2.0	0.004
GRT-033-E1844-20	S-6-04	0.54	0.013	10	0.56	0.52	0.04	2.5	0.004
GRT-211-E1844-20	A2-22	0.33	0.038	5	0.37	0.27	0.10	11.4	0.017
GRT-211-E1844-20	B2-22	0.59	0.015	5	0.61	0.57	0.04	2.5	0.007
GRT-211-E1844-20	C2-22	0.56	0.018	5	0.58	0.54	0.04	3.2	0.008
GRT-211-E1844-20	D2-22	0.46	0.011	5	0.47	0.44	0.03	2.5	0.005
GRT-211-E1844-20	E2-22	0.63	0.000	5	0.63	0.63	0.00	0.0	0.000
GRT-211-E1844-20	F2-22	0.63	0.011	5	0.64	0.62	0.02	1.7	0.005
IMAG-IRV-PIARC	B2-22	0.63	0.013	11	0.64	0.60	0.04	2.1	0.004
IMAG-IRV-PIARC	C2-22	0.60	0.008	11	0.61	0.59	0.02	1.3	0.002
IMAG-IRV-PIARC	D2-22	0.32	0.021	10	0.34	0.28	0.06	6.5	0.007
IMAG-IRV-PIARC	E2-22	0.57	0.017	11	0.60	0.54	0.06	3.0	0.005
IMAG-IRV-PIARC	F2-22	0.61	0.013	11	0.64	0.60	0.04	2.0	0.004
IMAG-IRV-PIARC	S-6-04	0.55	0.045	10	0.60	0.49	0.11	8.3	0.014
IMAG-IRV-PIARC-22	A2-22	0.25	0.050	10	0.32	0.20	0.12	19.7	0.016
RFT-FAA-E1551-100	A2-22	0.37	0.029	10	0.42	0.33	0.09	7.9	0.009
RFT-FAA-E1551-100	S-6-04	0.52	0.024	10	0.55	0.48	0.07	4.6	0.008
SFT-212-E1551-100	A2-22	0.47	0.018	10	0.50	0.44	0.06	3.8	0.006
SFT-212-E1551-100	S-6-04	0.62	0.023	10	0.64	0.57	0.07	3.6	0.007
SFT-TC85-E1551-100	A2-22	0.54	0.046	10	0.62	0.50	0.12	8.5	0.015
SFT-TC85-E1551-100	S-6-04	0.64	0.032	10	0.69	0.59	0.10	5.0	0.010

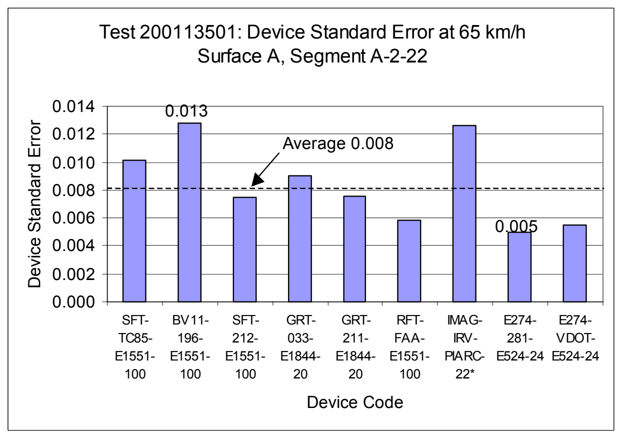
Appendix B. Plots by Surface Segment

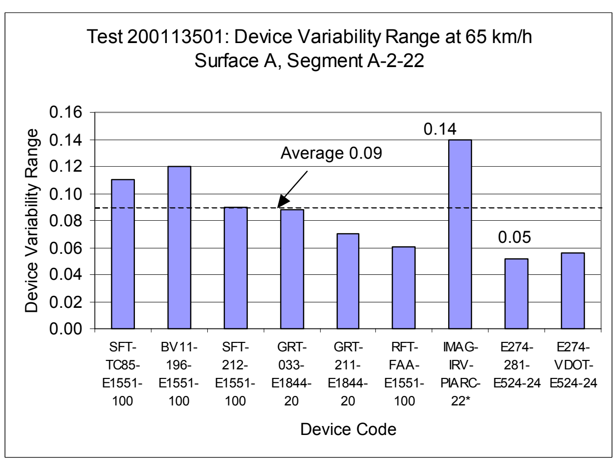
A-2-22 (65 km/h)



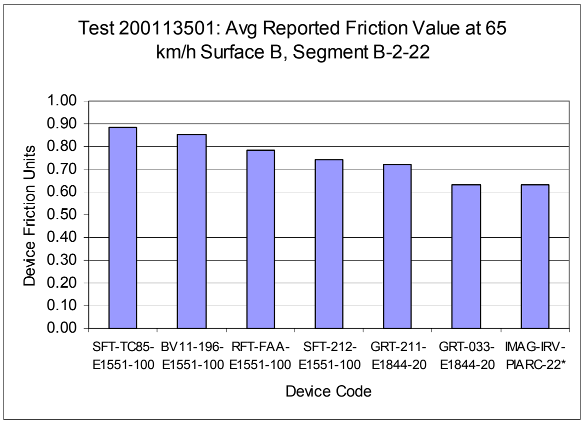


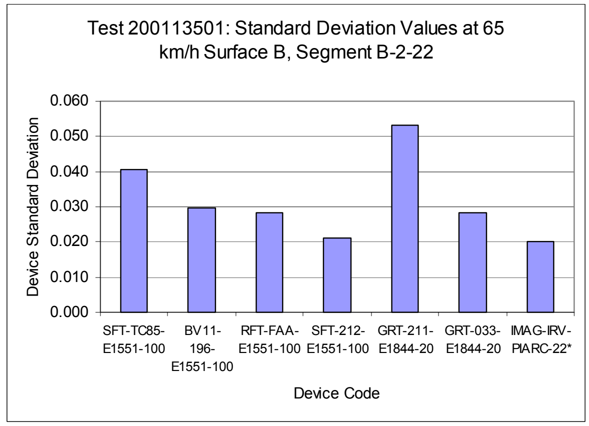


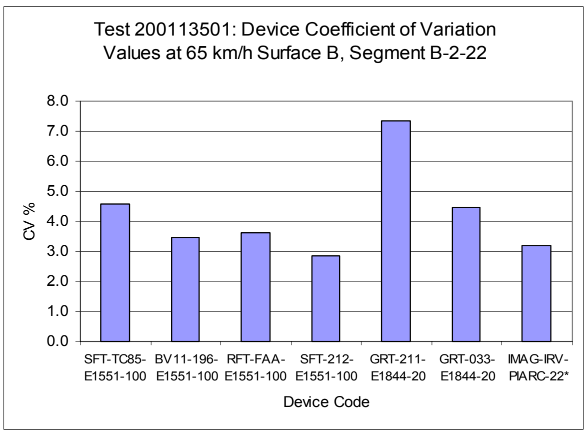


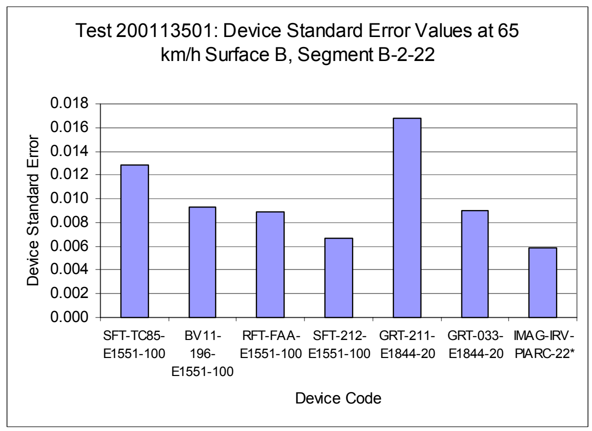


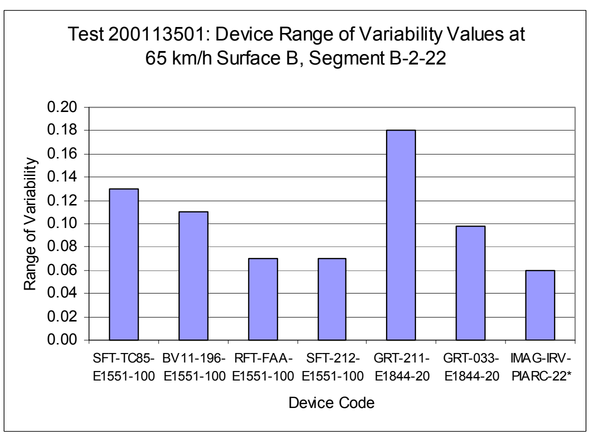
B-2-22 (65 km/h)


Test 200113501: Avg Reported Friction Value at 65 km/h Surface B, Segment B-2-22
Device Friction Units
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
Device Code

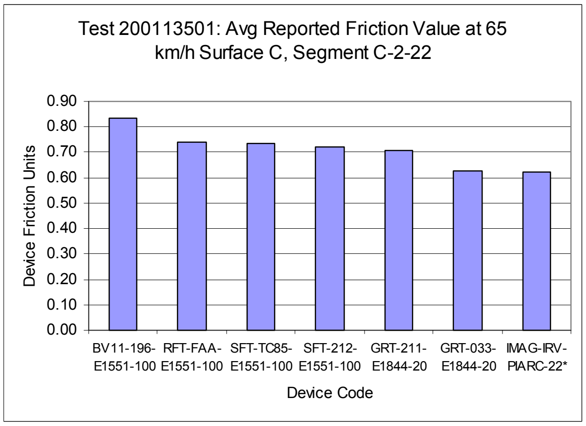

Test 200113501: Standard Deviation Values at 65 km/h Surface B, Segment B-2-22
Device Standard Deviation
0.060
0.050
0.040
0.030
0.020
0.010
0.000
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
Device Code


Test 200113501: Device Coefficient of Variation Values at 65 km/h Surface B, Segment B-2-22
CV %
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
Device Code

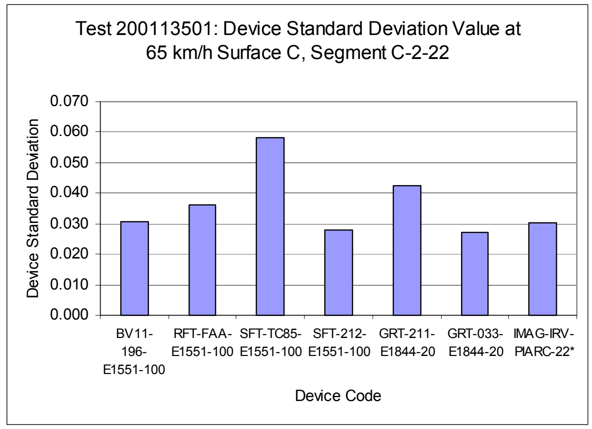

Test 200113501: Device Standard Error Values at 65 km/h Surface B, Segment B-2-22
Device Standard Error
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
Device Code


Test 200113501: Device Range of Variability Values at 65 km/h Surface B, Segment B-2-22
Range of Variability
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
Device Code

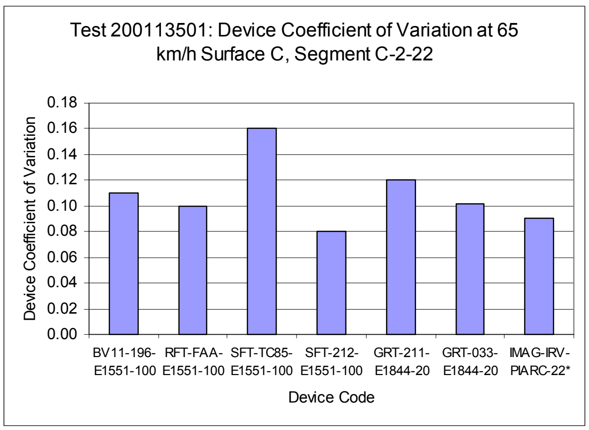
C-2-22 (65 km/h)



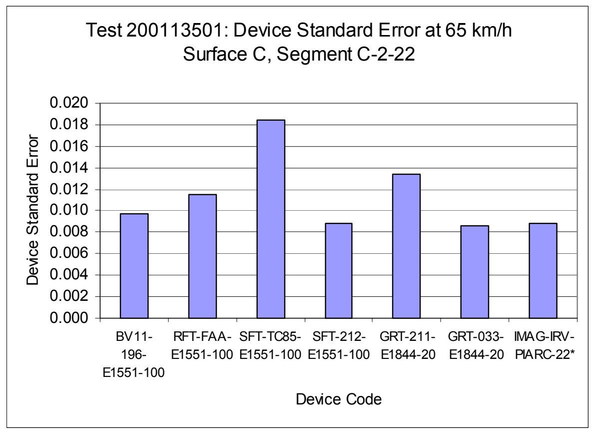
Test 200113501: Avg Reported Friction Value at 65 km/h Surface C, Segment C-2-22
Device Friction Units
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-TC85-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
Device Code



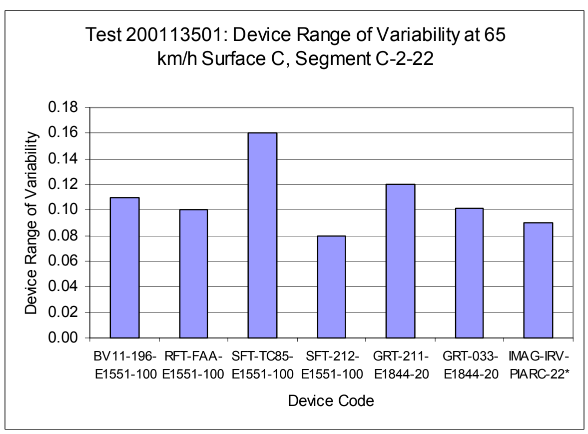
Test 200113501: Device Standard Deviation Value at 65 km/h Surface C, Segment C-2-22
Device Standard Deviation
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-TC85-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
Device Code



Test 200113501: Device Coefficient of Variation at 65 km/h Surface C, Segment C-2-22
Device Coefficient of Variation
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-TC85-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
Device Code

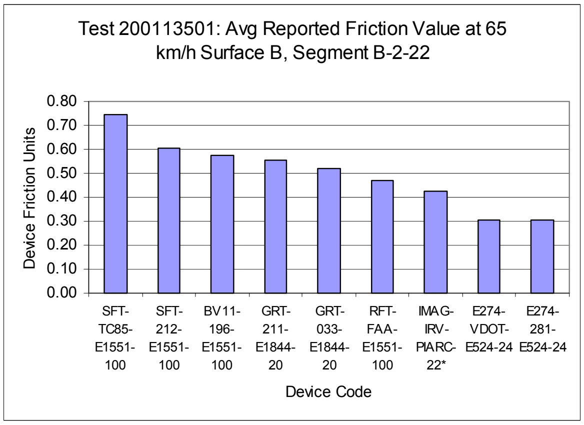


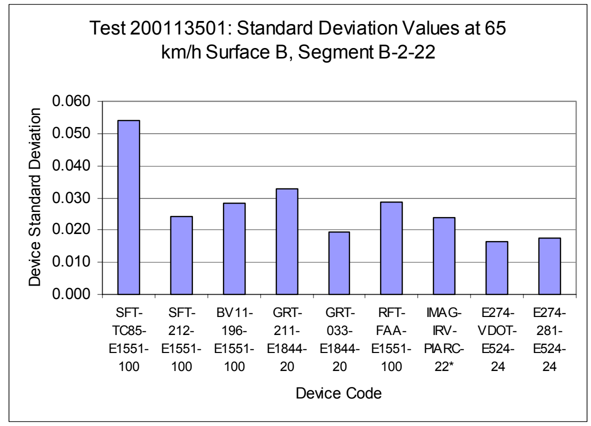
Test 200113501: Device Standard Error at 65 km/h Surface C, Segment C-2-22
Device Standard Error
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-TC85-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
Device Code

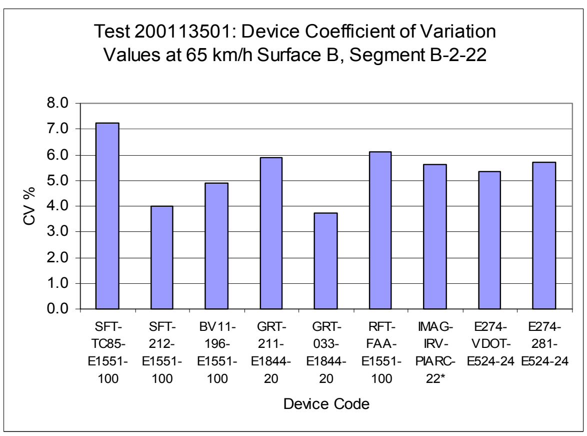


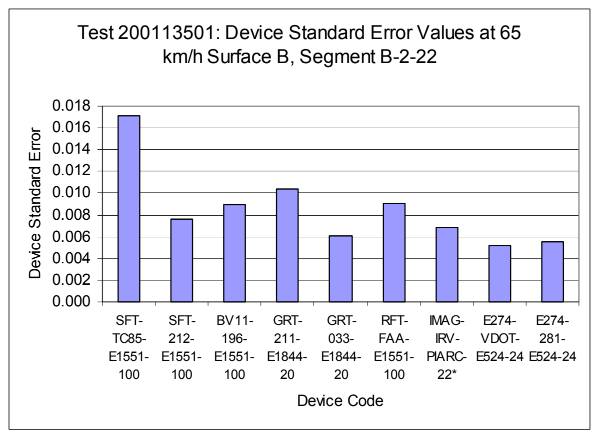
Test 200113501: Device Range of Variability at 65 km/h Surface C, Segment C-2-22
Device Range of Variability
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-TC85-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
Device Code

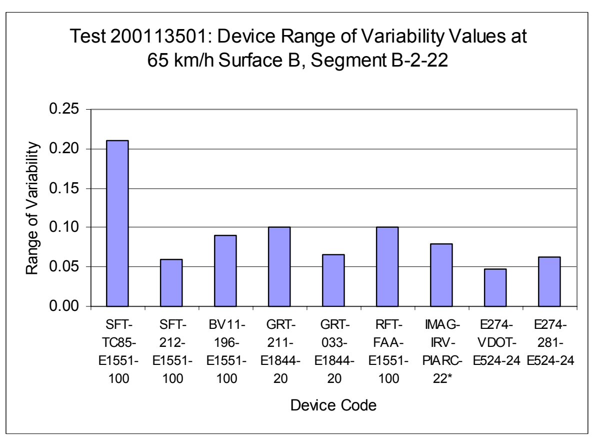
D-2-22 (65 km/h)


Test 200113501: Avg Reported Friction Value at 65 km/h Surface B, Segment B-2-22
Device Friction Units
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SFT-TC85-E1551-100
SFT-212-E1551-100
BV11-196-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

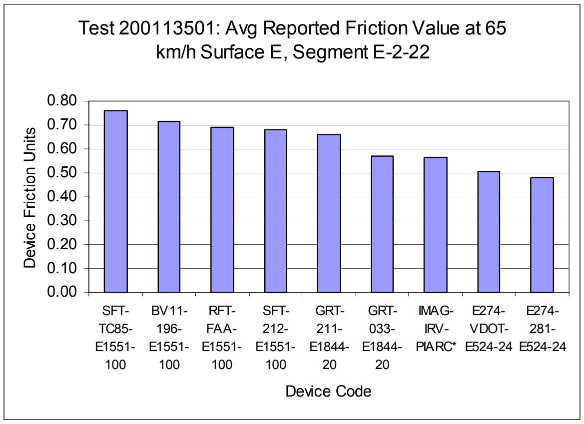

Test 200113501: Standard Deviation Values at 65 km/h Surface B, Segment B-2-22
Device Standard Deviation
0.060
0.050
0.040
0.030
0.020
0.010
0.000
SFT-TC85-E1551-100
SFT-212-E1551-100
BV11-196-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22*
E274-VDOT-E524-24
E274-281-E524-24
Device Code


Test 200113501: Device Coefficient of Variation Values at 65 km/h Surface B, Segment B-2-22
CV %
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
SFT-TC85-E1551-100
SFT-212-E1551-100
BV11-196-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

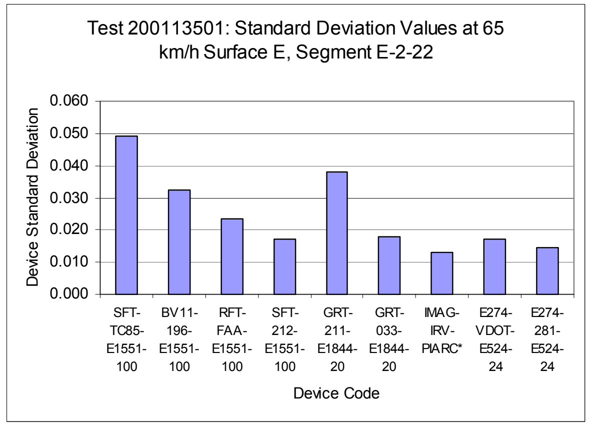

Test 200113501: Device Standard Error Values at 65 km/h Surface B, Segment B-2-22
Device Standard Error
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
SFT-TC85-E1551-100
SFT-212-E1551-100
BV11-196-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22*
E274-VDOT-E524-24
E274-281-E524-24
Device Code


Test 200113501: Device Range of Variability Values at 65 km/h Surface B, Segment B-2-22
Range of Variability
0.25
0.20
0.15
0.10
0.05
0.00
SFT-TC85-E1551-100
SFT-212-E1551-100
BV11-196-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

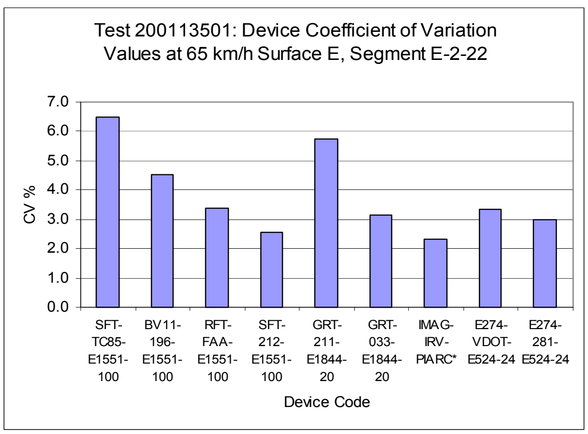
E-2-22 (65 km/h)



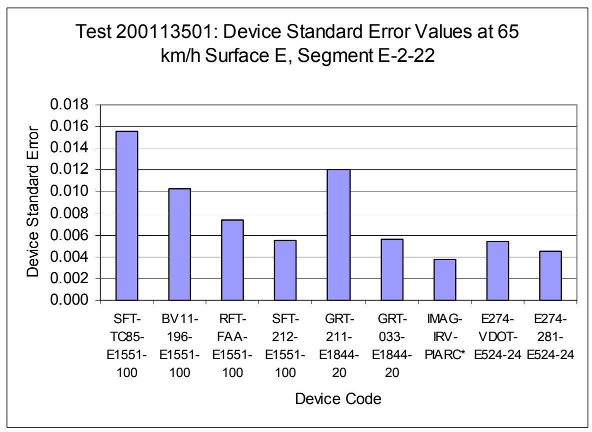
Test 200113501: Avg Reported Friction Value at 65 km/h Surface E, Segment E-2-22
Device Friction Units
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC*
E274-VDOT-E524-24
E274-281-E524-24
Device Code



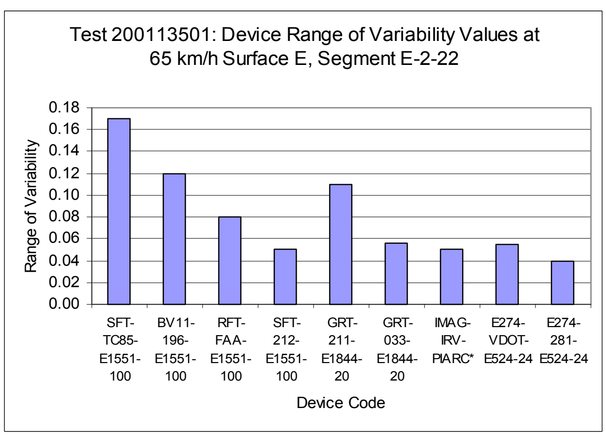
Test 200113501: Standard Deviation Values at 65 km/h Surface E, Segment E-2-22
Device Standard Deviation
0.060
0.050
0.040
0.030
0.020
0.010
0.000
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC*
E274-VDOT-E524-24
E274-281-E524-24
Device Code



Test 200113501: Device Coefficient of Variation Values at 65 km/h Surface E, Segment E-2-22
CV %
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

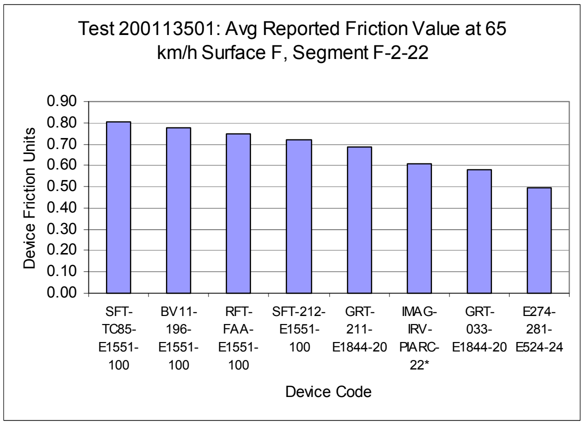


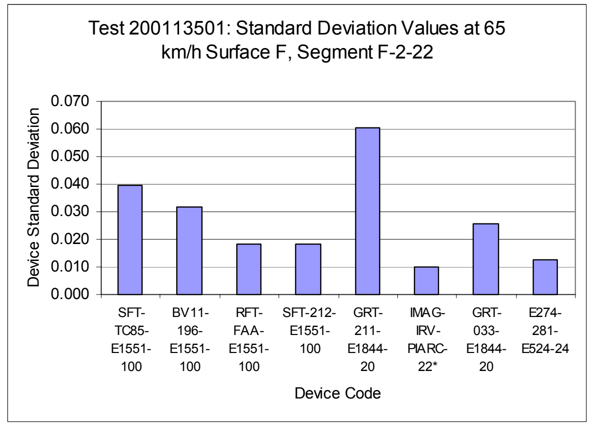
Test 200113501: Device Standard Error Values at 65 km/h Surface E, Segment E-2-22
Device Standard Error
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

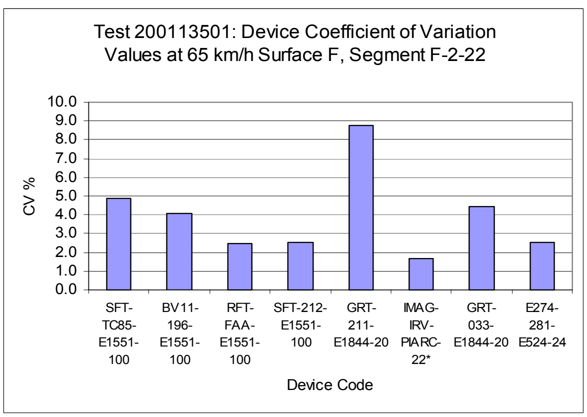


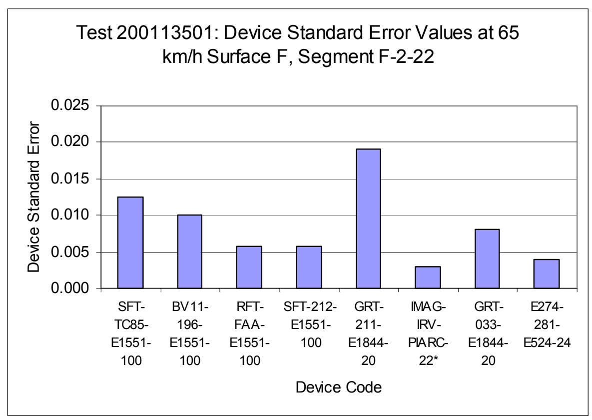
Test 200113501: Device Range of Variability Values at 65 km/h Surface E, Segment E-2-22
Range of Variability
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

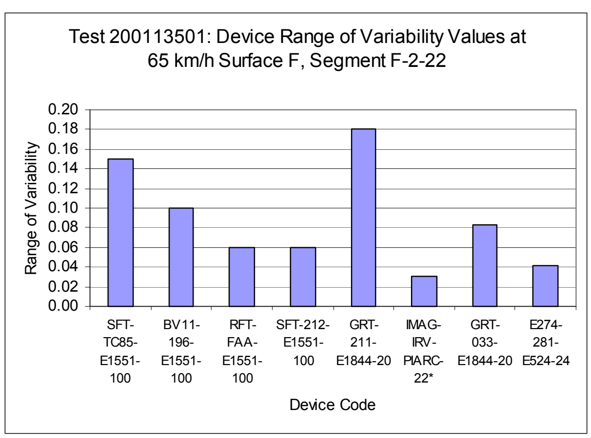
F-2-22 (65 km/h)


Test 200113501: Avg Reported Friction Value at 65 km/h Surface F, Segment F-2-22
Device Friction Units
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
IMAG-IRV-PIARC-22*
GRT-033-E1844-20
E274-281-E524-24
Device Code

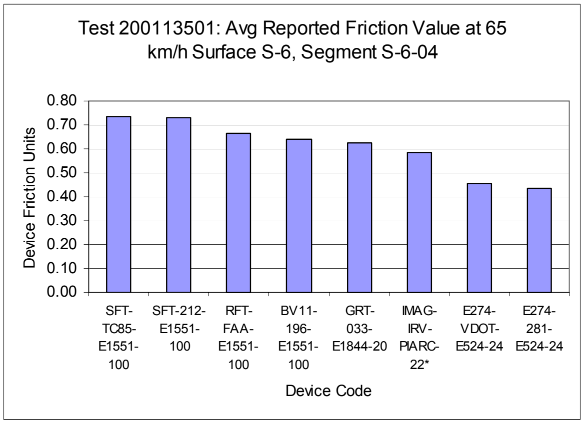

Test 200113501: Standard Deviation Values at 65 km/h Surface F, Segment F-2-22
Device Standard Deviation
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
IMAG-IRV-PIARC-22*
GRT-033-E1844-20
E274-281-E524-24
Device Code

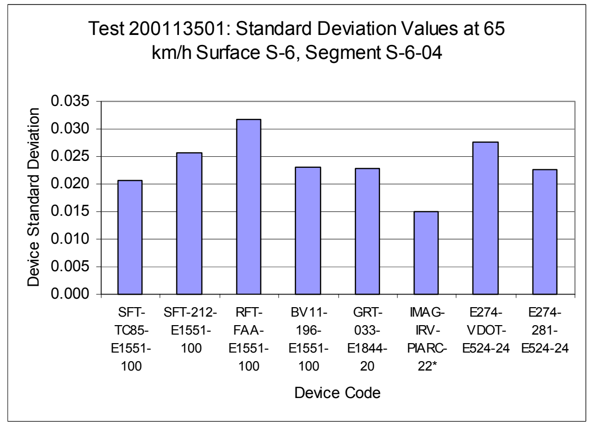

Test 200113501: Device Coefficient of Variation Values at 65 km/h Surface F, Segment F-2-22
CV %
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
IMAG-IRV-PIARC-22*
GRT-033-E1844-20
E274-281-E524-24
Device Code

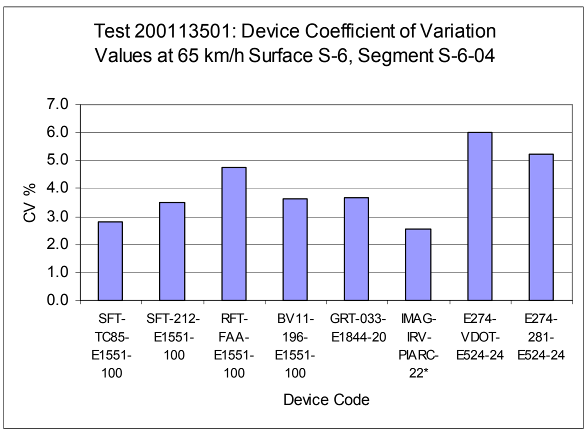

Test 200113501: Device Standard Error Values at 65 km/h Surface F, Segment F-2-22
Device Standard Error
0.025
0.020
0.015
0.010
0.005
0.000
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
IMAG-IRV-PIARC-22*
GRT-033-E1844-20
E274-281-E524-24
Device Code

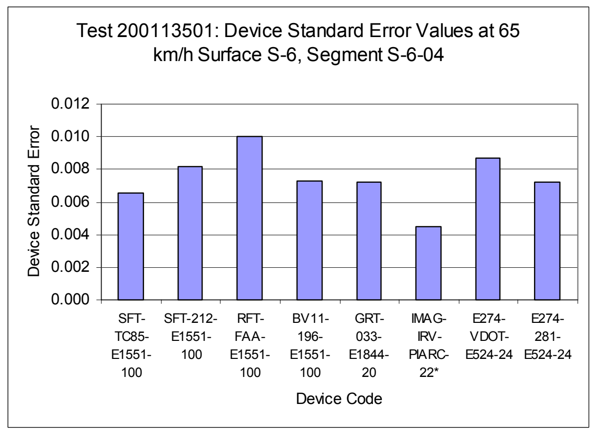

Test 200113501: Device Range of Variability Values at 65 km/h Surface F, Segment F-2-22
Range of Variability
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
SFT-TC85-E1551-100
BV11-196-E1551-100
RFT-FAA-E1551-100
SFT-212-E1551-100
GRT-211-E1844-20
IMAG-IRV-PIARC-22*
GRT-033-E1844-20
E274-281-E524-24
Device Code

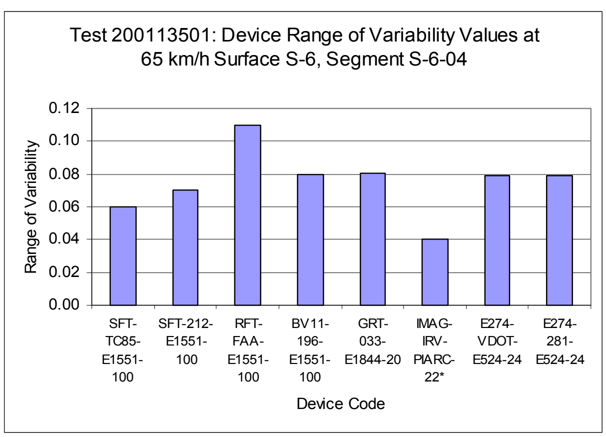
S-6-04 (65 km/h)


Test 200113501: Avg Reported Friction Value at 65 km/h Surface S-6, Segment S-6-04
Device Friction Units
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
SFT-TC85-E1551-100
SFT-212-E1551-100
RFT-FAA-E1551-100
BV11-196-E1551-100
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

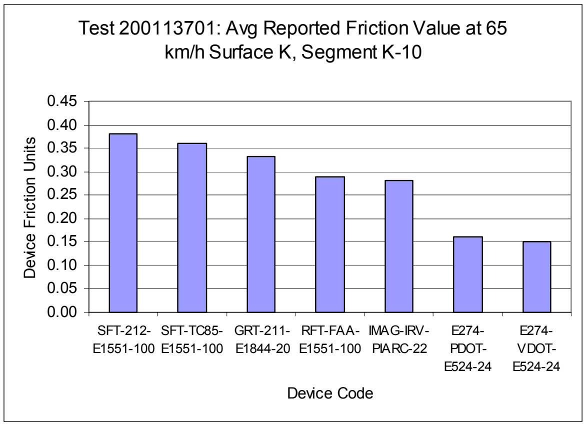

Test 200113501: Standard Deviation Values at 65 km/h Surface S-6, Segment S-6-04
Device Standard Deviation
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
SFT-TC85-E1551-100
SFT-212-E1551-100
RFT-FAA-E1551-100
BV11-196-E1551-100
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

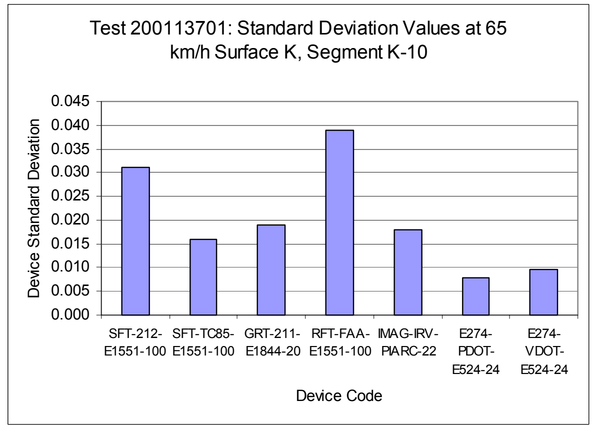

Test 200113501: Device Coefficient of Variation Values at 65 km/h Surface S-6, Segment S-6-04
CV %
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
SFT-TC85-E1551-100
SFT-212-E1551-100
RFT-FAA-E1551-100
BV11-196-E1551-100
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

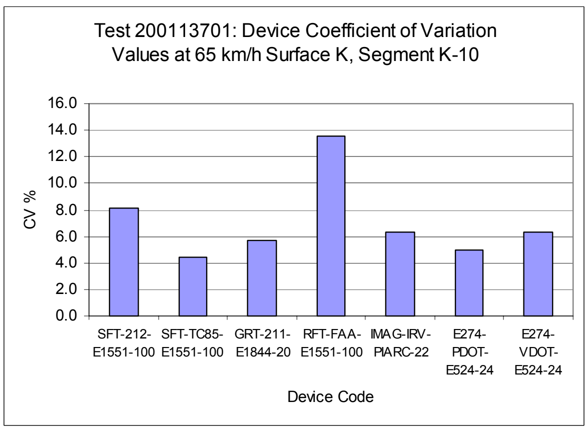

Test 200113501: Device Standard Error Values at 65 km/h Surface S-6, Segment S-6-04
Device Standard Error
0.000
0.002
0.004
0.006
0.008
0.010
0.012
SFT-TC85-E1551-100
SFT-212-E1551-100
RFT-FAA-E1551-100
BV11-196-E1551-100
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

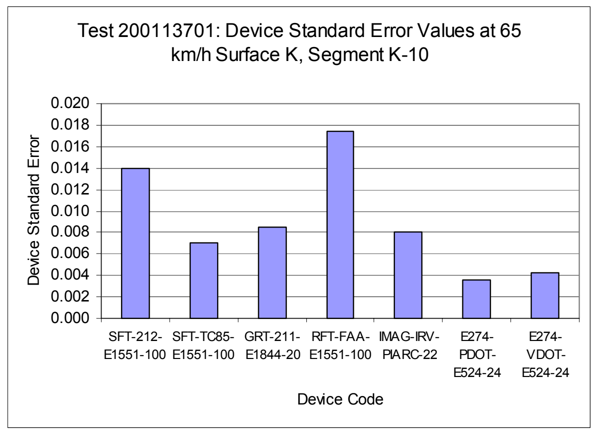

Test 200113501: Device Range of Variability Values at 65 km/h Surface S-6, Segment S-6-04
Range of Variability
0.00
0.02
0.04
0.06
0.08
0.10
0.12
SFT-TC85-E1551-100
SFT-212-E1551-100
RFT-FAA-E1551-100
BV11-196-E1551-100
GRT-033-E1844-20
IMAG-IRV-PIARC-22*
E274-VDOT-E524-24
E274-281-E524-24
Device Code

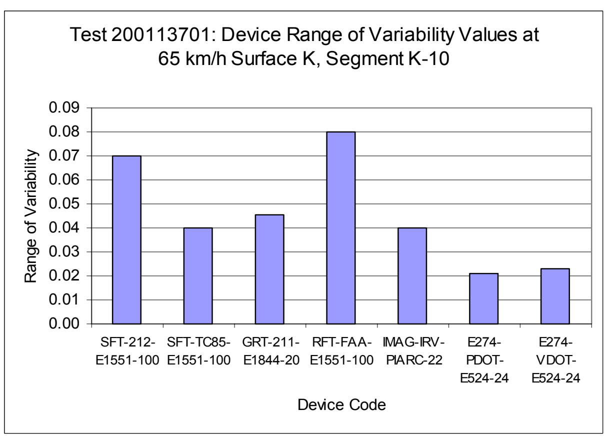
K-10 (65 km/h)


Test 200113701: Avg Reported Friction Value at 65 km/h Surface K, Segment K-10
Device Friction Units
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SFT-212-E1551-100
SFT-TC85-E1551-100
GRT-211-E1844-20
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

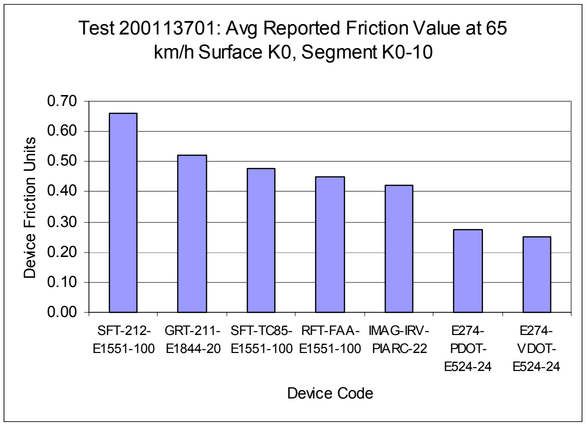

Test 200113701: Standard Deviation Values at 65 km/h Surface K, Segment K-10
Device Standard Deviation
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
SFT-212-E1551-100
SFT-TC85-E1551-100
GRT-211-E1844-20
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

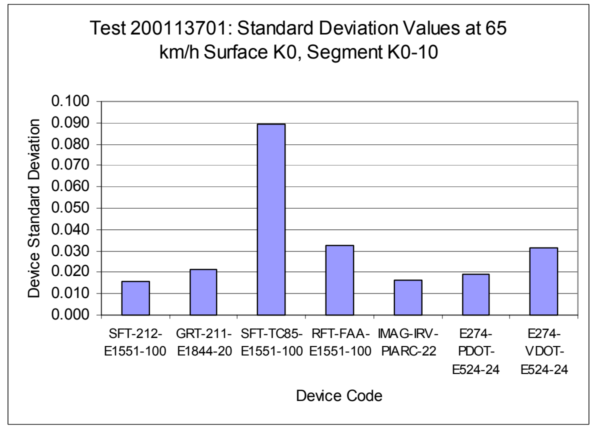

Test 200113701: Device Coefficient of Variation Values at 65 km/h Surface K, Segment K-10
CV %
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
SFT-212-E1551-100
SFT-TC85-E1551-100
GRT-211-E1844-20
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

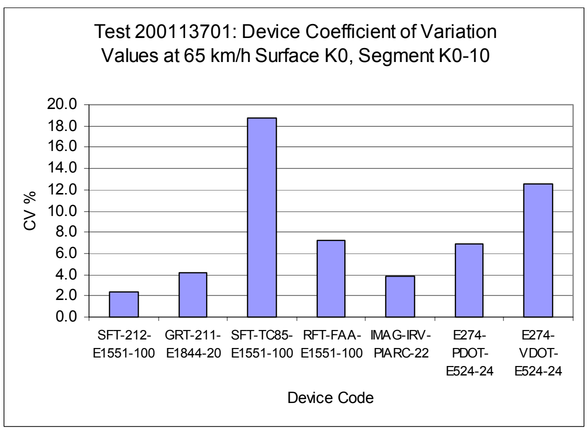

Test 200113701: Device Standard Error Values at 65 km/h Surface K, Segment K-10
Device Standard Error
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
SFT-212-E1551-100
SFT-TC85-E1551-100
GRT-211-E1844-20
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

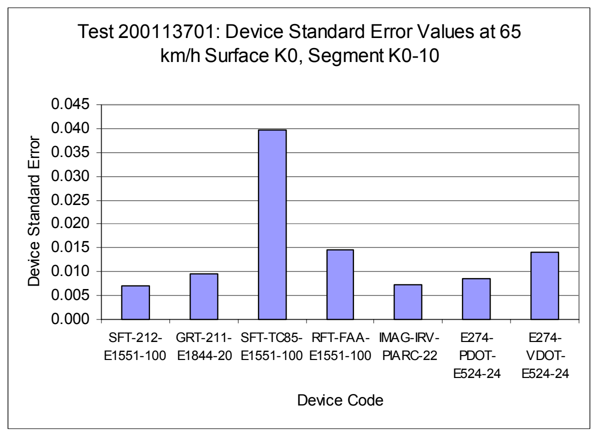

Test 200113701: Device Range of Variability Values at 65 km/h Surface K, Segment K-10
Range of Variability
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
SFT-212-E1551-100
SFT-TC85-E1551-100
GRT-211-E1844-20
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

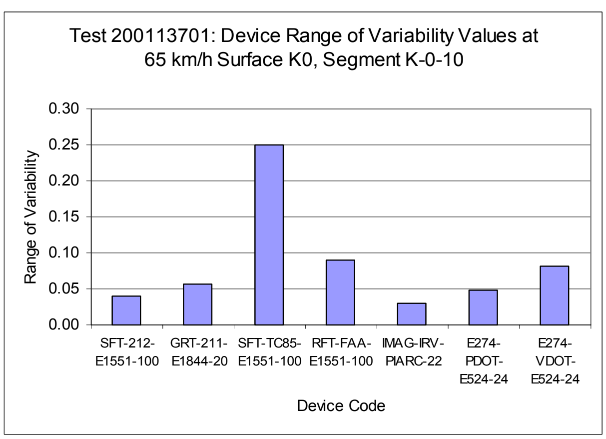
K0-10 (65 km/h)


Test 200113701: Avg Reported Friction Value at 65 km/h Surface K0, Segment K0-10
Device Friction Units
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SFT-212-E1551-100
GRT-211-E1844-20
SFT-TC85-E1551-100
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

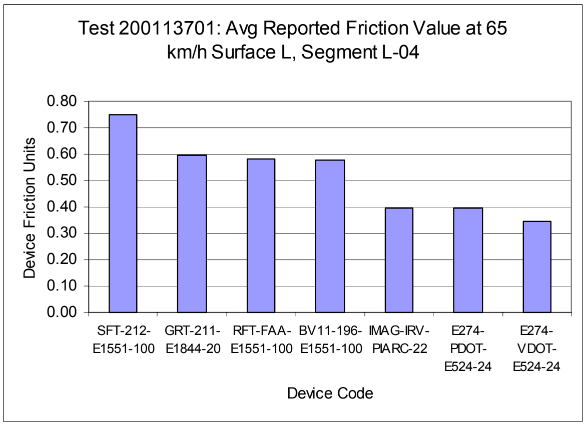

Test 200113701: Standard Deviation Values at 65 km/h Surface K0, Segment K0-10
Device Standard Deviation
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
SFT-212-E1551-100
GRT-211-E1844-20
SFT-TC85-E1551-100
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

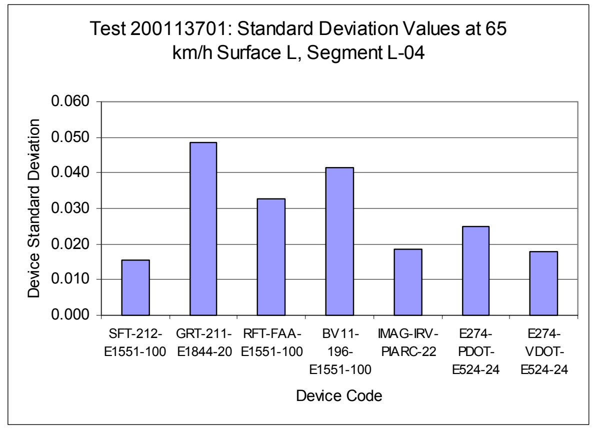

Test 200113701: Device Coefficient of Variation Values at 65 km/h Surface K0, Segment K0-10
CV %
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
SFT-212-E1551-100
GRT-211-E1844-20
SFT-TC85-E1551-100
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

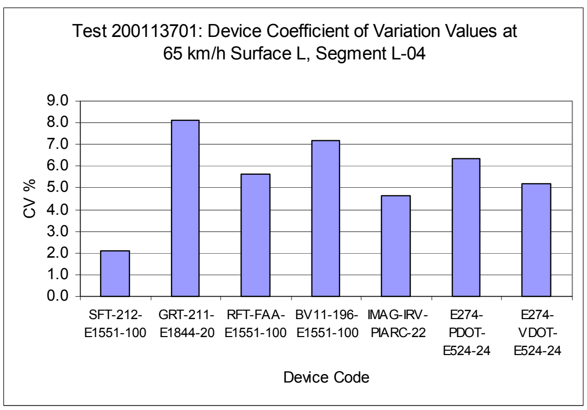

Test 200113701: Device Standard Error Values at 65 km/h Surface K0, Segment K0-10
Device Standard Error
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
SFT-212-E1551-100
GRT-211-E1844-20
SFT-TC85-E1551-100
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

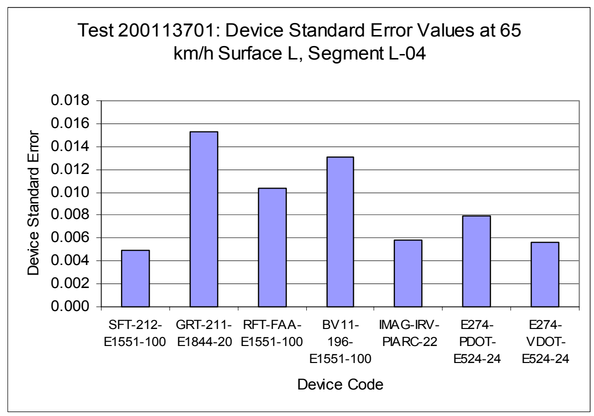

Test 200113701: Device Range of Variability Values at 65 km/h Surface K0, Segment K-0-10
Range of Variability
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SFT-212-E1551-100
GRT-211-E1844-20
SFT-TC85-E1551-100
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

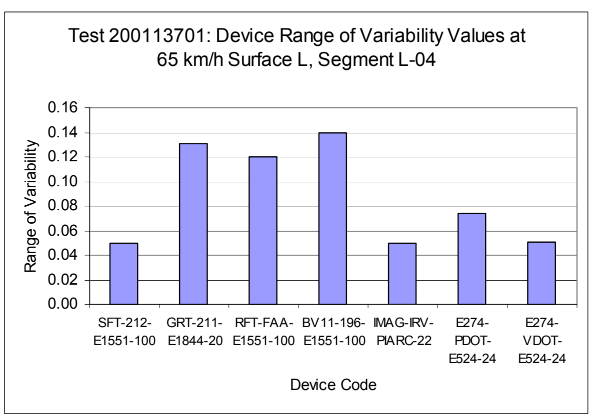
L-04 (65 km/h)


Test 200113701: Avg Reported Friction Value at 65 km/h Surface L, Segment L-04
Device Friction Units
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SFT-212-E1551-100
GRT-211-E1844-20
RFT-FAA-E1551-100
BV11-196-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

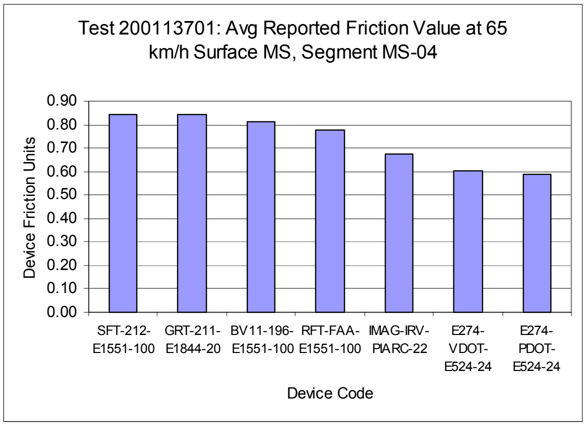

Test 200113701: Standard Deviation Values at 65 km/h Surface L, Segment L-04
Device Standard Deviation
0.060
0.050
0.040
0.030
0.020
0.010
0.000
SFT-212-E1551-100
GRT-211-E1844-20
RFT-FAA-E1551-100
BV11-196-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code


Test 200113701: Device Coefficient of Variation Values at 65 km/h Surface L, Segment L-04
CV %
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
SFT-212-E1551-100
GRT-211-E1844-20
RFT-FAA-E1551-100
BV11-196-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

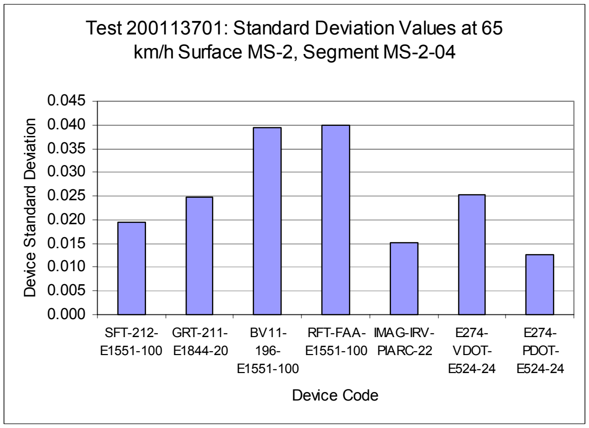

Test 200113701: Device Standard Error Values at 65 km/h Surface L, Segment L-04
Device Standard Error
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
SFT-212-E1551-100
GRT-211-E1844-20
RFT-FAA-E1551-100
BV11-196-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code


Test 200113701: Device Range of Variability Values at 65 km/h Surface L, Segment L-04
Range of Variability
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
SFT-212-E1551-100
GRT-211-E1844-20
RFT-FAA-E1551-100
BV11-196-E1551-100
IMAG-IRV-PIARC-22
E274-PDOT-E524-24
E274-VDOT-E524-24
Device Code

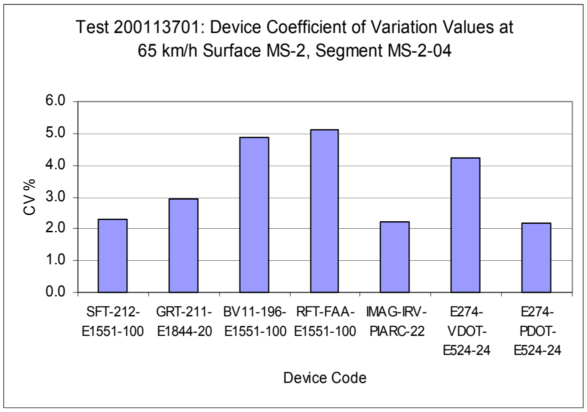
MS-2-04 (65 km/h)



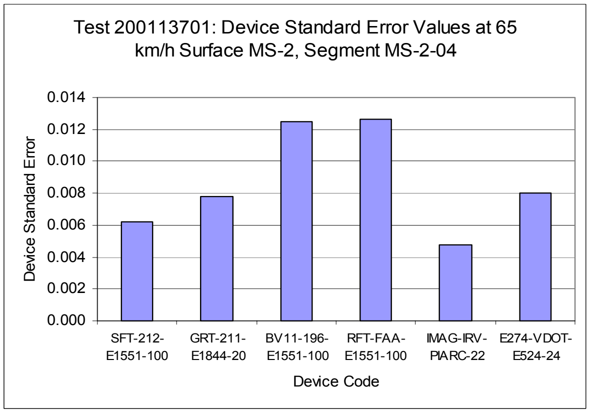
Test 200113701: Avg Reported Friction Value at 65 km/h Surface MS, Segment MS-04
Device Friction Units
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SFT-212-E1551-100
GRT-211-E1844-20
BV11-196-E1551-100
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-VDOT-E524-24
E274-PDOT-E524-24
Device Code



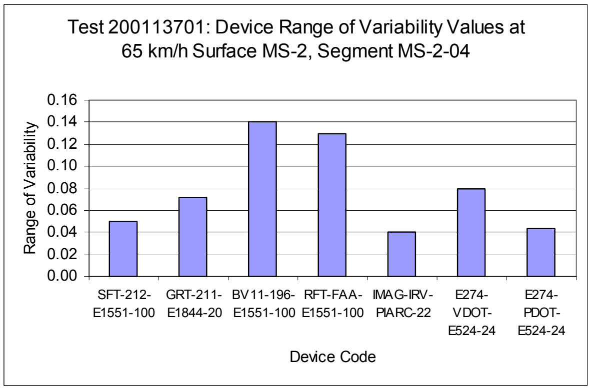
Test 200113701: Standard Deviation Values at 65 km/h Surface MS-2, Segment MS-2-04
Device Standard Deviation
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
SFT-212-E1551-100
GRT-211-E1844-20
BV11-196-E1551-100
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-VDOT-E524-24
E274-PDOT-E524-24
Device Code



Test 200113701: Device Coefficient of Variation Values at 65 km/h Surface MS-2, Segment MS-2-04
CV %
6.0
5.0
4.0
3.0
2.0
1.0
0.0
SFT-212-E1551-100
GRT-211-E1844-20
BV11-196-E1551-100
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-VDOT-E524-24
E274-PDOT-E524-24
Device Code

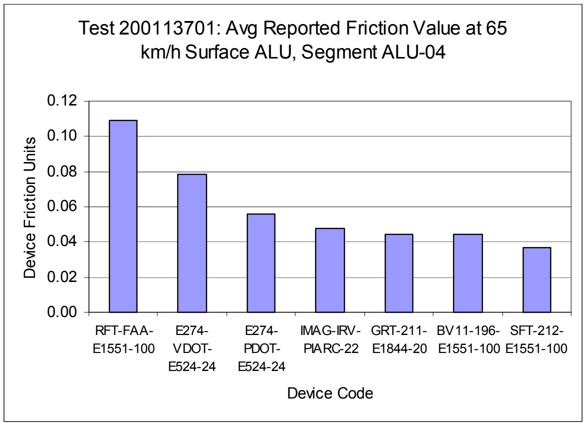


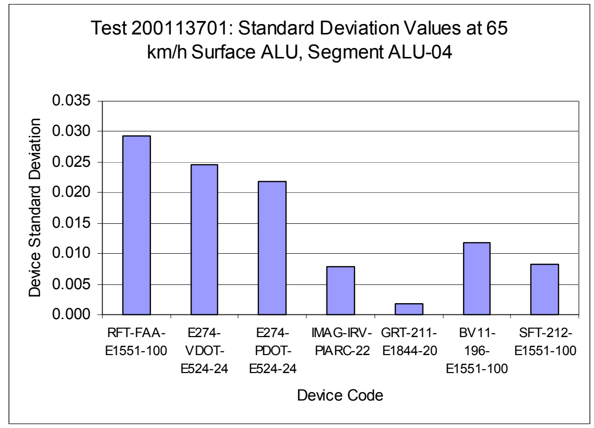
Test 200113701: Device Standard Error Values at 65 km/h Surface MS-2, Segment MS-2-04
Device Standard Error
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
SFT-212-E1551-100
GRT-211-E1844-20
BV11-196-E1551-100
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-VDOT-E524-24
Device Code

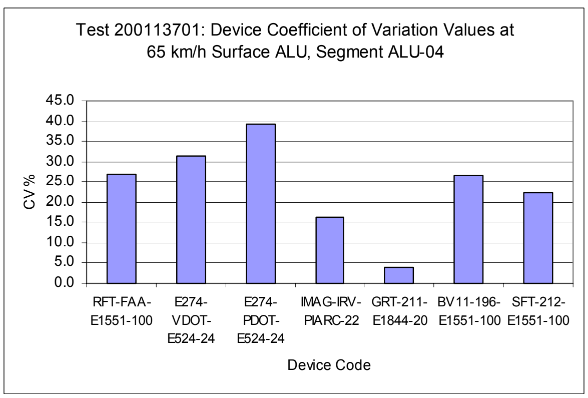


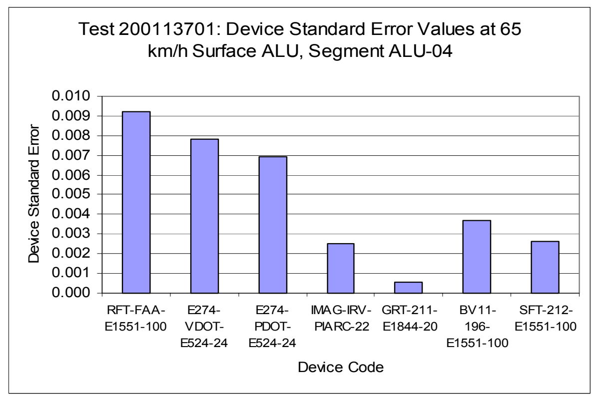
Test 200113701: Device Range of Variability Values at 65 km/h Surface MS-2, Segment MS-2-04
Range of Variability
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
SFT-212-E1551-100
GRT-211-E1844-20
BV11-196-E1551-100
RFT-FAA-E1551-100
IMAG-IRV-PIARC-22
E274-VDOT-E524-24
E274-PDOT-E524-24
Device Code

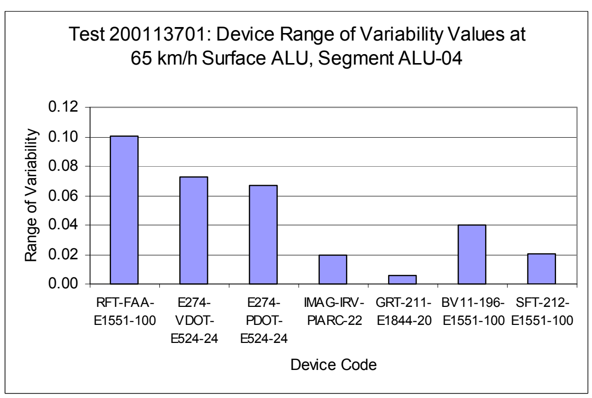
ALU (65 km/h)


Test 200113701: Avg Reported Friction Value at 65 km/h Surface ALU, Segment ALU-04
Device Friction Units
0.12
0.10
0.08
0.06
0.04
0.02
0.00
RFT-FAA-E1551-100
E274-VDOT-E524-24
E274-PDOT-E524-24
IMAG-IRV-PIARC-22
GRT-211-E1844-20
BV11-196-E1551-100
SFT-212-E1551-100
Device Code

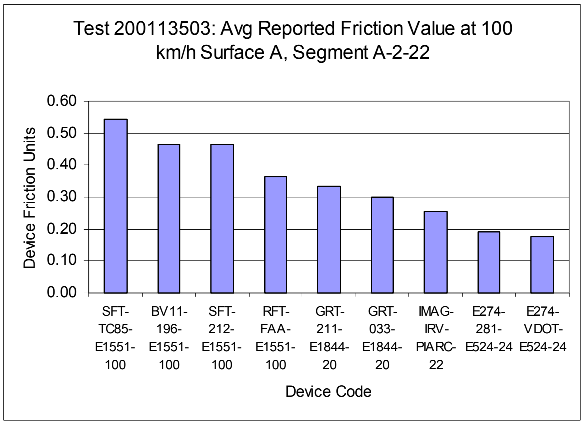

Test 200113701: Standard Deviation Values at 65 km/h Surface ALU, Segment ALU-04
Device Standard Deviation
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
RFT-FAA-E1551-100
E274-VDOT-E524-24
E274-PDOT-E524-24
IMAG-IRV-PIARC-22
GRT-211-E1844-20
BV11-196-E1551-100
SFT-212-E1551-100
Device Code

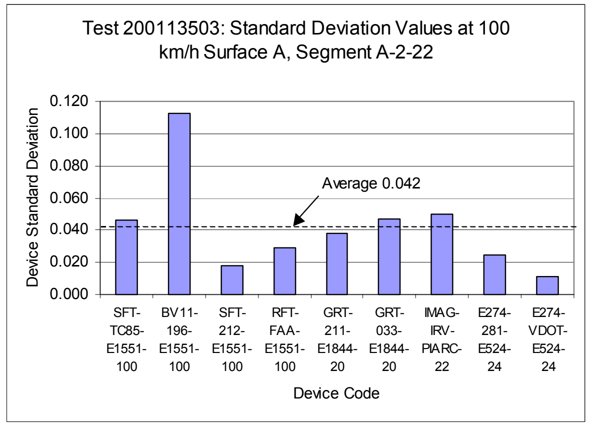

Test 200113701: Device Coefficient of Variation Values at 65 km/h Surface ALU, Segment ALU-04
CV %
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
RFT-FAA-E1551-100
E274-VDOT-E524-24
E274-PDOT-E524-24
IMAG-IRV-PIARC-22
GRT-211-E1844-20
BV11-196-E1551-100
SFT-212-E1551-100
Device Code

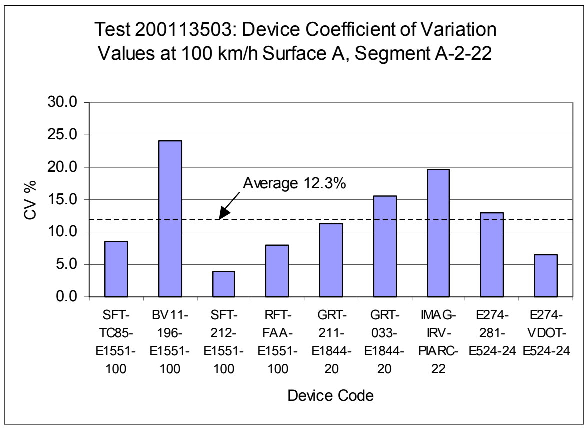

Test 200113701: Device Standard Error Values at 65 km/h Surface ALU, Segment ALU-04
Device Standard Error
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
RFT-FAA-E1551-100
E274-VDOT-E524-24
E274-PDOT-E524-24
IMAG-IRV-PIARC-22
GRT-211-E1844-20
BV11-196-E1551-100
SFT-212-E1551-100
Device Code

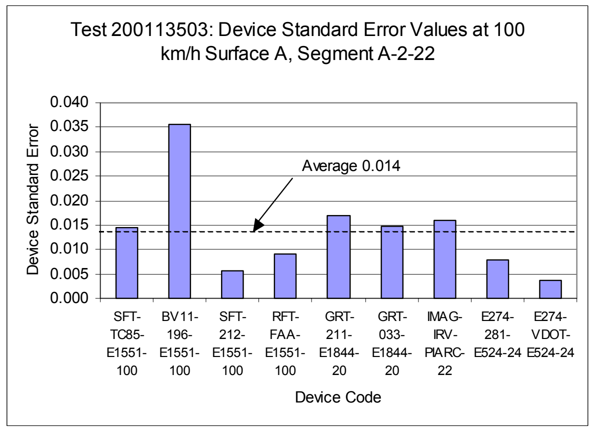

Test 200113701: Device Range of Variability Values at 65 km/h Surface ALU, Segment ALU-04
Range of Variability
0.12
0.10
0.08
0.06
0.04
0.02
0.00
RFT-FAA-E1551-100
E274-VDOT-E524-24
E274-PDOT-E524-24
IMAG-IRV-PIARC-22
GRT-211-E1844-20
BV11-196-E1551-100
SFT-212-E1551-100
Device Code

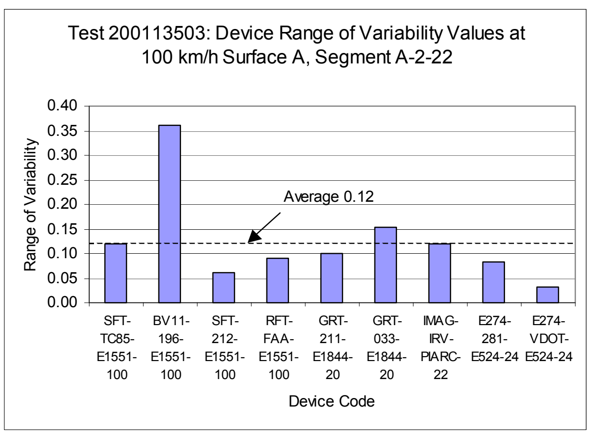
A-2-22 (100 km/h)


Test 200113503: Avg Reported Friction Value at 100 km/h Surface A, Segment A-2-22
Device Friction Units
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SFT-TC85-E1551-100
BV11-196-E1551-100
SFT-212-E1551-100
RFT-FAA-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22
E274-281-E524-24
E274-VDOT-E524-24
Device Code

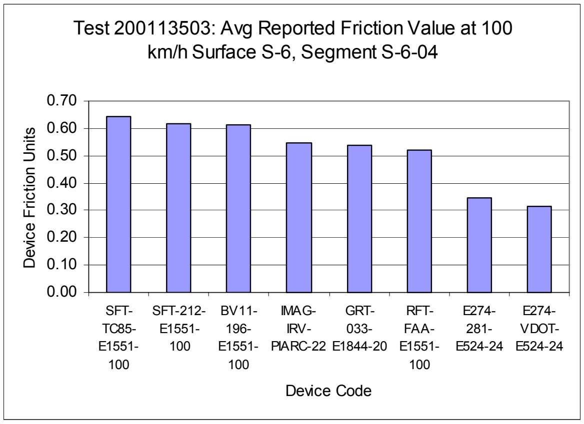

Test 200113503: Standard Deviation Values at 100 km/h Surface A, Segment A-2-22
Device Standard Deviation
0.120
0.100
0.080
0.060
0.040
0.020
0.000
Average 0.042
SFT-TC85-E1551-100
BV11-196-E1551-100
SFT-212-E1551-100
RFT-FAA-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22
E274-281-E524-24
E274-VDOT-E524-24
Device Code


Test 200113503: Device Coefficient of Variation Values at 100 km/h Surface A, Segment A-2-22
CV %
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Average 12.3%
SFT-TC85-E1551-100
BV11-196-E1551-100
SFT-212-E1551-100
RFT-FAA-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22
E274-281-E524-24
E274-VDOT-E524-24
Device Code

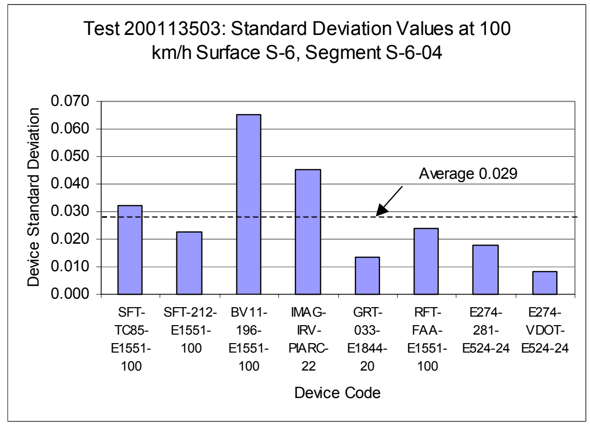

Test 200113503: Device Standard Error Values at 100 km/h Surface A, Segment A-2-22
Device Standard Error
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Average 0.014
SFT-TC85-E1551-100
BV11-196-E1551-100
SFT-212-E1551-100
RFT-FAA-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22
E274-281-E524-24
E274-VDOT-E524-24
Device Code


Test 200113503: Device Range of Variability Values at 100 km/h Surface A, Segment A-2-22
Range of Variability
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Average 0.12
SFT-TC85-E1551-100
BV11-196-E1551-100
SFT-212-E1551-100
RFT-FAA-E1551-100
GRT-211-E1844-20
GRT-033-E1844-20
IMAG-IRV-PIARC-22
E274-281-E524-24
E274-VDOT-E524-24
Device Code

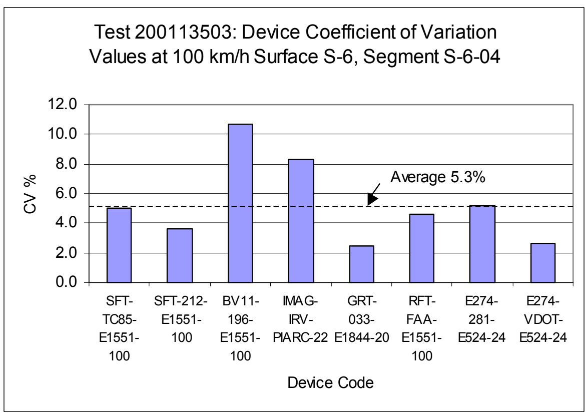
S-6-04 (100 km/h)



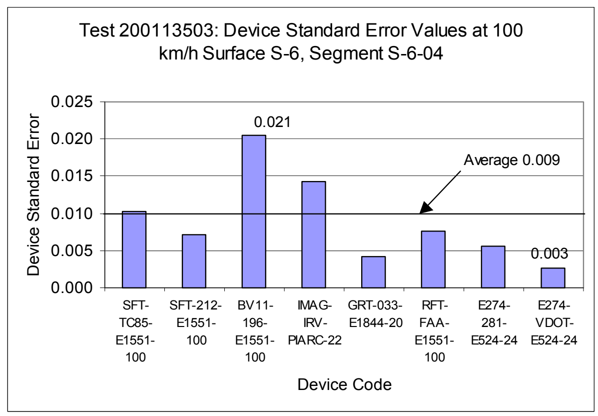
Test 200113503: Avg Reported Friction Value at 100 km/h Surface S-6, Segment S-6-04
Device Friction Units
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SFT-TC85-E1551-100
SFT-212-E1551-100
BV11-196-E1551-100
IMAG-IRV-PIARC-22
GRT-033-E1844-20
RFT-FAA-E1551-100
E274-281-E524-24
E274-VDOT-E524-24
Device Code



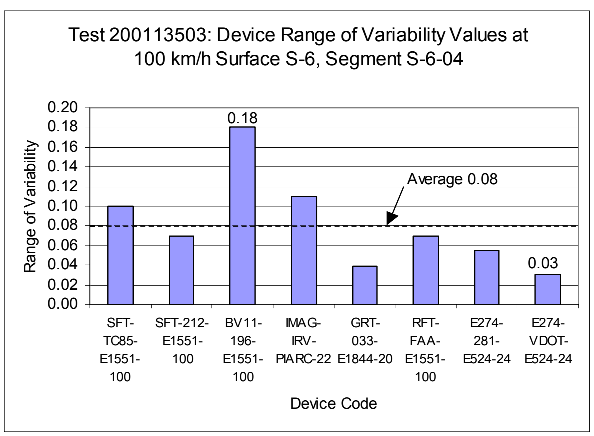
Test 200113503: Standard Deviation Values at 100 km/h Surface S-6, Segment S-6-04
Device Standard Deviation
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Average 0.029
SFT-TC85-E1551-100
SFT-212-E1551-100
BV11-196-E1551-100
IMAG-IRV-PIARC-22
GRT-033-E1844-20
RFT-FAA-E1551-100
E274-281-E524-24
E274-VDOT-E524-24
Device Code



Test 200113503: Device Coefficient of Variation Values at 100 km/h Surface S-6, Segment S-6-04
CV %
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Average 5.3%
SFT-TC85-E1551-100
SFT-212-E1551-100
BV11-196-E1551-100
IMAG-IRV-PIARC-22
GRT-033-E1844-20
RFT-FAA-E1551-100
E274-281-E524-24
E274-VDOT-E524-24
Device Code

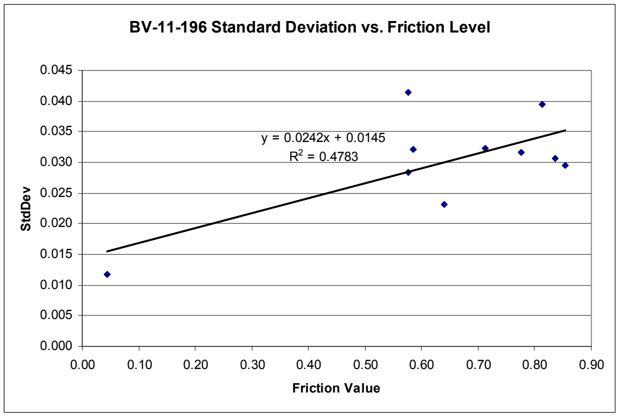


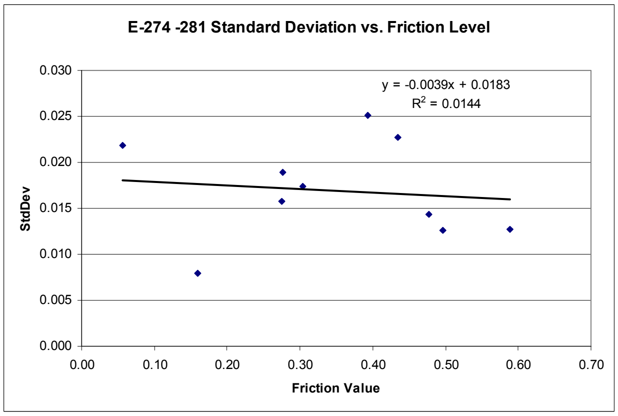
Test 200113503: Device Standard Error Values at 100 km/h Surface S-6, Segment S-6-04
Device Standard Error
0.025
0.020
0.015
0.010
0.005
0.000
0.021
Average 0.009
0.003
SFT-TC85-E1551-100
SFT-212-E1551-100
BV11-196-E1551-100
IMAG-IRV-PIARC-22
GRT-033-E1844-20
RFT-FAA-E1551-100
E274-281-E524-24
E274-VDOT-E524-24
Device Code

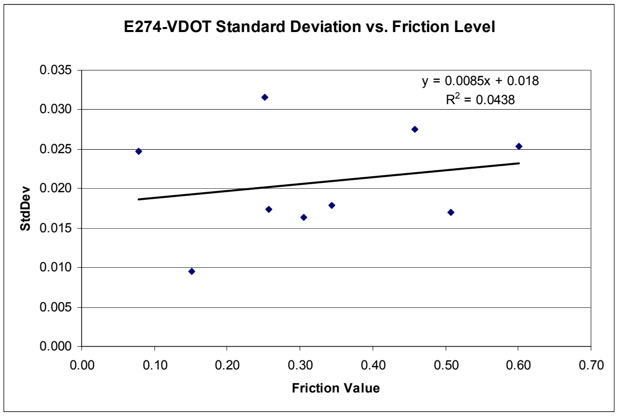


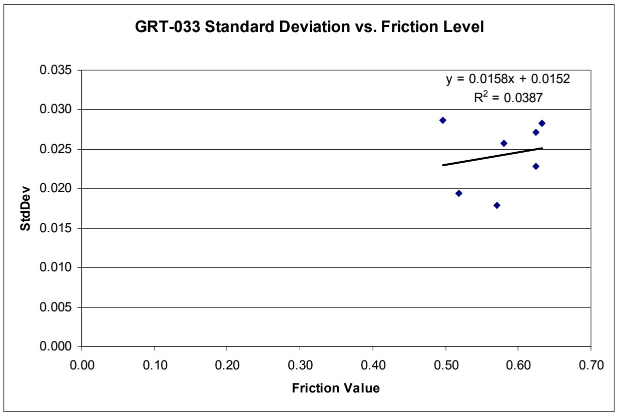
Test 200113503: Device Range of Variability Values at 100 km/h Surface S-6, Segment S-6-04
Range of Variability
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.18
Average 0.08
0.03
SFT-TC85-E1551-100
SFT-212-E1551-100
BV11-196-E1551-100
IMAG-IRV-PIARC-22
GRT-033-E1844-20
RFT-FAA-E1551-100
E274-281-E524-24
E274-VDOT-E524-24
Device Code

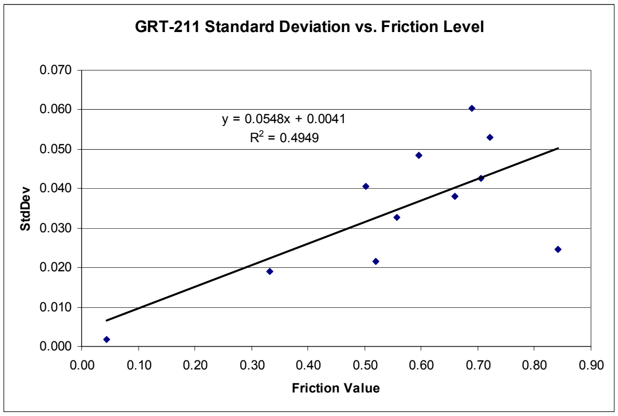
Appendix C. Device Standard Deviation vs. Friction Level.

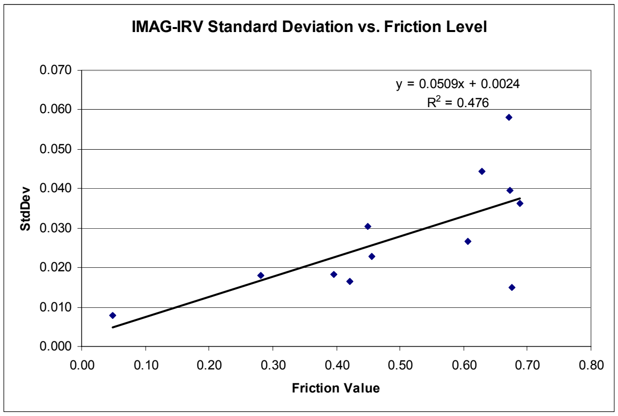


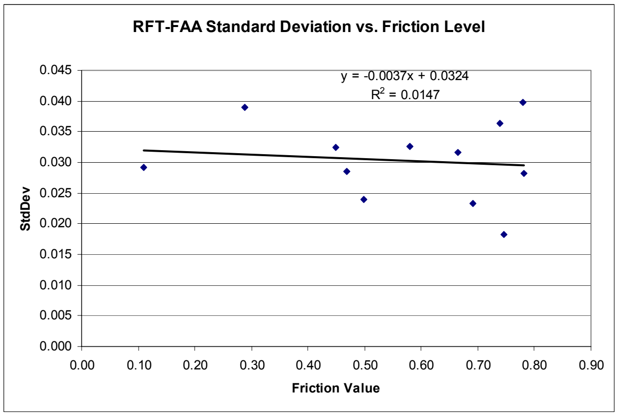


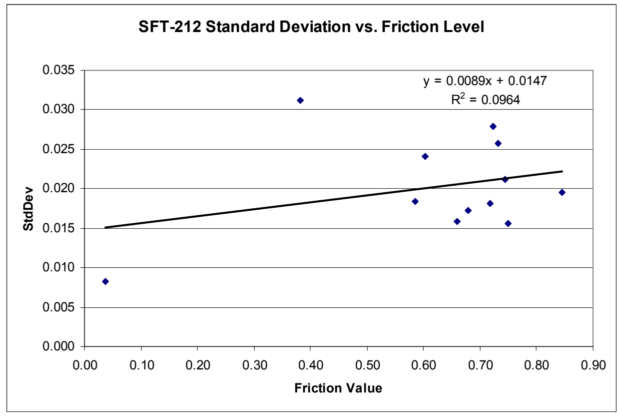


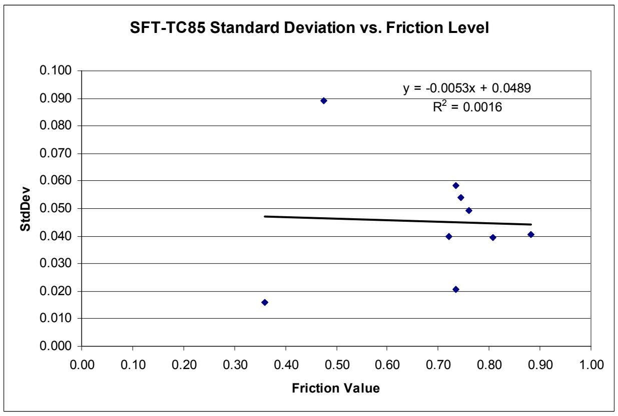







RFT-FAA Standard Deviation vs. Friction Level
y = -0.0037x + 0.0324
R2 = 0.0147
StdDev
Friction Value
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90


SFT-212 Standard Deviation vs. Friction Level
y = 0.0089x + 0.0147
R2 = 0.0964
StdDev
Friction Value
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90


SFT-TC85 Standard Deviation vs. Friction Level
y = -0.0053x + 0.0489
R2 = 0.0016
StdDev
Friction Value
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

Appendix D. Schematics of Surfaces.