



Advisory Circular

Subject: Runway Friction Measurement

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1.0 INTRODUCTION

- (1) This Advisory Circular (AC) is provided for information and guidance purposes. It describes an example of an acceptable means, but not the only means, of demonstrating compliance with regulations and standards. This AC on its own does not change, create, amend or permit deviations from regulatory requirements, nor does it establish minimum standards.

1.1 Purpose

- (1) The purpose of this document is to outline methodologies for the measurement, evaluation, and maintenance of airport pavement surface friction. In addition, the document outlines performance specifications and correlation methods for Continuous Friction Measuring Equipment (CFME).

1.2 Applicability

- (1) This document applies to airport operators and to manufacturers/suppliers of continuous friction measuring equipment. The document is also available to the aviation industry for information purposes.

1.3 Description of Changes

- (1) Issue 03 of this AC includes the following principal revisions:
 - a) Guidance regarding applicability of runway friction standards given in TP 312 4th and 5th Editions added to section 4.0 (2).
 - b) Addition of new section 5.5 *Training of CFME Operators*.
 - c) Guidance related to runway pavement surface texture measurement added to section 9.0 (1).
 - d) Guidance related to the removal of rubber deposits added to section 9.0 (4).
 - e) Other minor changes of an editorial nature.

2.0 REFERENCES AND REQUIREMENTS

2.1 Reference Documents

- (1) It is intended that the following reference materials be used in conjunction with this document:
 - (a) Part III, Subpart 2 of the *Canadian Aviation Regulations (CARs) — Airports*;
 - (b) Transport Canada Publication (TP) 312 5th Edition — *Aerodrome Standards and Recommended Practices*;
 - (c) TP 312 4th Edition — *Aerodrome Standards and Recommended Practices*;
 - (d) Advisory Circular (AC) 300-008 — *Runway Grooving*;
 - (e) TP 14825E, January 2008 — *Proposed Performance Specifications and Standard Correlation Method for Continuous Friction Measuring Equipment*;
 - (f) International Civil Aviation Organization (ICAO) Annex 14 to the *Convention on International Civil Aviation — International Standards and Recommended Practices: Aerodromes* (Seventh Edition, July 2016);
 - (g) ICAO Doc 9137-AN/898 — *Airport Services Manual, Part 2 Pavement Surface Conditions* (Fourth Edition, 2002);
 - (h) ASTM E965, 2015 — *Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique Specification*;

- (i) ASTM E1551, 2016 — *Standard Specification for a Size 4.00-8 Smooth Tread Friction Test Tire*;
- (j) ASTM E1844, 2008 (Reapproved 2015) — *Standard Specification for a Size 10 x 4-5 Smooth-Tread Friction Test Tire*; and
- (k) ASTM E2340/E2340M, 2011 (Reapproved 2015) — *Standard Test Method for Measuring the Skid Resistance of Pavements and Other Trafficked Surfaces Using a Continuous Reading, Fixed-Slip Technique*.

2.2 Cancelled Documents

- (1) Not applicable.
- (2) By default, it is understood that the publication of a new issue of a document automatically renders any earlier issues of the same document null and void.

2.3 Definitions and Abbreviations

- (1) The following **definitions** are used in this document:
 - (a) **Damp**: a surface condition that appears wet but the moisture depth cannot be readily determined;
 - (b) **Macro-texture**: the coarse-scale roughness of the pavement surface as a whole, created by the hills and valleys formed by aggregate particles;
 - (c) **Micro-texture**: the fine-scale roughness of the individual aggregate particles, which may not be readily discernible to the eye but should be apparent to the touch;
 - (d) **Traffic Density**: the relative degree of aircraft movements at an aerodrome determined from the number of movements per hour at the mean busy hour and classified as follows:
 - (i) Light: not greater than 15 movements per runway or less than 20 total aerodrome movements;
 - (ii) Medium: 16 to 25 movements per runway or between 20 to 35 total aerodrome movements;
 - (iii) Heavy: 26 or more movements per runway or more than 35 total aerodrome movements.
 - (e) **Variable Slip Device**: a device that sweeps through a range of slip ratios while it is in motion.

Note: *A device which only allows the slip ratio to be changed when the device is at rest, is considered to be a fixed-slip CFME for the purpose of this AC.*

- (2) The following **abbreviations** are used in this document:
 - (a) **AC**: Advisory Circular
 - (b) **ASTM**: American Society for Testing and Materials
 - (c) **CFME**: Continuous Friction Measuring Equipment
 - (d) **COF**: Coefficient of Friction
 - (e) **ICAO**: International Civil Aviation Organization
 - (f) **SFT**: Surface Friction Tester
 - (g) **TP**: Transport Canada Publication

3.0 BACKGROUND

- (1) TP 312 5th Edition – *Aerodrome Standards and Recommended Practices* gives the following standards with respect to runway friction:

“2.5.1.3 A runway or its portion is deemed as having low friction, such as due to rubber accumulation or surface texture degradation, when the friction measurements, as measured by a continuous friction measuring device, are below the minimum friction level specified in 9.1.2.2.

Note 1: When a runway has low friction, this is normally disseminated to the aircrews through NOTAM, ATIS, etc. stating the runway may be slippery when wet.

Note 2: 2.5.1.3 excludes any condition associated with winter operations.”

and

“9.1.2.1 For a runway serving turbojet aircraft, measurements of the friction characteristics of a runway surface are made periodically with a continuous friction-measuring device using self-wetting features.

Note: New, reconstructed or resurfaced paved runways would typically have friction characteristics measured prior to or as soon as possible following the return to service to establish a baseline for trend measurements of friction characteristics.

9.1.2.2 Corrective maintenance action is taken when:

- (a) the average coefficient of friction (COF) for the entire runway is below 0.50; or
- (b) any portions of a runway surface that are 100 m or greater in length have an average COF less than 0.30.

Note 1: A NOTAM advising pilots that the runway may be slippery when wet is common practice when the measured coefficient of friction is below the values in 9.1.2.2. See 2.5.1.3.

Note 2: The COF levels specified in 9.1.2.2 apply to the COF measurements made with the surface friction tester (SFT) and to the following test conditions:

- (a) *the friction test tire is manufactured to meet the requirements of ASTM E1551 Standard Specification for Special Purpose, Smooth-Tread Tire, Operated on Fixed Braking Slip Continuous Friction Measuring Equipment;*
- (b) *the friction test tire is inflated to a tire pressure of 207 kPa (± 3 kPa);*
- (c) *the test speed is held constant at 65 km/h (± 5 km/h); and*
- (d) *the depth of water placed in front of the friction test tire by the self-wetting system is 1.0 mm.”*

- (2) Over time, the friction characteristics of a runway deteriorate due to a number of factors such as mechanical wear, the polishing action of aircraft tires rolling or braking on the pavement, and the accumulation of contaminants, primarily rubber from aircraft tires on the pavement surface. The effect of these factors is dependent upon the volume and type of aircraft traffic as well as other site specific factors.
- (3) Rubber accumulation is dependent upon the type and frequency of aircraft landing operations, such as the weight of the aircraft, the number of wheels that touch down on the surface, as well as the climate, the runway length, and the runway composition.
- (4) The 100 metre section with the lowest Coefficient of Friction (COF) normally occurs in the touchdown zone where the build-up of tire rubber contaminant can lead to reduced friction values.
- (5) It is the airport operator's responsibility to conduct periodic friction testing of runway pavements and to establish the frequency of testing based on the unique circumstances of their site.

- (6) As data are collected on the rate of change of runway friction under various traffic conditions, the scheduling of friction surveys may be adjusted to ensure reliable identification of the need to take corrective action.
- (7) The factors to be considered include historical runway friction data and the expected aircraft traffic volume and type (weight).

4.0 RUNWAY FRICTION MEASUREMENTS GUIDANCE

- (1) Guidance material on the measurement, evaluation and maintenance of airport pavement surface friction is given subsequently.
- (2) Table 1 Runway Pavement Friction Standards (derived from section 9.1 of TP 312 5th Edition) gives guidance on the application of the standard. For runways certified to TP 312 4th Edition, the friction standards (including corrective maintenance programming levels) given in TP 312 4th Edition would apply.
- (3) When friction measurements are below either of the levels requiring that corrective maintenance action be taken, a NOTAM will be issued by the airport operator identifying the runway and the portion thereof (by runway thirds) that may be slippery when wet.
- (4) The measured friction value will not be reported in the NOTAM. The NOTAM will remain in effect until such time as the subsequent measurements demonstrate that the friction levels have improved to meet or exceed the specified minimum levels.
- (5) Data collected in support of the period of testing, identified by the operator, respecting runway friction must remain on file and be available to Transport Canada inspectors.
- (6) Guidance material on performance specifications for continuous friction measuring equipment is included in Appendix A.
- (7) Guidance material on correlation testing for continuous friction measuring equipment is included in Appendix B.

Table 1: Runway Pavement Friction Standards (from 9.1 of TP 312 5th Edition)

Runway Pavement Friction Standards Determining the Need for Corrective Action to Restore Surface Friction	
Corrective Action ⁽⁴⁾ to Restore Runway Surface Friction	Coefficient of Friction (COF) Numbers as Measured with a Surface Friction Tester ⁽²⁾
	When the “Runway Average COF” ⁽³⁾ Is Less Than
Is Taken	0.50
*****	When A “Runway 100 Metre Section Average COF” ⁽³⁾ Is Less Than
Is Taken	0.30
<p>1. The above friction standards are taken from TP 312 5th Edition and are used to establish the need for corrective action to be taken to restore runway surface friction that has deteriorated below the Coefficient of Friction (COF) levels shown.</p> <p>2. The friction levels specified in the above table apply to Coefficient of Friction (COF) measurements made with the benchmark Surface Friction Tester device as defined in Section 5.2 (1) and in accordance with the conditions of test specified in Section 5.4.</p> <p>3. For the purposes of interpreting the above table:</p> <p>a) the “Runway Average COF” value is to be taken to mean the average coefficient of friction measured over the entire length of the runway less a distance required for test vehicle acceleration and deceleration; and</p> <p>b) the “Runway 100 Metre Section Average COF” is to be taken to mean any contiguous section of the runway that is 100 metres or greater in length.</p> <p>4. When COF values are below either of the levels specified in the above table, surface restoration to restore friction is to be undertaken immediately and the requirements respecting the provision of “slippery when wet” NOTAMs are to be complied with in accordance with the standard.</p> <p>5. The objective of the corrective maintenance is to restore the surface friction characteristics of the affected pavement areas so that subsequently measured COF values will meet or exceed the minimum levels specified in the above table.</p>	

5.0 RUNWAY SURFACE FRICTION MEASUREMENTS

5.1 Requirements for Friction Measurements

- (1) Friction measurements are specified for all hard-surfaced runways serving turbojet aircraft because the higher weights and operating speeds of turbojet versus turboprop aircraft make turbojet-braking performance on runway surfaces, particularly when wet, a significant safety concern.
- (2) Considerations should also be given to measuring the friction characteristics of runways serving heavy turboprop aircraft (operating weights of approximately 12,750 kg or greater) that have runway takeoff and landing distance requirements close to the limits of the available runway length.

5.2 Standard Friction Measuring Device

- (1) The Surface Friction Tester (SFT) is used as the benchmark friction measuring device for the purpose of defining the standard runway coefficient of friction levels against which all other friction measurements are assessed to determine the need for corrective maintenance action.
- (2) When a continuous friction measuring device other than the SFT is used, device correlation will be required to ensure that the alternative device produces friction measurements comparable to those that would be obtained with the SFT. The owner or operator of the device has the responsibility for correlating an alternative friction measuring device to the SFT.
- (3) In cases of discrepancy or dispute between measurements made with the SFT and any other friction testing device, the measurements made with the SFT will govern.

5.3 Frequency and Timing of Measurements

- (1) The frequency and timing of friction measurements are to be established by the airport operator so as to ensure the reliable identification of the need to take corrective action respecting the maintenance of coefficient of friction levels as specified in as specified by Table 1 (from section 9.1 of TP 312 5th Edition).
- (2) The optimum frequency and timing for runway friction measurements requires the assessment of many site specific factors including:
 - (a) the type, mix and frequency of aircraft operating on the runway;
 - (b) the micro- and macro-texture characteristics of the pavement surface;
 - (c) the presence, extent and severity of surface contaminants such as tire rubber;
 - (d) the existence of pavement surface problems such as “asphalt bleeding” and wheel path “aggregate polishing” which are often detrimental to the achievement of satisfactory friction levels;
 - (e) pilot reports of low friction levels being experienced during aircraft braking;
 - (f) the frequency and timing of past programs for the removal of surface rubber contaminants;
 - (g) the recent construction or replacement of pavement surfacing courses; and
 - (h) the degree to which past friction measurements have exceeded the minimum friction levels specified in Table 1.
- (3) Where possible, the airport operator should rely on past experience for establishing the frequency for runway friction measurements. The following guidelines based on measurements made with the Surface Friction Tester (SFT) could be used to establish the frequency of measurements, in particular for airports with medium to high traffic density:
 - (a) When the last measured **Runway Average** Coefficient of Friction value for the runway is in the range of:
 - (i) 0.59 and below, the runway should be tested a minimum of once per month;
 - (ii) 0.60 to 0.69, the runway should be tested a minimum of once per year; and
 - (iii) 0.70 and above, the runway should be tested a minimum of once every two years.
 - (b) When any one or more of the last measured **100 Metre Section Average** Coefficient of Friction values for the runway is in the range of:
 - (i) 0.39 and below, the runway should be tested a minimum of once per month;
 - (ii) 0.40 to 0.49, the runway should be tested a minimum of once every two months;

- (iii) 0.50 to 0.59, the runway should be tested a minimum of once per year; and
 - (iv) 0.60 and above, the runway should be tested a minimum of once every two years.
- (4) Friction test frequencies may have to be increased after consideration of the following items:
- (a) Should any of the site and/or pavement conditions that affect friction levels (refer to Section 5.3 (2) above) change significantly, the friction test frequency for the runway should be increased as appropriate to ensure timely identification of the need to take corrective action.
 - (b) As the airport operator accumulates data on the rate of change of runway friction under various traffic types/levels and site conditions, the scheduling of friction measurements should be adjusted to ensure that marginal friction conditions are detected in time for the necessary corrective action to be taken.
 - (c) Friction testing on a weekly to monthly basis should be performed during non-winter months on runways that serve a high frequency of heavy wide-bodied turbojet aircraft and that have a demonstrated history of rubber deposit build-up, in order to develop a maintenance program that optimally times the removal of rubber deposits.
 - (d) The frequency of friction testing should be increased to provide for the close monitoring of special runway friction problems. Determination of the required frequency of testing should take into account the nature of the friction problem and the probable rate of deterioration of in measured friction values.
- (5) When it is suspected that a runway may become slippery under other than normal wet conditions or due to unusual surface conditions, then additional friction measurements should be made when such conditions occur and/or studies conducted to determine the cause, extent and severity of the friction problem. Information detailing the nature, extent and severity of the unusual slippery runway conditions should be made available by issuance of a NOTAM by the airport operator to provide a cautionary warning respecting the slippery conditions.

5.4 Conditions of Test

- (1) The following conditions of test are applicable to measurements that are made with the Surface Friction Tester and will be assessed against the friction standards given in Table 1 (from section 9.1 of TP 312 5th Edition):
- (a) The friction test tire must be manufactured to meet the requirements of ASTM E1551;
 - (b) The friction test tire is to be inflated to a pressure of 207 ± 3 kPa;
 - (c) The vertical load on the friction test tire is to be 1400 ± 20 N;
 - (d) The vehicle test speed must be held constant at 65 ± 5 km/h;
 - (e) The depth of the water placed in front of the friction test tire by the self-wetting system must be 1.0 mm in thickness;
 - (f) The friction test tire is to be continuously braked during testing and have a constant slip ratio in the range of 10-20 percent;
 - (g) The friction measuring system and components are to be calibrated in accordance with the manufacturer's instructions so as to ensure a consistent relationship between measured forces and the coefficient of friction output;
 - (h) The friction tests are to be conducted only when both the pavement surface and the ambient air temperatures are above 0°C (zero degrees Celsius) and the pavement is dry or no more than damp prior to testing;
 - (i) The friction measurements are to be taken on tracks parallel to the runway longitudinal centreline at right and left offsets of:

- (i) three (3) metres for **Runways Serving only Narrow Body Aircraft**; and
 - (ii) three (3) and six (6) metres for Runways Serving **Narrow and Wide Body Aircraft**.
- (2) The right and left offsets from runway centreline specified for friction measurements are based on the type and/or mix of aircraft operating on the runway. The lowest friction levels will generally occur in the wheel path areas as a result of the wearing action of aircraft tires on the pavement surface texture characteristics and the build-up of surface contaminants such as tire rubber.
- (3) It is recommended that two (2) friction measurement runs be performed at each of the left and right three and six metre offsets, as applicable. Results of the four (4) measured runs should be averaged to determine "100 Metre Section Average COF" values along the length of the runway and the overall "Runway Average COF" as specified in Section (3) of Table 1.
- (4) When low friction values are measured, additional friction runs should be performed outside the wheel path area in order to assess the degree to which wear and contaminants have lowered friction levels in the centre trafficked area. A test track profile located 5 to 10 metres from the outer edge of the paved runway surface is normally optimum for the purposes of wear and contaminant comparison tests.
- (5) To allow adequate distance for test vehicle acceleration and deceleration, friction measurement should begin 200 metres away from the runway threshold end and terminate approximately 200 metres from the opposite end of the runway.

5.5 Training of CFME Operators

- (1) The operator of the friction measuring device should be adequately trained in the calibration, operation and normal maintenance of the device and in the procedures for conducting friction measurements.

6.0 ALTERNATIVE FRICTION MEASURING DEVICES

6.1 Alternative Device Requirements

- (1) Friction-testing devices should meet the performance specifications defined in Appendix A.
- (2) As indicated in Section 5.2 (2), friction testing devices other than the Surface Friction Tester should be correlated to produce friction measurements comparable to those that would be obtained with the Surface Friction Tester thereby permitting assessment of measured friction results against the corrective action standards of Table 1. Such correlations should be established by performing parallel field tests using the benchmark Surface Friction Tester and the alternate friction-testing device, as defined in Appendix B.

6.2 The GripTester

- (1) An alternative continuous friction-testing device is the GripTester, a small, compact and relatively lightweight trailer device that can be towed by any suitable passenger vehicle that can accommodate a water supply tank/bag.
- (2) For GripTester data collected using a 0.25 mm water depth (as indicated in Section 6.3), GripTester friction readings may be compared directly to the friction criteria defined in Table 1 for the SFT benchmark device. GripTester friction results obtained using a 0.25 mm water depth will be approximately the same as those obtained with the SFT under standard conditions of test. As a result, any runway surface that meets friction standards under the GripTester 0.25 mm water depth, will also likely meet standards if tested with the reference SFT equipment.
- (3) Because a correlation has already been established by Transport Canada between the GripTester using a 0.25 mm water depth and the Surface Friction Tester under standard

conditions of test, additional correlation testing for the current model of the GripTester is not required. However, test results obtained using the GripTester with any other water depth would require additional correlation testing.

6.3 Conditions of Test for the GripTester

- (1) The offsets from runway centreline, test frequencies and timing of measurements to be made with the GripTester should be identical to those specified for the Surface Friction Tester.
- (2) The following conditions of test are applicable to measurements made with the GripTester:
 - (a) The friction test tire must be manufactured to meet the requirements of ASTM E1844;
 - (b) The friction test tire is to be inflated to a pressure of 138 ± 3 kPa;
 - (c) The vertical load on the friction test tire is to be the standard GripTester tire load of 205 N;
 - (d) The test speed must be held constant at 65 ± 5 km/h;
 - (e) The depth of the water placed in front of the friction test tire by the self-wetting system should be 0.25 mm in thickness;
 - (f) The friction test tire is to be continuously braked during testing and have a constant slip ratio in the range of 10-20 percent;
 - (g) The friction measuring system and components are to be calibrated in accordance with the manufacturer's instructions so as to ensure a consistent relationship between measured forces and the COF output;
 - (h) The friction tests are to be conducted only when both the pavement surface and the ambient air temperatures are above 0°C (zero degrees Celsius) and the pavement is dry or no more than damp prior to testing;
 - (i) The friction measurements are to be taken on tracks parallel to the runway longitudinal centreline at right and left offsets of:
 - (i) three (3) metres for **Runways Serving only Narrow Body Aircraft**; and
 - (ii) three (3) and six (6) metres for Runways Serving **Narrow and Wide Body Aircraft**.

7.0 FRICTION STANDARDS AND CORRECTIVE ACTION

- (1) Based on measurements made with the Surface Friction Tester under the conditions defined in Section 5.4, corrective action is to be taken to restore runway friction to acceptable levels when the measured friction values fall below either of the minimum levels specified in Table 1 (from section 9.1 of TP 312 5th Edition) and the requirements respecting the provision of "slippery when wet" NOTAMs are to be complied with in accordance with the standard.
- (2) Following completion of the corrective action and before cancellation of "slippery when wet" NOTAMs, the airport operator is to demonstrate by means of friction measurements that friction values have been restored to meet or exceed the minimum levels specified in Table 1.
- (3) The airport operator develop should plan corrective action so that measured friction values will not be allowed to reach the minimum levels specified in Table 1.

8.0 LIMITATIONS OF FRICTION MEASUREMENTS

- (1) Runway friction measurements made in accordance with this AC are intended for use in detecting the deterioration of friction characteristics; and for determining the need for and timing of

corrective action to restore friction to acceptable levels. Such runway friction measurements are not intended for any application related to the determination of aircraft operational braking performance and/or the calculation of factored aircraft stopping distances.

9.0 PAVEMENT SURFACE TEXTURE

- (1) Both the micro- and macro-texture characteristics of a pavement surface can significantly affect the measured friction values. Measurements of pavement surface texture are not normally required unless texture related friction problems are suspected. The provision of good pavement micro- and macro-texture characteristics is nonetheless an essential prerequisite for the maintenance of satisfactory friction levels on runway surfaces. A method for evaluating runway pavement surface texture is given in ASTM E965 *Standard Test Method for Measuring Pavement Macrottexture Depth Using a Volumetric Technique*.
- (2) Normally, it is not necessary to specify minimum texture depths for the construction of new asphalt or Portland cement concrete surfaces. In order to withstand the detrimental weathering effects of the Canadian environment, it is generally best that new asphalt surfaces be constructed with a fairly dense, tight and closed surface. As the asphalt pavement ages, the surface will gradually “open up”, thereby providing additional and improved macro-texture characteristics which will promote and increase the friction levels measured under wet conditions. For Portland cement concrete surfaces, however, construction specifications should contain a requirement that one of a number of available methods be used to apply macro-texture characteristics to the surface during the finishing process.
- (3) Pavement micro-texture may become polished and smooth as the surface ages and wears under traffic. The macro-texture of a new asphaltic concrete surface may be initially quite smooth as a result of the rolling done during construction to achieve a highly compact and dense surface wearing course. As an asphalt pavement ages, the macro-texture will generally increase due to the effects of weathering and gradual loss of fine aggregate from the surface. A high level of macro-texture is normally built into the surface of Portland cement concrete pavements during construction but subsequently wears down under traffic action.
- (4) Depending on the aircraft traffic types and traffic levels, both the micro- and macro-texture of a pavement may become obliterated by the build-up of contaminants on the surface such as aircraft tire rubber. On such surfaces, the maintenance of satisfactory friction levels may require the periodic removal of rubber deposits and/or the re-texturing of the pavement surface. Methods for the removal of rubber deposits include biodegradable chemicals, high pressure water, high velocity impact (usually steel shots) and mechanical grinding.

10.0 SURFACE WATER DRAINAGE

- (1) The transverse and/or other slopes of movement area pavements that affect surface water drainage should be maintained so as to provide for the prompt and effective runoff of storm water from the surface, and to minimize surface depressions which may result in the accumulation of standing water of a depth sufficient to impair the braking, operational performance and/or directional control of the aircraft.
- (2) The airport operator should periodically conduct visual inspections of the runway during natural rainfall conditions to observe the drainage characteristics of the pavement surface and to assess the extent and severity of areas where ponding is occurring. When there is reason to believe that the drainage characteristics of a runway or portions thereof are poor due to inadequate slopes or surface depressions and that the runway friction characteristics may be adversely affected, then appropriate corrective action should be taken to improve the surface drainage.
- (3) The presence of excessive water depths on the surface of a pavement during aircraft operations may create the potential for the aircraft tires to hydroplane under certain conditions. Where such

conditions are deemed to exist on a runway surface or portion thereof for excessive periods of time, runway grooving may be considered by the airport operator as an option for minimizing surface water depths and reducing the potential for hydroplaning. However, surface grooving is not a requirement for new or existing runway pavements in Canada. AC 300-008 – *Runway Grooving* provides information and guidance regarding the grooving of runway pavements.

11.0 INFORMATION MANAGEMENT

- (1) Not applicable.

12.0 DOCUMENT HISTORY

- (1) Advisory Circular (AC) 302-017 Issue 01, RDIMS 9733626 (E), 9778115 (F), dated 2014-12-15 – *Runway Friction Measurement*.
- (2) Advisory Circular (AC) 302-017 Issue 02, RDIMS 11129758 (E), 11149706 (F), dated 2015-11-10 – *Runway Friction Measurement*.

13.0 CONTACT OFFICE

For more information, please contact:

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Suggestions for amendment to this document are invited, and should be submitted via:

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APPENDIX A — PERFORMANCE SPECIFICATIONS FOR CFME**1.0 SCOPE**

- (1) This appendix describes performance specifications for continuous fixed slip friction measuring equipment. It contains specifications identifying the mechanical, operational, and reporting requirements for a continuous fixed slip, friction measuring device.
- (2) The specification covers only continuously braked wheel, fixed slip measurement equipment, for devices with less than 100% slip. It does not cover side force measurement devices, variable slip measurement devices, locked wheel measurement devices or other spot measurement equipment.

2.0 GENERAL MECHANICAL REQUIREMENTS

- (1) The device may be vehicle mounted or towed.
- (2) The device should provide fast, continuous, accurate and reliable friction measurements for the entire length of the runway, less 200 m at each runway end allowed for acceleration and deceleration purposes.
- (3) The device should be designed to sustain rough usage and still maintain calibration.
- (4) The device should be capable of accelerating to a testing speed of 65 km/h within 200 m, whether it is vehicle mounted or towed. This performance should be attainable when the device is loaded with the required amount of water.
- (5) The device should be designed to achieve (for vehicle integrated systems) or withstand (for towed systems) high speeds and to maintain directional stability.
- (6) The device should be able to apply a constant normal load on the measuring wheel and be capable of dynamically maintaining the load regardless of the pavement surface roughness.

3.0 BASIC EQUIPMENT REQUIREMENTS

- (1) The device should have a high precision force or torque transducer for measuring the braking force on, or the torque of, the test tire.
- (2) The device should have a high precision force transducer to measure the force acting vertically on the measurement tire. As an alternative, a device which maintains a constant vertical force on the instrumented tire is acceptable provided that it meets the "Data Collection and Signal Conditioning" requirements defined subsequently.
- (3) The device should have a measurement sensor capable of accurately measuring the test speed and distance travelled.
- (4) The device's suspension system for the measurement tire should be designed to minimize the influence of normal pavement roughness on the accuracy and fidelity of the data collection.
- (5) The device should be equipped with data acquisition, signal conditioning and digital recording equipment that provide linear output and allow data reading resolution to meet the "Data Collection and Signal Conditioning" requirements defined subsequently.

4.0 OPERATING CONDITIONS

- (1) The device should provide reliable and accurate measurements at ambient air temperatures between -20°C and 40°C (0°F and 100°F).
- (2) The device should provide reliable and accurate measurements at up to 100% relative humidity.

- (3) The device should tolerate rain, snow, sleet, high pressure water spray and other adverse conditions.
- (4) The device should be designed to be resistant to de-icing chemicals, dust, shock, and vibrations that may be encountered during operations in an airport environment.

5.0 SPEED

- (1) The device should provide reliable and accurate measurements at test speeds between 30 and 100 km/h.

6.0 TEST TIRE

- (1) The device should use a standard measuring tire specially designed for friction measurement that conforms to an appropriate ASTM standard.
- (2) The device should deliver a normal loading force on the test tire within the limits given in the corresponding ASTM standard.
- (3) The normal inflation pressure of the test tire should be in accordance with the relevant ASTM specification for the tire.

7.0 WATERING SYSTEM

- (1) The device should be equipped with a self-watering system that distributes water in front of the friction measuring wheel at a uniform depth.
- (2) The device should be capable of providing a specified nominal water film depth from 0.25 to 1.00 mm thickness, over the full width of the test tire tread.
- (3) The device should be capable of applying water film depths over the full range of test speeds (30 to 100 km/h).
- (4) The self-watering system should provide the water flow rate required to achieve the specified water film depth corresponding to the actual test speed, within a tolerance of $\pm 10\%$.
- (5) The device should be capable of continuously measuring the water flow rate, and it is recommended that the measured water flow rate be recorded.
- (6) The device should be equipped with a water tank of sufficient capacity to complete two friction survey runs on a 3000 m long runway using a 1.0 mm water depth.

8.0 INSTRUMENTATION

- (1) If the vertical force on the test tire is measured, the vertical force transducer should have an output that is directly proportional to the loading force with hysteresis less than 1% of the applied load. The sensitivity to any cross-axis loading should be less than 1% of the applied load.
- (2) If the vertical force on the test tire is not measured, the loading system should keep the vertical force constant within 1% of the specified value under the full range of dynamic conditions to be experienced by the CFME.
- (3) For a device which determines the friction coefficient based on measurements of the braking force on the test tire, the force transducer should measure the load with an output that is directly proportional to the braking force with hysteresis less than 1% of the applied load. The sensitivity to any cross-axis loading should be less than 1% of the applied load.
- (4) For a device which determines the friction coefficient based on measurements of the torque on the instrumented tire, the torque transducer should provide an output that is directly proportional to the torque with hysteresis less than 1% of the applied load. The sensitivity to any cross-axis loading should be less than 1% of the applied load.

- (5) The device should measure the speed with an accuracy of ± 1 km/h.
- (6) The device should measure the distance travelled with an accuracy of $\pm 0.5\%$.
- (7) The device should be equipped with electronic instrumentation, including a keyboard or touch screen for data entry and memory for data storage, either internally or through external peripherals such as flash cards.

9.0 DATA COLLECTION AND SIGNAL CONDITIONING

- (1) The minimum sampling frequency for the data should be such that a single measurement of the friction, speed, and distance is provided for every 1 m of travel on the test section.
- (2) Measurements should be recorded in phase. The measurement of the vertical and frictional forces on the test tire should be simultaneous.
- (3) All the measured parameters should be measured, analyzed and reported on the same time scale.
- (4) The CFME should be equipped with a signal conditioning and filtering system that prevents the recorded friction coefficients from being affected significantly by dynamic effects resulting from the pavement surface and/or machine design. The CFME designer is referred to the signal conditioning requirements set out in ASTM E2340 for further information regarding how the requirement to avoid significant dynamic effects may be achieved.
- (5) The signal to noise ratio of each individual measurement signal before sampling should be a minimum of 100 to 1.
- (6) The measurement range for the device for the recorded friction coefficient should be at least from 0 to 1.0.

10.0 REPEATABILITY AND REPRODUCIBILITY

- (1) The device should be capable of achieving a single device repeatability standard deviation of ± 0.03 coefficient of friction units on all types of pavement surfaces.
- (2) Experience has shown that the readings from individual units of the same friction device family may vary when they are operated at the same time on the same surface. Test programs have been conducted to measure the reproducibility of some device families. However, universally accepted criteria for device family reproducibility are not yet available, nor are universally accepted procedures for establishing device family reproducibility. Nevertheless, there is an increasing awareness regarding this issue and users are cautioned regarding it.

11.0 BRAKING SLIP

- (1) The friction measuring tire should be continuously braked during testing at a constant slip ratio in the range of 10-20%. The specified slip ratio should be independent of the friction level and it should be maintained throughout the length of the test run over the runway test surface within a tolerance of $\pm 2\%$. As an example, if the nominal slip ratio is 15%, the actual slip during a test run should lie with the range of 13% to 17%.

12.0 REPORTING

- (1) The device should be capable of automatically outputting average friction values for runway segments that are 100 m long, and also one-third segments of the runway length.
- (2) The device should be capable of providing data so that the average friction value for any segment of a runway can be calculated, including the whole runway.

- (3) The device should be capable of producing a permanent hard copy record of friction versus distance along the length of the runway at a scale of at least 1:4000, which means that every 25 mm on the trace equals 100 m of runway length. The friction trace should include the following information:
- (a) runway designator;
 - (b) date and time of friction survey;
 - (c) printed marks (delineations) depicting each 100 m section of the runway length;
 - (d) average friction value for each 100 m section;
 - (e) average speed for each 100 m section; and
 - (f) plot of speed (in km/h) versus runway length.

APPENDIX B — TEST METHOD FOR CORRELATING CFME**1.0 SCOPE**

- (1) This appendix defines the procedure for conducting field correlation testing of alternate Continuous Friction Measuring Equipment (CFME) to the Surface Friction Tester (SFT) benchmark device.
- (2) An alternate CFME should have an acceptable correlation to the benchmark SFT device in order to produce friction measurements comparable to those that would be obtained with the SFT, thereby permitting assessment of the measured friction results against the Runway Pavement Friction Standards given in Table 1 of this AC.
- (3) As updates and design changes are made to a CFME that has previously met the correlation requirements, correlation tests should be repeated to ensure that the newer device also meets the requirements.
- (4) This correlation test method covers only continuously braked wheel, fixed slip measurement equipment, for devices with less than 100% slip. It does not cover side force measurement devices, variable slip measurement devices, locked wheel measurement devices or other spot measurement equipment.
- (5) The correlation procedure is applicable to bare and dry pavement surfaces with no contaminants on them, and with self-wetting applied both the alternate CFME and the reference SFT device.
- (6) The test method defines and describes how to:
 - (a) select test surfaces for the purpose of conducting friction measurements to correlate an alternate CFME to the reference SFT;
 - (b) establish a test plan for the correlation measurements;
 - (c) conduct the measurement runs and control the quality of the data;
 - (d) analyse and report the measured data;
 - (e) calculate the correlation parameters, including statistical parameters describing the uncertainty of the correlation; and
 - (f) determine if the alternate CFME meets the acceptance criteria.

2.0 TEST SURFACE SELECTION

- (1) At least sixteen (16) different pavement test sections should be selected.
- (2) Each test section should be at least 200 m long for a 100 m actual data collection and a minimum 100 m run-in, unless data are being collected using sequential test sections, in which case a run-in portion is only required for the first test section.
- (3) The test surfaces should span the range of Coefficient of Friction (COF) levels from approximately 0.30 to 1.00. The average friction level of each test surface should differ from the other test surfaces by a minimum of 0.05 as measured by the reference SFT.
- (4) The test surfaces should have at least two different texture levels that differ by a reasonable amount. One of the test surfaces should have a mean texture depth of less than about 0.5 mm, while another of the test surface should have a mean texture depth that exceeds about 0.7 to 0.8 mm. A wider range of different texture depth levels is preferable.
- (5) The test sections should be straight with uniform friction and homogeneous texture.
- (6) The test surfaces should be free from excessive roughness and surface distress.
- (7) The test surfaces should be free of dirt and/or loose material.

3.0 TEST CONDITIONS

- (1) The friction tests should be conducted only when both the pavement surface and the ambient air temperatures are above 0°C (zero degrees Celsius) and the pavement is dry.
- (2) The water used for the self-wetting should be clean and free of chemicals or dirt.
- (3) To produce the minimum number of statistically required measurements, four (4) repeated measurement runs should be completed on each of the sixteen (16) different surfaces giving a minimum of sixty-four (64) measurements.
- (4) The test speed should be 65 km/h for all test runs and should be maintained within ± 3 km/h of the target speed for the entire length of the test section.
- (5) The water film depth placed in front of the measurement tire by the device's self-wetting system should be nominally 1.0 mm in thickness.
- (6) The test tire of the candidate CFME should conform to an ASTM standard such as ASTM E1551 or ASTM E1844, which should be the normal test tire of the device used in everyday operations.
- (7) The inflation pressure of the measurement tire should be maintained within the tolerance specified in the applicable ASTM standard.
- (8) The slip ratio of the alternate CFME should be verified before the correlation testing, and should be maintained in accordance with the manufacturer's instructions.

4.0 TEST METHODOLOGY

- (1) The friction measuring systems and components should be calibrated in accordance with the manufacturer's instructions.
- (2) The alternate friction device should be operated according to the standard test method for the device and the manufacturer's instructions for the device.
- (3) All operational parameters for the device should be verified to ensure that they are in accordance with the manufacturer's verification procedures (e.g. tire pressure, tire wear, etc.).
- (4) Each device should be in the measurement mode with the self-wetting system "ON" at least 100m prior to the collection of calibration test data, to ensure good and stable dynamic tire conditions undisturbed data collection.
- (5) All test runs should be started at the same longitudinal position along the test surface, or as close as possible.
- (6) Efforts should be made to avoid the build up of large amounts of water on the test section, as this may introduce variations in the actual water depth.
- (7) Four (4) repeated test runs should be conducted on each of the selected test surfaces. The measurement runs should be planned so that the four repeated runs are completed in pairs for the alternate CFME and the reference SFT. The running order of the devices should be reversed after each run.
- (8) The correlation tests on a specific test section should be conducted one after the other, with minimal time delay between them. No specific time frame is given in recognition of the need for flexibility. In cases where significant delays occurred between the collection of data pairs, or significant changes in conditions occurred over the duration of the test program, the candidate device should be re-tested.
- (9) The friction values should be collected in a single digital data archive and stored for further processing. The data should be kept for future records.

5.0 REPORTING AND CORRELATION PROCEDURES

- (1) A Test Surface Field report should be prepared for each of the surfaces tested. The Test Surface Field Report should contain the following information:
 - (a) Airport (or facility) and designation of movement area where test surface is located;
 - (b) date and time of the testing;
 - (c) weather data containing air temperature, humidity, and wind data; and
 - (d) the average surface temperature for the test section.
- (2) A Test Surface Measurement report should be prepared for all runs on each test surface. The Test Surface Measurement report should include the following data:
 - (a) the high resolution (minimum 1 m) reporting record of the measured friction traces for all four runs, if available;
 - (b) the high resolution (minimum 1 m) reporting record of the measurement speed traces for all four runs, if available;
 - (c) the calculated average friction measurement for the 100 m test section for all four runs;
 - (d) the calculated average measurement speed for the 100 m test section for all four runs; and
 - (e) the data measured by the alternate CFME and the reference SFT should be recorded in paired format allowing the paired data to be arranged in chronological order.
- (3) A Summary Test Report should be prepared for the entire correlation test trial upon the completion of the measurements on all the selected test surfaces. The Summary Test Report should contain the following items, data and information:
 - (a) the device type, make and model of the alternate CFME with a description of the complete test configuration including towing vehicle, if applicable;
 - (b) the date and time for the start of the correlation trials;
 - (c) the date and time for the end of the correlation trials;
 - (d) the collected and compiled Test Surface Field Reports; and
 - (e) the collected and compiled Test Surface Measurement Report.
- (4) The Summary Test Report together with the correlation data analysis will form the Final Correlation Test Report, and should be filed as a permanent record of the correlation trial.
- (5) The collected data from the Test Surface Measurement Reports for all test surfaces should be used for the calculation of correlation and correlation uncertainty parameters.
- (6) The data from the Test Surface Measurement Reports should be compiled in a single data set where the measurements from the alternate CFME and the reference SFT are to be paired and arranged in chronological order.
- (7) The correlation equation should be calculated by linear regression using the method of least squares. The following procedures should be followed:
 - (a) First order linear regression of the form below should be calculated from the test data and used in subsequent evaluations, such as whether or not an alternate device meets the specified criteria.

$$\mu_{\text{Reference SFT}} = a + b * \mu_{\text{Alternate CFME}}$$

where;

$\mu_{\text{Reference SFT}}$ = the friction coefficient measured by the reference SFT

$\mu_{\text{Alternate CFME}}$ = the friction coefficient measured by the alternate CFME

a, b = empirical constants determined from the regression analysis.

- (b) The data may be paired based on either the averages (means) recorded by each device for all of the runs made on each surface, or alternatively, they may be paired based on individual test runs.
- (8) The data produced for the linear regression should contain the following as a minimum:
 - (a) the computed Intercept (a in equation above) and Slope (b in equation above) parameters of the correlation equation;
 - (b) the R-squared value (Coefficient of Determination) of the regression;
 - (c) the Standard Error of the Estimate of the regression;
- (9) The data produced by the regression analysis should be recorded and compiled with the summary test report to form the Final Correlation Test Report. The Final Correlation Test Report will be used in the acceptance criteria and the correlation number calculation.

6.0 MINIMUM CORRELATION PERFORMANCE LIMITS

- (1) The R-squared value (Coefficient of Determination) should be greater than 0.80.
- (2) The Standard Error of the Estimate should not exceed 0.06 friction coefficient units.