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Study: SRTT Transition for ASTM F1805

Report on E1136 to F2493 SRTT Transition for ASTM F1805

SUMMARY:

Background

- The E1136 SRTT (SRTT14) is manufactured solely by Michelin. It has been produced since 1986 and is the reference tire for ASTM F1805.
- It is rapidly approaching a state of obsolescence due to availability of specific materials for the tread compound and rapid decrease in the popularity of 14-inch tires.
- Since May 2015 Michelin has notified stakeholders of its intention to stop production of this tire. The target proposed was end of year 2019.
- ASTM Committee F09 on Tires commissioned the "F09.20 Task Force on E1136/F1805 Winter Traction" to study replacing SRTT14 with the F2493 SRTT (SRTT16) as the reference tire for ASTM F1805.

Objectives

- Determine SRTT Tractive Coefficient min and max values based on SRTT16 for the six surface types in Table A2.1 of ASTM F1805.
- Develop a Correlation Factor to calculate an equivalent rating versus SRTT14 using the measured rating versus SRTT16 as input.

Results

- Table A2.1 revised in ASTM F1805-18 to update some min/max Tractive Coefficients versus SRTT14 and add Tractive Coefficients versus SRTT16 for each surface type.

Surface Type	E1136 (SRTT14) Min, Max	F2493 (SRTT16) Min, Max
Soft pack (new) snow	0.18, 0.22	0.17, 0.21
Medium pack snow	0.25, 0.38	0.23, 0.38
Medium hard pack snow	0.25, 0.36	0.25, 0.38
Hard pack snow	0.15, 0.20	0.15, 0.23
Ice – wet	0.06, 0.12	0.06, 0.13
Ice - dry	0.06, 0.14	0.08, 0.13

- Two Correlation Factor options developed based on a Linear Model approach and a Constant Ratio approach.
- Consensus of ASTM F09 Committee on Tires is to move forward with the Constant Ratio approach.
    - Equivalent SRTT14 Rating = Measured SRTT16 Rating x SRTT16 Correlation Factor (where SRTT16 Correlation Factor = 0.987)

Summary

- The F2493 SRTT (SRTT16) is an acceptable replacement for the E1136 SRTT (SRTT14) as a reference tire for ASTM F1805 winter traction testing.
- The necessary tools are now in place to transition ASTM F1805 testing away from SRTT14 as it is phased out of production in late 2019 or 2020.

Recommendations

- Communicate results of this study to all ASTM F1805 stakeholders.

Reference: ASTM F1805, ASTM E1136, ASTM F2493

Table of Contents

1. Terminology

For purposes of this report, the following terms and abbreviations are used:

SRTT = Standard Reference Test Tire

SRTT14 = E1136 P195/75R14 Standard Reference Test Tire

SRTT16 = F2493 P225/60R16 97S Standard Reference Test Tire

ASTM F1805 = Standard Test Method for Single Wheel Driving Traction in a Straight Line on Snow and Ice-Covered Surfaces

Task Force = ASTM F09.20 Task Force on E1136/F1805 Winter Traction

SRMT = Surface Rating Monitor Tire; A matrix made up of SRTT16 and three market tires from different performance categories (e.g., all season, performance, light truck). Required to be run several times per test season by all snow test vendors in the study.

2. SRTT Transition – The Case for Change

SRTT14 has been produced since 1986 and is the reference tire for ASTM F1805. It is rapidly approaching a state of obsolescence due to availability of specific materials for the tread compound and rapid decrease in the popularity of 14-inch tires. In May 2015, Michelin (sole producer of this and other ASTM SRTTs) first notified industry groups, governments, regulators, and standards organizations of this approaching obsolescence. In June 2017 Michelin further communicated an intention to stop production of SRTT14 by the end of 2019.

As a result of these developments, the ASTM Committee F09 on Tires commissioned the Task Force to study replacing SRTT14 with SRTT16 as the reference tire for ASTM F1805. The Task Force (consisting of representatives from tire manufacturers, snow test vendors and OEMs) designed a study program to better understand how ASTM F1805 would be affected by this transition. These studies continued from late 2015 through early 2018 and were made possible with funding provided by the US Tire Manufacturers Association.

3. Surface Characterization – Update to Table A2.1 in ASTM F1805

ASTM F1805 defines the standard test procedure for measuring traction on “snow” and “ice” surfaces. However, there are multiple surface types in both the “snow” and “ice” categories. The surface types characterized in ASTM F1805 are:

- Soft pack (new) snow
- Medium pack snow
- Medium hard pack snow
- Hard pack snow
- Ice – wet
- Ice – dry

Medium pack snow is by far the most popular surface type. It is the surface type specified for severe snow tire certification and application of the Alpine, or 3-Peak Mountain Snowflake (3PMSF), marking when a tire meets the requirements for use in severe snow conditions. It is also the surface type specified by several OEMs who use the ASTM F1805 method (or a close variation) to approve tires relative to internal snow performance targets.

Table A2.1 in ASTM F1805 characterizes each of these surface types by defining the acceptable range for specific parameters used to measure these surfaces. One of the parameters is the “SRTT Tractive Coefficient”. Prior to the 2018 revision of ASTM F1805, the tractive coefficient range for each surface type was specified only with respect to SRTT14. The tractive coefficient ranges for the six surface types were originally developed more than 20 years ago, and the complete history on how they were developed is no longer available. What is known is that the limits were derived empirically through observation of test results from multiple snow test vendors rather than through a scientific study.

Because of this, the originators of ASTM F1805 anticipated that the limits would be updated when justified by the availability of additional data. **Table 1** below shows the evolution of the Table A2.1 minimum and maximum tractive coefficients throughout the prior history of ASTM F1805. Red font indicates the tractive coefficient range changed from the previous version of Table A2.1.

Surface Type	1999	2000	2006	2012	2016
Soft pack (new) snow	0.18, 0.22	0.18, 0.22	0.18, 0.22	0.18, 0.22	0.18, 0.22
Medium pack snow	0.25, 0.41	0.25, 0.41	0.25, 0.41	0.25, 0.41	0.25, 0.41
Medium hard pack snow	0.20, 0.25	0.20, 0.25	0.20, 0.25	0.20, 0.25	0.20, 0.25
Hard pack snow	0.15, 0.20	0.15, 0.20	0.15, 0.20	0.15, 0.20	0.15, 0.20
Ice – wet	none	none	none	0.06, 0.12	0.06, 0.12
Ice - dry	0.07, 0.10	0.07, 0.10	0.06, 0.11	0.06, 0.12	0.06, 0.14

Table 1: Historical Evolution of ASTM F1805 Table A2.1 SRTT14 Tractive Coefficient limits (min, max)

The 2016 version of Table A2.1 (from before the Task Force study) is shown below in **Figure 1**, complete with Ambient and Surface Temperatures, Surface Compaction and SRTT Tractive Coefficients.

TABLE A2.1 Course Characteristics

NOTE 1—Determining the need for regrooming is largely subjective; however, regrooming is required after the test course has been fully utilized.

NOTE 2—A packed base is generally obtained by mechanically smoothing and packing the test course and allowing the resultant smooth surface to set up in the overnight cold temperatures (preferably −12°C (10°F) or less).

Surface Description	Temperatures			Penetrometer Snow Compaction	SRTT (E1136) Tractive Coefficient[A]	Surface and Footprint Characteristics[B]	Remarks
		Surface					
	Amb. Max	Min.	Max.				
Soft pack (new) snow	+3°C (+38°F)	−15°C (+5°F)	−4°C (+25°F)	50–70	0.18–0.22	5.0–7.5 cm (2–3 in.) loose snow. Distinctive footprint.	C
Medium pack snow	+3°C (+38°F)	−15°C (+5°F)	−4°C (+25°F)	70–80	0.25–0.41[D]	2.5–5.0 cm (1–2 in.) loose snow. Distinctive footprint.	E
Medium hard pack snow	+3°C (+38°F)	−15°C (+5°F)	−4°C (+25°F)	80–84	0.20–0.25	1.0–2.0 cm (0.4–0.8 in.) loose snow. Slight footprint.	F
Hard pack snow	+3°C (+38°F)	−15°C (+5°F)	−4°C (+25°F)	84–93	0.15–0.20	No loose snow. Little or no footprint.	G
Ice-wet	0°C (+32°F)	−8°C (+18°F)	0°C (+32°F)	93–98	0.06–0.12	Smooth ice with no loose materials. No footprint.	H
Ice-dry	0°C (+32°F)	−20°C (−4°F)	−7°C (+20°F)	93–98	0.06—0.14	Smooth ice with no loose materials. No footprint.	H

[A] See Specification E1136.
[B] Footprint characteristics are determined by walking or driving on the prepared surface and examining the extent of the imprint or lack thereof.
[C] Freshly fallen snow or deeply groomed base snow.
[D] Testing in the range above 0.38 should be avoided.
[E] Generally obtained by grooming packed base prior to testing in morning.
[F] Typical surface for snow tire/vehicle handling tests.
[G] Packed base with no grooming.
[H] Avoid bright sun on course. Broom or resurface as required.

Figure 2: 2016 Version of ASTM F1805 Table A2.1 (SRTT Tractive Coefficient relative to SRTT14)

As SRTT14 phases out and is replaced by SRTT16, it is necessary to determine the appropriate range of SRTT Tractive Coefficient for each surface type as measured by SRTT16. To determine the appropriate ranges for SRTT16, the Task Force enlisted four ISO-17025 accredited snow test vendors to participate in the study and run SRTT16 versus SRTT14 comparisons on each surface type. The vendors were:

- Goodyear Tire & Rubber Company
- Mobility Research, Inc.
- Ride Solutions, Inc.
- Smithers Rapra

These vendors do not receive an equal number of requests for each surface type; therefore, the number of SRTT comparisons generated over the three year study was not equal for each surface type. The Medium pack and Hard pack snow surfaces generated the most comparisons with the other four surface types generating a smaller number of comparisons.

The Task Force intentionally chose not to simply duplicate the SRTT14 limits based on SRTT16. Instead, it wanted to establish appropriate SRTT16 limits based on observation and experience with well-groomed examples of the six surface types. Vendor observation and experience was coupled with the data specifically generated during the three year study, and the Task Force came to an agreement on what it believes to be the appropriate minimum and maximum tractive coefficients for SRTT16.

As with the original F1805, there is an expectation that the limits could be updated in the future as more experience and observations become available.

Based on its analysis, the Task Force also took advantage of the opportunity presented by this study to revise the SRTT14 tractive coefficient range for the Medium pack and Medium hard pack surfaces as shown below in **Table 2**. Again, red font indicates the tractive coefficient range changed from the previous version of Table A2.1.

Surface Type	2016	2018
Soft pack (new) snow	0.18, 0.22	0.18, 0.22
Medium pack snow	0.25, 0.41	0.25, 0.38
Medium hard pack snow	0.20, 0.25	0.25, 0.36
Hard pack snow	0.15, 0.20	0.15, 0.20
Ice – wet	0.06, 0.12	0.06, 0.12
Ice - dry	0.06, 0.14	0.06, 0.14

Table 2: 2018 Revision of ASTM F1805 Table A2.1 SRTT14 Tractive Coefficient limits (min, max)

The plots in **Figure 2** through **Figure 7** show the comparison of SRTT16 and SRTT14 for each surface type. The Task Force evaluated these plots in multiple face-to-face and virtual meetings over the three year study. Outlier data points were discussed and agreed upon for removal via consensus. The remaining points were used to determine the final minimum and maximum SRTT16 tractive coefficients for each surface type. This determination was also made via consensus in multiple meetings of the Task Force.

In **Figure 2** through **Figure 7**, the red dashed lines represent the 2018 revised minimum and maximum tractive coefficient limits versus SRTT14. The blue dashed lines show the new 2018 consensus minimum and maximum tractive coefficient limits versus SRTT16.

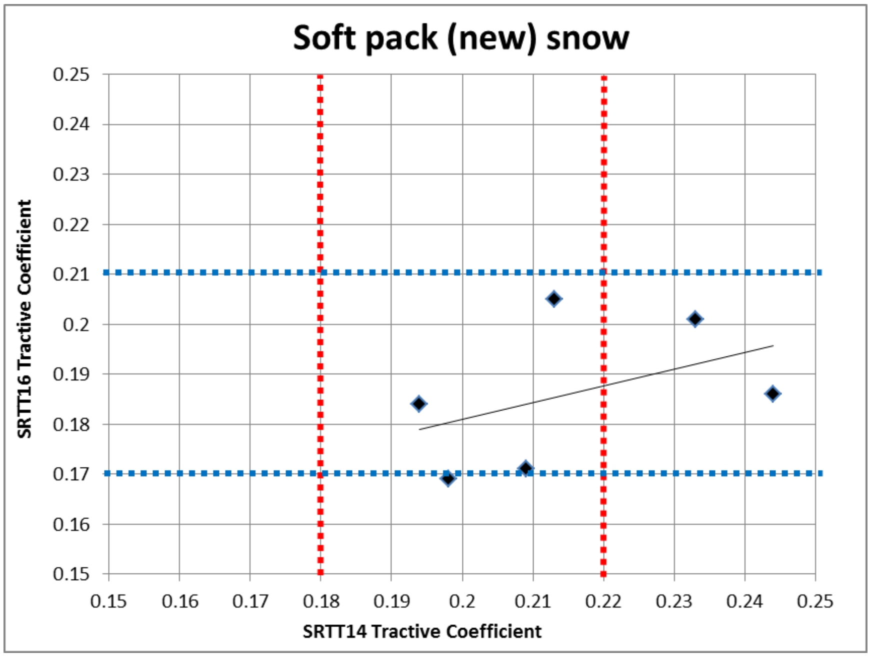

Figure 2: SRTT16 vs SRTT14 Tractive Coefficients for Soft pack (new) snow

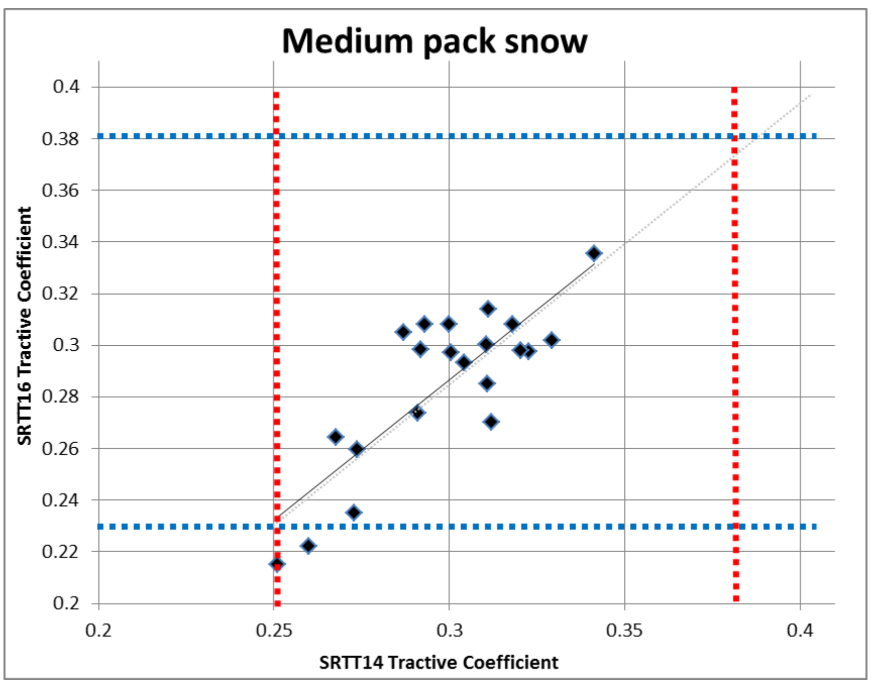

Figure 3: SRTT16 vs SRTT14 Tractive Coefficients for Medium pack snow

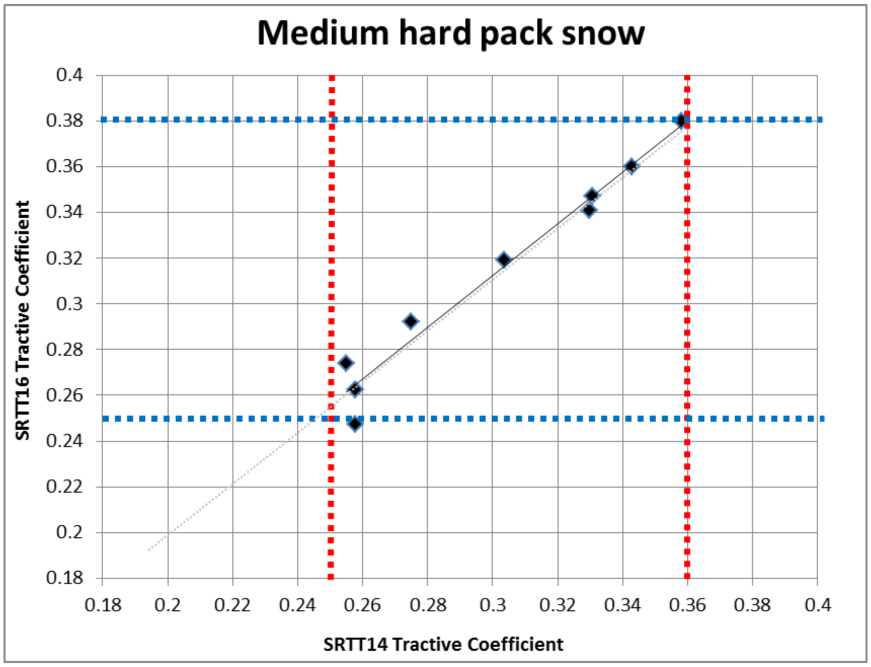

Figure 4: SRTT16 vs SRTT14 Tractive Coefficients for Medium hard pack snow

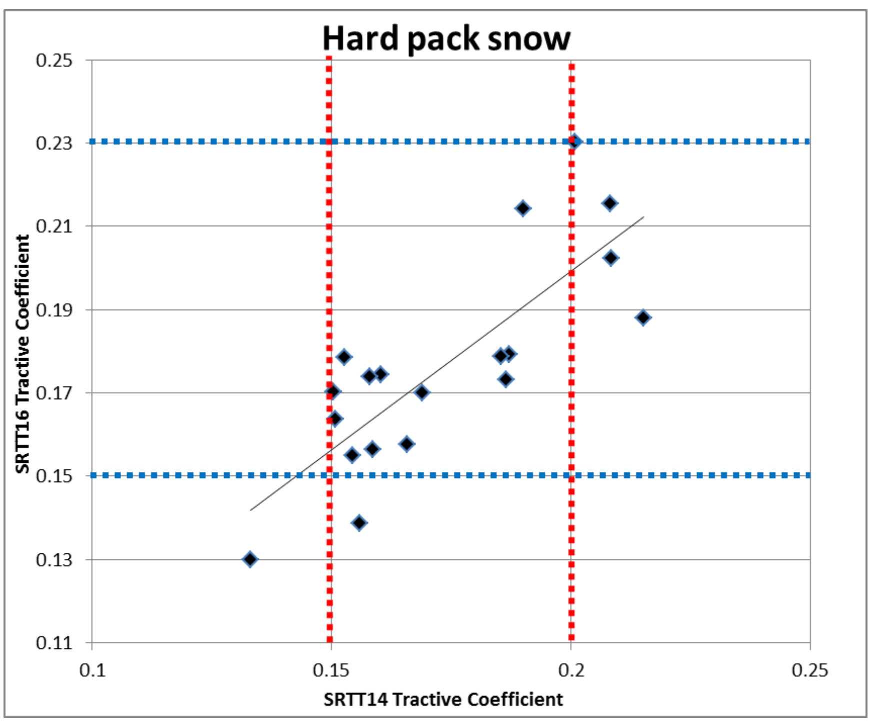

Figure 5: SRTT16 vs SRTT14 Tractive Coefficients for Hard pack snow

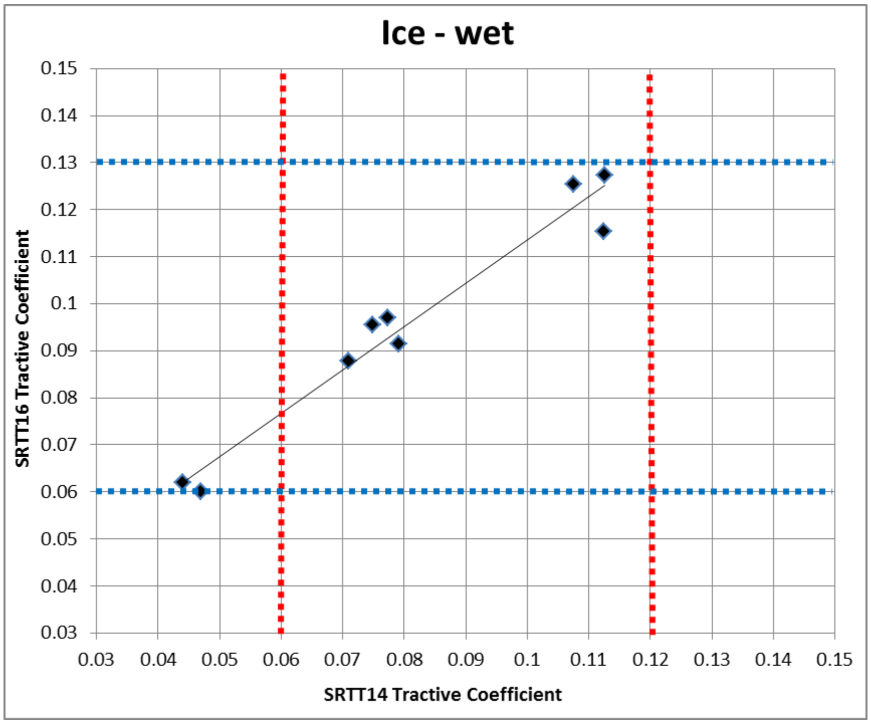

Figure 6: SRTT16 vs SRTT14 Tractive Coefficients for Ice – wet

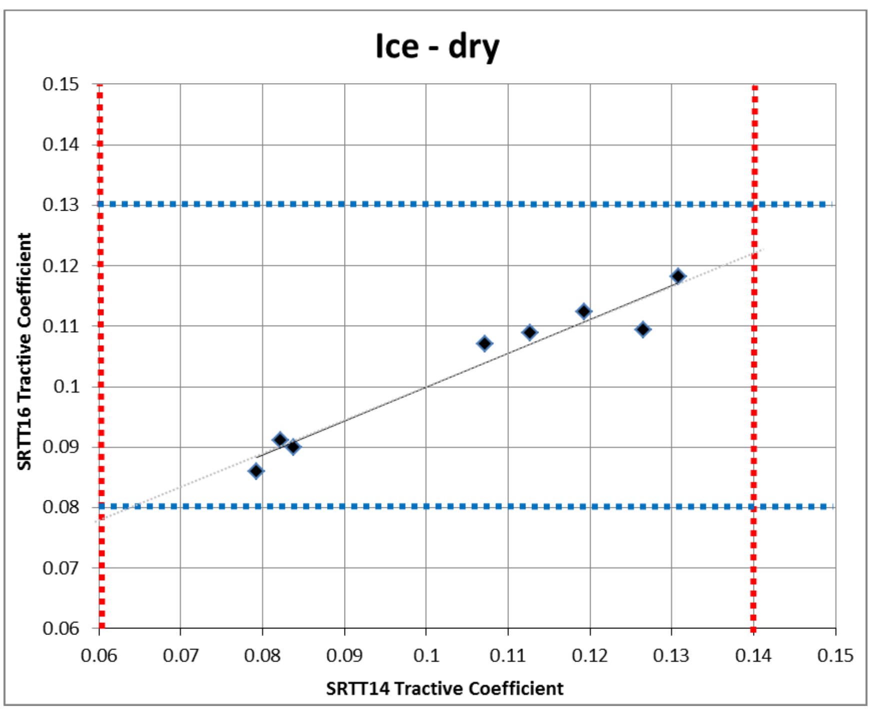

Figure 7: SRTT16 vs SRTT14 Tractive Coefficients for Ice - dry

Analysis of these plots by the Task Force led to consensus agreement on the minimum and maximum SRTT16 Tractive Coefficient values. A 2018 revision of ASTM F1805 updated Table A2.1 to include these values as shown below in **Figure 8**.

TABLE A2.1 Course Characteristics

NOTE 1—Determining the need for regrooming is largely subjective; however, regrooming is required after the test course has been fully utilized.

NOTE 2—A packed base is generally obtained by mechanically smoothing and packing the test course and allowing the resultant smooth surface to set up in the overnight cold temperatures (preferably –12°C (10°F) or less).

Surface Description	Temperatures			Penetrometer Snow Compaction	SRTT F2493 (SRTT E1136) Tractive Coefficient[A]	Surface and Footprint Characteristics[B]	Remarks
	Amb. Max	Surface Min.	Surface Max.				
Soft pack (new) snow	+3°C (+38°F)	–15°C (+5°F)	–4°C (+25°F)	50–70	0.17–0.21 (0.18–0.22)	5.0–7.5 cm (2–3 in.) loose snow. Distinctive footprint.	C
Medium pack snow	+3°C (+38°F)	–15°C (+5°F)	–4°C (+25°F)	70–80	0.23–0.38 (0.25–0.38)	2.5–5.0 cm (1–2 in.) loose snow. Distinctive footprint.	D
Medium hard pack snow	+3°C (+38°F)	–15°C (+5°F)	–4°C (+25°F)	80–84	0.25–0.38 (0.25–0.36)	1.0–2.0 cm (0.4–0.8 in.) loose snow. Slight footprint.	E
Hard pack snow	+3°C (+38°F)	–15°C (+5°F)	–4°C (+25°F)	84–93	0.15–0.23 (0.15–0.20)	No loose snow. Little or no footprint.	F
Ice-wet	0°C (+32°F)	–8°C (+18°F)	0°C (+32°F)	93–98	0.06–0.13 (0.06–0.12)	Smooth ice with no loose materials. No footprint.	G
Ice-dry	0°C (+32°F)	–20°C (–4°F)	–7°C (+20°F)	93–98	0.08–0.13 (0.06–0.14)	Smooth ice with no loose materials. No footprint.	G

[A] See Specification E1136 or F2493.
[B] Footprint characteristics are determined by walking or driving on the prepared surface and examining the extent of the imprint or lack thereof.
[C] Freshly fallen snow or deeply groomed base snow.
[D] Generally obtained by grooming packed base prior to testing in morning.
[E] Typical surface for snow tire/vehicle handling tests.
[F] Packed base with no grooming.
[G] Avoid bright sun on course. Broom or resurface as required.

Figure 8: 2018 revision of ASTM F1805 Table A2.1 (SRTT Tractive Coefficient range added for SRTT16)

4. Development of SRTT Correlation Factor for Medium pack snow

The second primary goal of the Task Force study was to determine the correlation factor (i.e., ratio) between SRTT16 and SRTT14 for the Medium pack snow surface which is used for regulations related to snow performance. If the correlation factor can be precisely estimated, then the equivalent SRTT14 rating for future tests (run without the SRTT14) can be predicted using only the SRTT16 as shown below in **Equation 1**. There is no regulatory need to determine this correlation factor for any surface type other than the Medium pack snow surface.

$$Tire1\ Rating = \frac{Tire1\ Coef.}{14"\ Coef.} = \frac{Tire1\ Coef.}{\cancel{16"\ Coef.}} \times \frac{\cancel{16"\ Coef.}}{14"\ Coef.}$$

Need to predict this value, because the 14" SRTT will not be available long term

(Therefore, the equivalent 14" rating can be estimated using only the 16" SRTT rating and the prediction of the 16"/14" ratio)

Equation 1: Equivalent SRTT14 Rating using only the SRTT16

The snow test vendors recorded SRTT16 and SRTT14 mu coefficients (along with the ambient and snow conditions) during each of the three seasons of the study. The following parameters were recorded:

1. SRTT14 mu coefficient (based on longitudinal slip velocity of 3.2 kph and continuing for 1.5 s)
2. SRTT16 mu coefficient (based on longitudinal slip velocity of 3.2 kph and continuing for 1.5 s)
3. Snow temperature
4. Air temperature
5. Test date
6. SRTT16 DOT date code
7. CTI (snow hardness)
8. Test location

a) Data Sources

The eight parameters listed above were collected from a variety of sources using both historical data from 2010 to 2015 and the three year Task Force study from 2016 to 2018. These sources were:

1. SRMT tests conducted 5 to 8 times per year as required by SRMT protocol
2. Auxiliary SRMT testing in addition to the required runs
3. Daily testing of SRTT16 versus SRTT14
4. Smithers "Evolution with Spins" for both SRTT16 and SRTT14
5. Additional candidate tire testing using both SRTT14 and SRTT16
6. Medium pack snow high & low grip level study at various temperatures

A total of 402 SRTT16 versus SRTT14 ratios were collected from 2010 to 2018. The majority of the data were from 2016 to 2018 due to the additional funding from USTMA. For most years, the ratio between SRTT14 and SRTT16 fluctuated between 0.95 and 0.99 on average as shown in **Figure 9**.

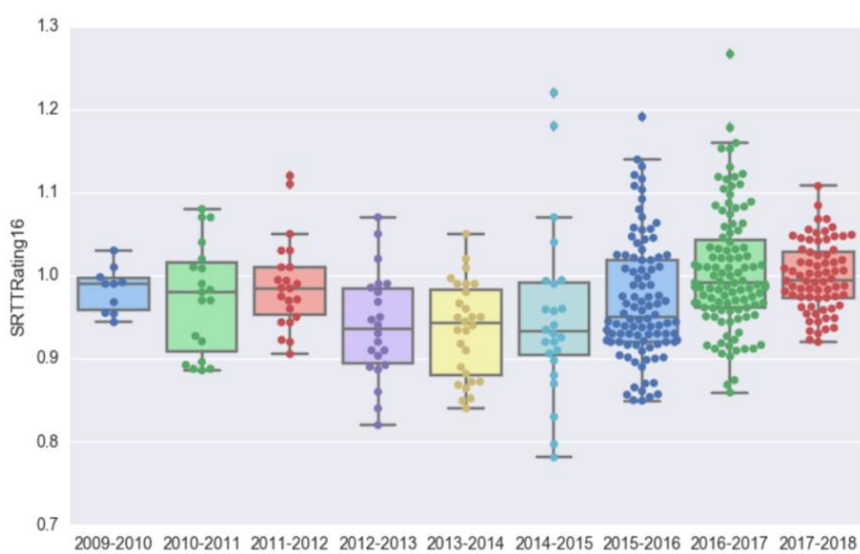

Figure 9: 2010 to 2018 SRTT16/SRTT14 ratio

Occasionally, the SRTT16/SRTT14 ratio was higher than 1.05 and lower than 0.88 at each of the four test locations (i.e., the snow test vendors, who each have their own test location) as shown in **Figure 10**. It is acknowledged that there is significant test variation when comparing these two SRTTs.

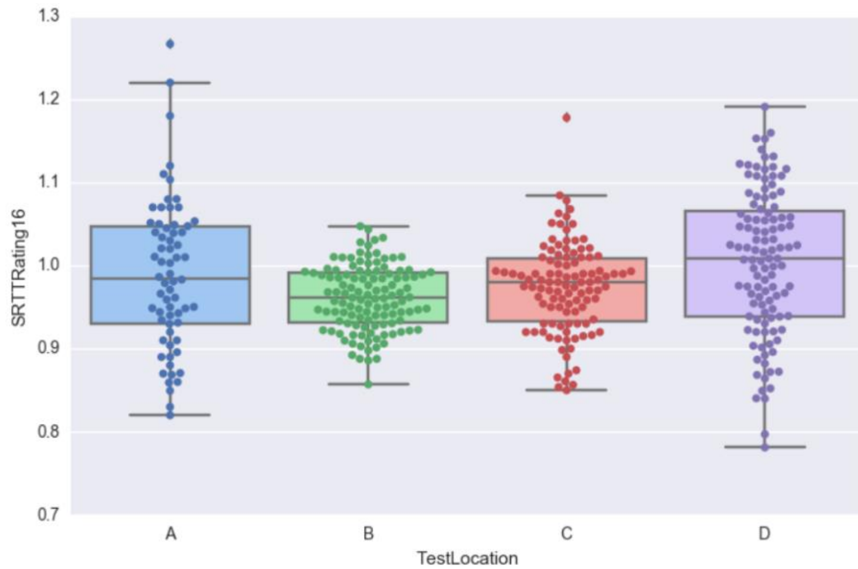

Figure 10: 2010 to 2018 SRTT16/SRTT14 ratio at 4 test locations

b) Rationale for Data Exclusions

Because of the variability associated with the data, the Task Force decided to exclude certain parts of the data set where a logical justification for excluding the data could be agreed upon.

The first exclusion was related to the rigor used in selecting the SRTTs used for testing. Even though the SRTT manufacturer has a well-defined and rigorous process to validate each "batch" (i.e., tire build) with verification of material properties, physical dimensions, machine testing and wet/dry traction testing, it cannot validate each batch of tires for snow performance. Therefore, prior to each winter test season, the SRTT manufacturer provides a group of SRTT14s to a reference snow test vendor. These SRTT14s are all from the same batch, and they are typically manufactured only a few weeks prior to their receipt by the reference snow test vendor. The reference snow test vendor conducts a snow validation process on this group of SRTT14s to measure the relative performance. The reference vendor then selects a sub-group of these SRTT14s which are most closely aligned for performance. This sub-group of SRTT14s is then divided among the group of snow test vendors for each to use as primary and secondary reference tires for the upcoming winter test season.

Historically, the SRTT16s used in the SRMT matrix were not subjected to the same snow validation process. Therefore, the condition and relative snow performance of SRTT16s was not as closely controlled as the SRTT14s in the 2010 through 2015 historical data. Even in the first year (2016) of the

Task Force study, the SRTT16s did not follow the exact same snow validation process as the SRTT14s, although there were aspects of control that were more rigorous than what was used in the 2010 – 2015 time period. After the first year of the study, the Task Force recognized that SRTT16s needed to follow the same snow validation process as the SRTT14s. In 2017 and 2018 the SRTT16s followed the exact same snow validation process as that used for many years on the SRTT14s.

Because of the differences in SRTT16 snow performance control between 2010-2015 and 2016-2018, the Task Force decided to exclude the 2010-2015 portion of the data set and concentrate on the data set from the three year period of 2016-2018 which was regarded as higher quality.

Another observation of the Task Force was that the SRTT16/SRTT14 ratio was affected by SRTT16 grip level, with the ratio increasing for higher SRTT16 grip levels (see **Figure 11**). The trend lines in **Figure 11** show that the SRTT16/SRTT14 ratio increases more than 10% at higher grip levels when performing the ASTM F1805 test. **Figure 11** also shows the effect of temperature by plotting three temperature ranges as separate colors. Blue is the coldest range from -15 to -12 °C; grey is the middle temperature from -11 to -8 °C; and red is the warmest temperature from -7 to -4 °C. Relative to the ratio at colder temperatures, the SRTT16/SRTT14 ratio is about 5 percent higher when the temperature is warmer.

After considering the impact of the trends seen in **Figure 11**, the Task Force decided not to exclude data based on temperature. However, the Task Force did decide to exclude data for which the SRTT16 grip level fell outside the 0.23 to 0.38 tractive coefficient range since this was validated as the acceptable range for Medium pack snow when going through the process of updating Table A2.1 in ASTM F1805 (see "3. Surface Characterization – Update to Table A2.1 in ASTM F1805" in this report).

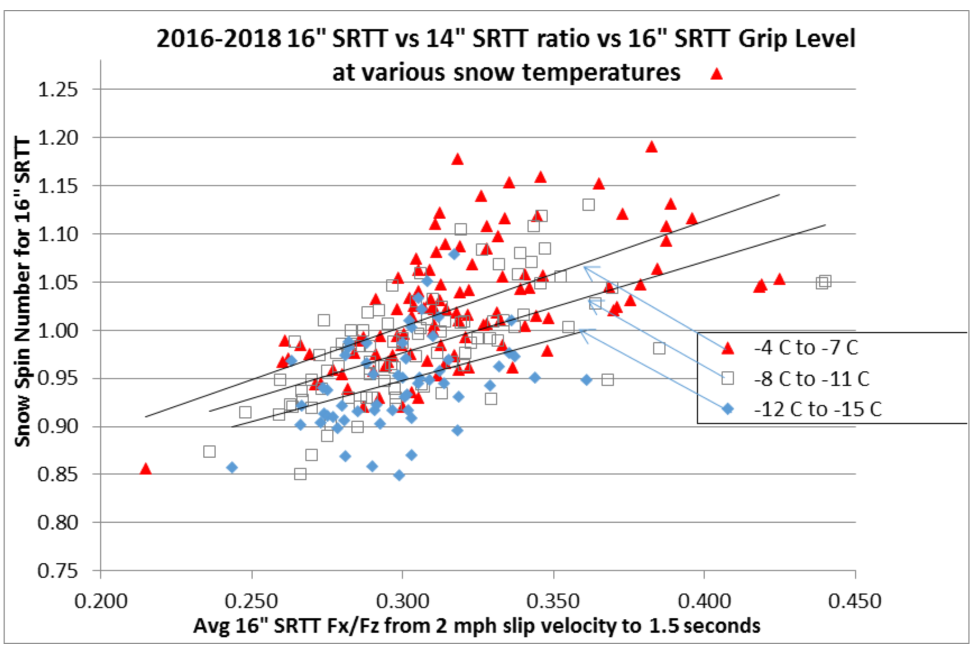

Figure 11: 2016-2018 SRTT16/SRTT14 ratio vs SRTT16 Grip Level

For the remaining subset of 2016-2018 data with SRTT16 tractive coefficient of 0.23 to 0.38, the Task Force decided to further apply a well-known process for rejection of outliers. Data points for which the SRTT16/SRTT14 ratio was more than 1.5 times the standard deviation from the mean within each test location were rejected as outliers.

c) Predictive Tools and Error: Linear Model versus Constant Ratio

As mentioned earlier in **Equation 1**, the reason we need to know the SRTT16/SRTT14 ratio is so that a SRTT16/SRTT14 Correlation Factor can be developed. The Task Force decided to evaluate two approaches for calculating this Correlation Factor: Linear Model and Constant Ratio.

<u>Linear Model</u>

The eight parameters recorded by the snow test vendors in each year of the study are found on page 10. Using these parameters as input, a model can be created to calculate a SRTT16/SRTT14 Correlation Factor. However, "Test location" and "SRTT14 mu coefficient" were not included as potential variables for the final model. "Test location" was not included because the model must be applicable to any future test location whether new vendors are added or current vendors choose to move their testing operation. "SRTT14 mu coefficient" was not included because SRTT14 will not be available in the future (which is the main reason for needing a model to begin with).

The linear regression analysis performed showed that the following three parameters were statistically significant for estimating the SRTT16/SRTT14 Correlation Factor:

- Snow temperature
- SRTT16 mu coefficient
- (Test date – SRTT16 DOT date code)

The linear model calculated using the subset of 2016-2018 data with SRTT16 mu coefficient of 0.23-0.38 and outliers rejected based on 1.5σ from the mean is shown in **Equation 2** where:

- a = Snow temperature in °C
- b = SRTT16 mu coefficient
- c = (Test date – SRTT16 DOT date code) in months

Equivalent SRTT14 Rating = SRTT16 Rating x [0.7514 + 0.004666a + 0.9616b - 0.002305c]

Equation 2: Equivalent SRTT14 Rating calculated using Linear Model Correlation Factor

It is important to note that this Linear Model Correlation Factor is valid <u>only</u> for the Medium pack snow surface.

The data set and the fit of the Linear Model are shown below in **Figure 12**.

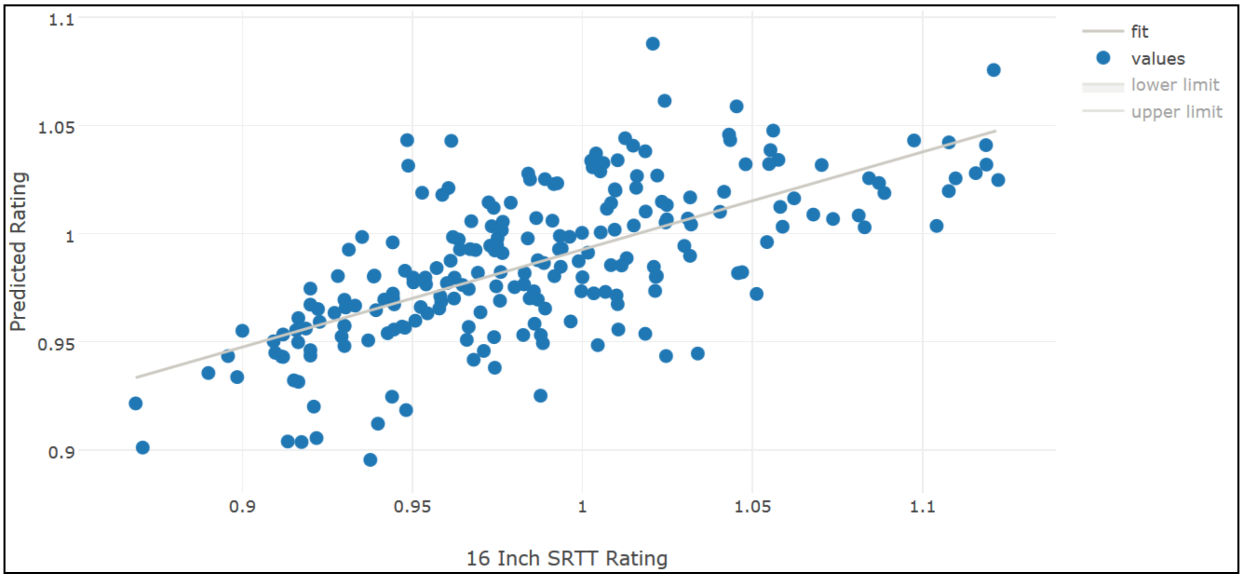

Figure 12: Equivalent SRTT14 Rating as a function of SRTT16 Rating using Linear Model

Constant Ratio

Determination of a SRTT16/SRTT14 Correlation Factor by the Constant Ratio approach is a much simpler process. Using the subset of 2016-2018 data with SRTT16 mu coefficient of 0.23-0.38 and outliers rejected based on 1.5σ from the mean, the calculation of the average SRTT16/SRTT14 ratio yields a value 0.987. Using this constant ratio as the Correlation Factor, the calculation of the Equivalent SRTT14 Rating would be expressed as shown in **Equation 3**. It is important to note that this Constant Ratio Correlation Factor is valid only for the Medium pack snow surface.

Equivalent SRTT14 Rating = SRTT16 Rating x 0.987

Equation 3: Equivalent SRTT14 Rating calculated using Constant Ratio Correlation Factor

Comparison of Error

The Linear Model produces an R^2 of 0.45, so there is still significant error when predicting the Equivalent SRTT14 Rating from the SRTT16 Rating. The histogram shown in **Figure 13** compares the error of the Linear Model compared to the SRTT16/SRTT14 Constant Ratio = 0.987. The Linear Model does have less error than the Constant Ratio approach, but the Linear Model also adds complexity to the process of calculating the Equivalent SRTT14 Rating.

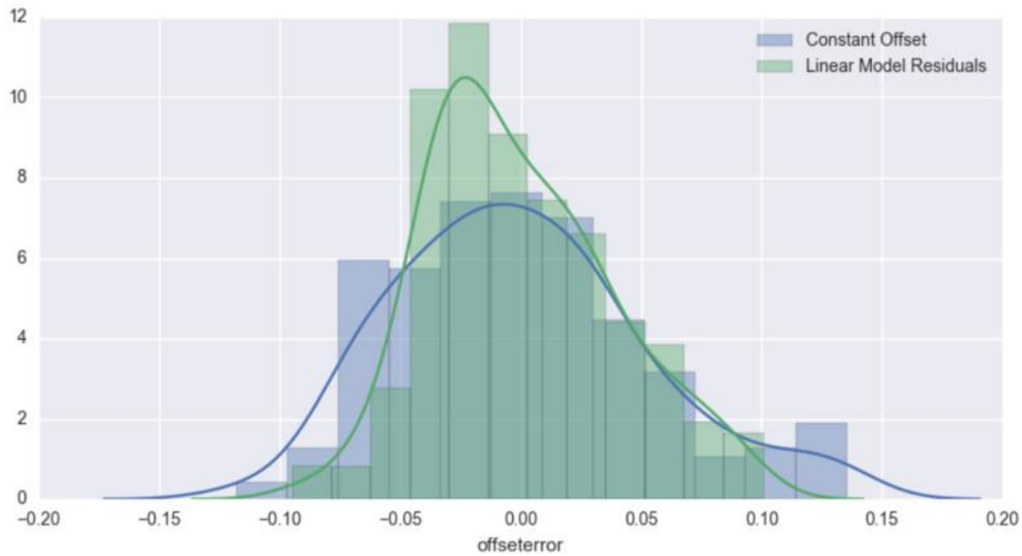

Figure 13: Histogram of Error; Linear Model and Constant Ratio

Since snow performance ratings are based on the average of at least three days of testing, the SRTT16/SRTT14 Correlation Factor average error can also be compared over three consecutive test days. Comparing the average value minimizes the impact of test variation. **Table 3** below shows the standard deviation of the error for the Linear Model and the Constant Ratio. Even when averaging three days together, the error from the Linear Model is less than the error from the Constant Ratio. The reduction in error seems logical given the ratio's sensitivity to grip and temperature.

	3-Day average error using Linear Model (2016-2018; 0.23-0.38; 1.5σ)	3-Day average error using 0.987 Constant Ratio (2016-2018; 0.23-0.38; 1.5σ)
Standard Deviation	0.037	0.055

Table 3: 3-Day Average Error; Linear Model versus Constant Ratio

<u>Comparison of Equivalent SRTT14 Ratings using the Linear Model and Constant Ratio</u>

Because of the rigor of each snow test vendor in running the SRMT matrix and the additional SRMT runs requested by the Task Force in 2018, the Task Force decided to use SRMT ratings as the primary tool for comparing the Linear Model and Constant Ratio. Before showing the results, it is beneficial to explain some more detail about the SRMT matrix and how it is run.

The standard SRMT matrix includes the SRTT16 plus three market tires. The market tires are:

- P255/65R18 Goodyear Fortera HL Edition
- LT245/75R16 LRE Bridgestone VSteel Rib 265
- P245/70R17 General Grabber HTS

The standard SRMT run sequence used by snow test vendors when making the required runs is:

SRTT14 – GY – GE - SRTT14 – BS - SRTT16 - SRTT14

This standard sequence allows ratings for the three market tires and the SRTT16 to be calculated versus the SRTT14 because it brackets each of the other four tires in the sequence. However, calculating ratings for the three market tires versus the SRTT16 would not be very accurate because the SRTT16 is run only one time.

In order to maximize efficiency, the SRTT16 was run multiple times in the 2018 SRMT tests so that SRTT16 ratings for the three market tires could be calculated just like the SRTT14 ratings. The additional SRTT16 tests allow for each market tire to be bracketed by both the SRTT14 and SRTT16 as shown below. The Bridgestone and Goodyear tires were tested more than the General tire to reduce the cost of the study.

Sequence A conducted on five different weeks:

SRTT14 - SRTT16 – GE - SRTT14 – BS - SRTT16 - SRTT14 – GY - SRTT16 - SRTT14

Sequence B conducted on five different weeks:

SRTT14 - SRTT16 – BS - SRTT14 - SRTT16 – GY - SRTT14 - SRTT16

Four types of ratings for the four vendors are shown in **Figure 14, 15 and 16**.

- The measured SRTT14 Rating is represented by the green bar (i.e., SRMT vs SRTT14)
- The measured SRTT16 Rating is represented by the solid blue bar (i.e., SRMT vs SRTT16)
- The predicted Equivalent SRTT14 Rating based on the Linear Model is represented by the red bar
- The predicted Equivalent SRTT14 Rating based on the Constant Ratio is represented by the dotted blue bar

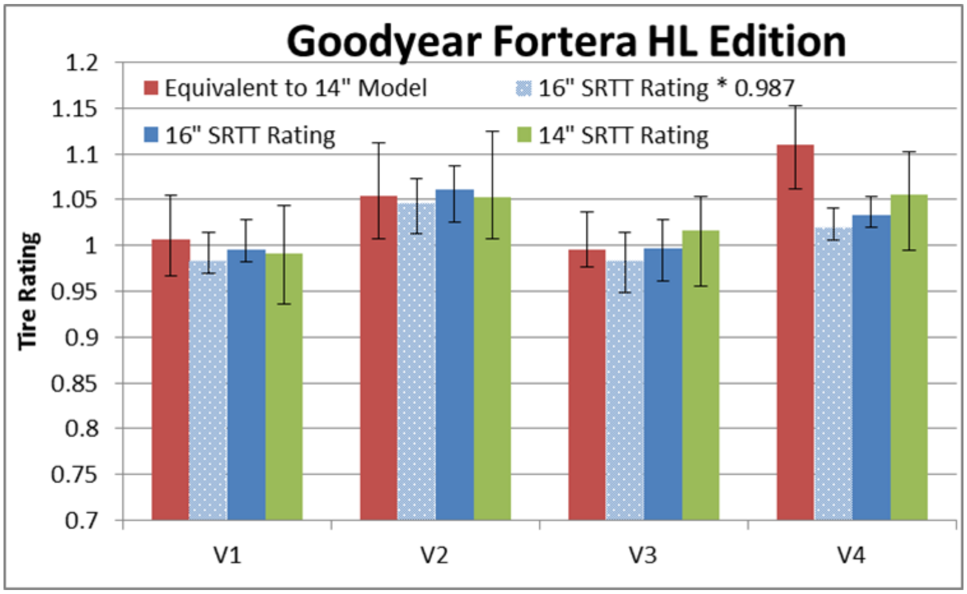

Figure 14: Measured ratings and model comparisons for Goodyear SRMT

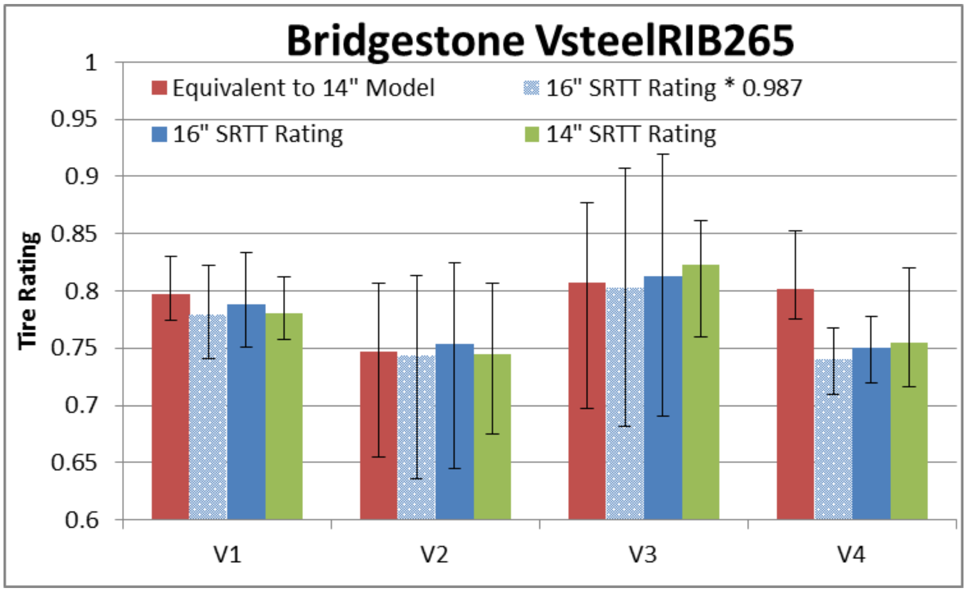

Figure 15: Measured ratings and model comparisons for Bridgestone SRMT

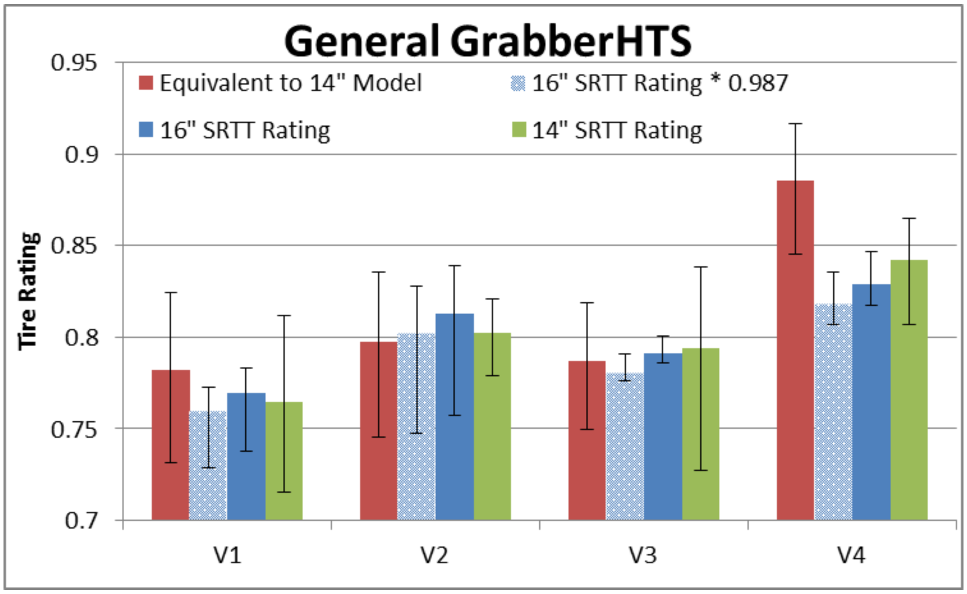

Figure 16: Measured ratings and model comparisons for General SRMT

The difference between the vendors' SRTT14 Rating is typically greater than the difference between the SRTT14 Rating and the SRTT16 Rating within a vendor. This means that vendor-to-vendor variation is probably greater than the effect of transitioning from SRTT14 to SRTT16.

The Linear Model (Equivalent SRTT14 Rating) agreement with the SRTT14 Rating is best for Vendors 2 and 3. It is not quite as good for Vendor 1, but it still predicts the SRTT14 Rating reasonably well. However, the Linear Model does not work well for Vendor 4. The Linear Model for Vendor 4 over-predicts the ratings because the grip level was higher at Vendor 4 compared with the other vendors in 2018. The SRTT16 mu coefficient was about 0.41 on average at Vendor 4 while it ranged from approximately 0.30 to 0.33 at the other three vendors.

In the **Figure 14, 15 and 16** plots above, the SRTT16 Rating without any adjustment had the best correlation to the SRTT14 Rating. This is surprising because the two SRTTs have different temperature and grip level sensitivities. However, we should also keep in mind that these SRTT16 Ratings are based only on data generated in the 2018 test season while the Linear Model and the Constant Ratio approach are both based on data from the three test seasons 2016 to 2018.

d) Recommendation for Constant Ratio Approach (0.987)

There are three options to consider when choosing how to move forward with snow testing on a Medium pack snow surface with SRTT16 as the reference tire in place of SRTT14:

- Linear Model
- Constant Ratio = 0.987
- SRTT16 Rating with no adjustment (i.e., constant ratio of 1.0)

All three options for producing snow performance ratings using SRTT16 as the reference tire are approximately equivalent. Using the 2018 SRMT data (averaging all 4 vendors together) as a basis, each of the methods using SRTT16 to produce snow spin ratings are within a few percent of the long term average SRTT14 ratings for the SRMTs.

Each of the three options has pros and cons. To summarize:

- The 3-day average error for the Linear Model is lower than for the Constant Ratio approach. However, the Linear Model rating compares well with SRTT14 Rating for only three of the four snow test vendors. Also, application of the model adds significantly more complexity for the vendors.
- The Constant Ratio of 0.987 has a 3-day average error that is slightly higher than the Linear Model, but the Constant Ratio still compares well with SRTT14 Ratings. The Constant Ratio also works well for all four vendors, and application of the Constant Ratio approach is much simpler for the snow test vendors compared to the Linear Model.
- The SRTT16 Rating with no adjustment (i.e., a constant ratio of 1.0) agreed most closely with the SRTT14 Rating for the SRMTs in the 2018 test season. While this is attractive, it is important to remember that this is based on limited data compared with the Linear Model and Constant Ratio which are based on three years of data. The high variability of winter testing should be taken into account when considering this approach. While ASTM task groups and vendors are always working to reduce dispersion and variability, the F1805 test method still sometimes produces test results with high variability. Changing from a constant ratio coefficient of 0.987 to a coefficient of 1.0 (i.e., no coefficient) could potentially induce a slight increase in the error.

The Task Force reviewed all of this data with the ASTM F09.20 Vehicular Testing Subcommittee and the ASTM Committee F09 Tires. The consensus decision of all involved was to move forward with the Constant Ratio 0.987 approach. Therefore, the Task Force recommends application of the following predictive tool for ASTM F1805 snow spin tests conducted after the SRTT14 phase-out:

Equivalent SRTT14 Rating = Measured SRTT16 Rating x SRTT16 Correlation Factor
where SRTT16 Correlation Factor = 0.987

It is important to note that this predictive tool is valid only for ASTM F1805 tests conducted on the Medium pack snow surface.

This Constant Ratio approach was preferred for the following reasons:

- Works equally well for all vendors whereas the Linear Model method did not
- Simple for snow test vendors to implement
- Does not artificially inflate ratings or grant the 3-Peak Mountain Snowflake (3PMSF) certification to tires which are undeserving (i.e., candidate tire would have to generate rating of 111.4 versus SRTT16 in order to correlate to a rating of 110 versus SRTT14)