Review of the Tire Fuel Efficiency Rating System Described in NHTSA's Notice of Proposed Rulemaking

Prepared on behalf of the
Rubber Manufacturers Association

Prepared by
ENVIRON International Corporation
Arlington, Virginia

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1.0 INTRODUCTION

ENVIRON International Corporation (ENVIRON) was retained by the Rubber Manufacturers Association (RMA) to review and provide comments on the tire fuel efficiency rating system proposed by the National Highway Transportation Safety Administration (NHTSA) in the Notice of Proposed Rulemaking (NPRM) issued on June 22, 2009 (FR 29542, vol. 74 no. 118). This report describes the characteristics of the proposed rating system in the context of procedures developed by the auto industry for analysis of measurement systems. It also includes a quantitative analysis of the likely effects of adoption of proposed system. An alternative system proposed previously by the RMA is also discussed and evaluated. In preparing this report, ENVIRON has relied on information provided by others; our scope of work does not include generating new rolling resistance measurements or other data.

This report is organized as follows:

- Section 1 states the purpose and defines the scope of the project.
- Section 2 provides an overview of procedures developed by the auto industry for analysis of measurement systems. Important concepts, characteristics, and terms are discussed in this section.
- Section 3 identifies and discusses four sources of uncertainty in the fuel efficiency ratings to be assigned under the system proposed in the NPRM. The total uncertainty associated with the ratings assigned to specific tires is estimated on the basis of this discussion and available data.
- Section 4 describes and evaluates the likely consequences of adopting the rating system proposed in the NPRM. An analysis of available data to forecast the reliability of this proposed rating system is presented.

- Section 5 compares an alternative rating system previously proposed by the RMA to the system described in the NPRM.
- Section 6 summarizes the findings of the analyses described in the preceding sections.

2.0 MEASUREMENT SYSTEMS

2.1 Concepts and Terminology

The tire fuel efficiency rating program described in the recent NPRM will be based on measurements of rolling resistance obtained by testing a wide variety of tire products at a number of different laboratories. Collectively, the methods used to collect these measurements, interpret the data, and assign fuel efficiency ratings to particular tire products constitute a measurement system. The concepts and characteristics of measurement systems used in the auto industry are explained and discussed in great detail in a publication titled *Measurement Systems Analysis Reference Manual* (3rd edition, 2002) produced by the Automotive Industry Action Group (AIAG). In the following text, Measurement Systems Analysis is shortened to MSA and the AIAG publication is referred to as "the MSA Reference Manual". The purpose of the MSA Reference Manual is to present guidelines for assessing the quality of a measurement system. ENVIRON has prepared this summary of the important MSA concepts and terms that are relevant to the tire fuel efficiency measurement system described in the recent NPRM to promote effective communication among the various stakeholders.

2.2 Scope of the Measurement System for Tire Fuel Efficiency Ratings

The following explanation of the concept of a measurement system is provided in the MSA Reference Manual:

> [A] Measurement system is the collection of instruments or gages, standards, operations, methods, fixtures, software, personnel, environment and assumptions used to quantify a unit of measure or fix assessment to the feature characteristic being measured; the complete process used to obtain measurements.

This concept can be applied to the process of developing fuel efficiency ratings for tire products. Note that in this report, the measurement system proposed in the NPRM is considered to be comprehensive. It does not end with a measured rolling resistance value for an individual tire, or when a manufacturer has assigned a rolling resistance force (RRF) value to a particular tire stock-keeping unit (SKU)[1]; it also includes the subsequent analysis used to assign the final tire fuel efficiency rating (RFE) that will be provided to consumers. The procedures used to obtain a rolling resistance measurement for an individual item and the procedures used to assign a representative value to all tires in a defined group (e.g., all tires with a particular SKU) are both components of the comprehensive measurement system proposed in the NPRM.

2.3 Characteristics of Measurement Systems

Reliability and uncertainty are the two key characteristics of the measurement system proposed in the NPRM that are discussed in this report. As explained below, the sources and levels of uncertainty are the primary factors in determining the reliability of the measurement system.

The purpose of the tire fuel efficiency rating system described in the recent NPRM is to provide consumers with information that they can use to select tires that are more fuel efficient. Thus, the system unavoidably involves comparisons among the fuel efficiency ratings assigned to various groups of tires (e.g., SKUs). To maximize the benefits of this system, the measurement system used to assign the ratings provided to the consumers should be reliable. At minimum, a comparison between the fuel efficiency ratings assigned to two SKUs should consistently allow the consumer to identify the more efficient SKU (i.e., the SKU with the lower rolling resistance value) or to conclude correctly that there is no significant difference between the fuel efficiency of the two SKUs being compared.

[1] As explained in the NPRM, an SKU is "a specific market brand and tire design and size combination." NHTSA is proposing to define SKU as "the alpha-numeric designation assigned by a manufacturer to uniquely identify a tire product. This term is sometimes referred to as a product code, a product ID, or a part number."

If the fuel efficiency rating (RFE) assigned to each SKU is sufficiently accurate, the measurement system should be reliable. The reliability of the system is called into question, however, if there is significant uncertainty associated with the assigned ratings. Therefore, the sources, levels, and consequences of uncertainty associated with the RFE values should be considered in developing and implementing the tire fuel efficiency rating system.

The RFE rating produced by the measurement system described in the NPRM represents the mean rolling resistance characteristic of all tires manufactured with a specific SKU.

Under the system proposed in the NPRM, the RFE rating for each tire SKU will be derived by the tire manufacturer using a measurement or estimate of the RRF value that is characteristic of that SKU. Calculation of the RFE rating from the selected RRF value involves rounding to the nearest whole number, which may contribute to the uncertainty of the measurement system to a small extent. The primary sources of uncertainty in the RFE ratings are more likely associated with selection of the RRF value from which the RFE rating is derived. These sources of uncertainty are discussed in Section 3 of this document.

2.4 Explanation of Relevant Terms

Many of the terms used in describing the important characteristics of a measurement system have common meanings that may differ substantially from the technical meanings assigned to these terms in the MSA Reference Manual. The technical meanings of the most relevant terms are explained below. As noted in the MSA Reference Manual, some of these terms have somewhat different meanings in documents produced by the American Society for Testing and Materials (ASTM).

- Resolution – The MSA Reference Manual indicates that resolution is equivalent to discrimination, which is "the amount of change from a reference value that an instrument can detect and faithfully indicate." For this discussion, the resolution of an instrument or process used to obtain a measurement can be thought of simply as the lowest difference in value that can be detected. For example, if items are weighed on a digital scale that reports the weight in grams, the resolution of the instrument would be 1 gram.

- Reference value - A reference value is a value that serves as an agreed-upon reference for comparison. In the context of the ISO 28580 rolling resistance measurement process, the rolling resistance of a reference tire as measured at the reference laboratory is a reference value. The reference value is often used as a surrogate for the true value because the true value cannot be determined by measurement.
- Standard – According to the MSA Reference Manual, a standard is anything taken by general consent as a basis for comparison. In the context of the ISO 28580 rolling resistance measurement process, a reference tire and the equipment and systems used to measure its rolling resistance at the reference laboratory are a standard. The measurement associated with this standard is a reference value. Various types of standards (e.g., calibration standards, transfer standards, working standards) are described in the MSA Reference Manual.
- True value - It is important to note and understand the difference between the reference value and the true value. The true value is the target of the measurement process; a perfect process would always provide a measurement exactly equal to the true value. Because no measurement process is perfect, the true value is unknown and unknowable. For this reason, the reference value is often used as a surrogate for the true value.
- Accuracy – The accuracy of a measurement system is an indication of how close the measurements are to the true value or an accepted reference value. Thus, accuracy refers to the size of the measurement errors.
- Bias – Bias refers to the systematic error of a measurement system, which is manifested in a tendency to over-estimate or under-estimate the reference

value. Bias is often quantified by comparing the average of many measurements to the reference value.

- Stability – Stability (also referred to as drift) is the degree to which the bias of a measurement system changes over time.
- Linearity – The linearity of a measurement system is the degree to which the bias of the system stays constant over the range of measurements.
- Precision – The precision of a measurement system represents the random error of the system, which can be quantified as the variation among repeated measurements.
- Repeatability – The repeatability of the measurement system is the variation in repeated measurements obtained by the same personnel using the same methods and equipment to measure the same characteristic of the same item. This is also referred to as the equipment variation, or E.V.
- Reproducibility - The reproducibility of the measurement system is the variation among measurements of the same characteristic of the same item obtained under differing conditions. The conditions that may vary include personnel, equipment, and environment.
- Consistency – Consistency is the degree of change in repeatability over time.
- Uncertainty – The uncertainty associated with a measurement is represented by the probability that the true value lies within a specified range derived from the measurement.

3.0 UNCERTAINTY IN THE PROPOSED RFE MEASUREMENT SYSTEM

The uncertainty associated with the RFE ratings that will be assigned to individual tire SKUs under the system proposed in the NPRM is evaluated in this section. The sources of this uncertainty are described and the total uncertainty associated with the RFE ratings is evaluated using a suitable data set. The consequences of uncertainty in the RFE ratings for decisions based on comparisons of these ratings are discussed in Section 4.

3.1 Sources of Uncertainty

The sources of uncertainty that apply to the process used to assign RFE ratings in the measurement system described in the NPRM are described and discussed in the following subsections.

3.1.1 Uncertainty Due to Measurement Repeatability

Some measurement-to-measurement variation is expected when the RRF value of a single tire is measured repeatedly, even if all of the measurements are made by the same laboratory personnel using the same method and test equipment. The NPRM states that "NHTSA analyzed the effect of repeating tests on the same tire and found that this had little to no effect on test results." This suggests that subjecting a single tire to repeated measurements does not affect the property (rolling resistance) being measured. Therefore, the measurement-to-measurement variation is expected to be random (not systematic, as it would be if there was a consistent upward or downward trend in the measured values).

The draft ISO 28580 standard addresses measurement-to-measurement variation in rolling resistance coefficient (RRC) values as *measurement reproducibility*, which is denoted in the standard by σ_m. Section 10.2 of the draft standard specifies that the reference laboratory must assure that σ_m (which is a function of the variation of repeated RRC measurements made on two reference tires on the same test equipment) is less than or equal to 0.05 newtons per kilonewton (N/kN) based on a minimum of three measurements on each tire.[2] Section 10.3 requires that candidate laboratories assure that the standard deviation for each of two reference tires ($\sigma_{m,i}$) is less than or equal to 0.075 N/kN based on a minimum of three measurements for each tire. Potential changes in repeatability over time (consistency) are addressed by requiring the laboratories to demonstrate that σ_m and $\sigma_{m,i}$ are within the specified limits on a monthly basis. The stability of the measurements (i.e., the potential change in bias over time) may be characterized by the data collected to demonstrate that the limits on σ_m and $\sigma_{m,i}$ (consistency) are met, but the draft ISO standard does not include limits for long-term stability.

The limits on repeatability included in the draft ISO standard can be used to derive limits for the standard deviation of repeated RRF measurements made on the same laboratory control tire. The actual numerical limit for RRF measurements depends on the maximum load for the control tire, but calculations with typical values indicate that the standard deviation of repeated RRF measurements will be less than one percent of the RRF value. Thus, the level of uncertainty in the RFE ratings to be assigned under the proposed system due to repeatability in the RRF measurement process over the short term is expected to be very small in tests conducted under ISO 28580 after the draft standard is adopted.

3.1.2 Uncertainty Due to Product Variation

Some item-to-item variation is expected when the RRF values of different tires with the same SKU are measured by the same laboratory personnel using the same method and test equipment.[3] The level of variation in RRF values obtained under these conditions can be evaluated using the data set compiled for the California Energy Commission (CEC) by a contract laboratory (Smithers Scientific Services, Inc.). The data set includes

[2] Page 29580 of the NPRM refers to the limit specified for the reference laboratory in ISO 28580 as “the machine variability specification under ISO 28580.”

[3] Page 29580 of the NPRM acknowledges that differences in manufacturing dates, batches of material, and manufacturing plants may cause differences in rolling resistance; but some level of product variation from one tire to another is inevitable even when the factors named in the NPRM are not different.

a single RRF measurement for each of five tires for each of 149 SKUs. The coefficients of variation[4] for the 149 SKUs tested for the CEC range from 0.21 percent to 10.4 percent
with an average of 1.94 percent. The serial numbers reported for these tires indicate that in almost all cases, all five tested tires for each SKU were produced in the same plant within a period of a few weeks. Therefore, these values may underestimate the level of variation in RRF that should be expected in the entire population of tires with a single SKU produced over a longer period (perhaps several years). Data sets produced recently by RMA members indicate that when many tires from the same SKU are tested over a longer time, the coefficient of variation for a typical SKU over the long term is likely to be about 2.5 percent (i.e., somewhat greater than the average value suggested by the CEC data set).

In assigning an RFE rating to a particular SKU, the level of uncertainty due to product variation is dependent on the number of available measurements that represent tires with that SKU. In general, the average of a number of measurements provides a more accurate estimate of the true value (i.e., the rolling resistance that is characteristic of the tires with that SKU) than a single measurement does. If all of the available measurements are independent and equally representative of the tires with that SKU, the uncertainty due to product variation can be determined for an average value computed for any number of measurements. The standard deviation of the average (i.e., the arithmetic mean) of the available measurements is inversely related to the square root of the number of measurements; as the number increases, the standard deviation of the average decreases.

[4] The coefficient of variation expresses the standard deviation of a group of measurements as a percentage (or proportion) of the average measurement. It is used in this report as a convenient index of variability because it is not affected by transforming measurements reported as RRF to RRC (or vice versa) and is independent of the units of measurement (pounds-force, newtons, etc.).

3.1.3 Uncertainty Due to Variation in Test Machines or Laboratories

Some variation in measurements is expected when the RRF value of a single tire is measured by the same method on different test equipment, either in the same or different laboratories. This variation is referred to most frequently in this report as lab-to-lab variation, although differences between test machines in the same laboratory are also a source of uncertainty. The level of variation in data sets produced by such testing could be estimated using data produced during development of the draft ISO 28580 standard. This estimate is not relevant, however, if the testing to support the tire fuel efficiency rating system is performed under ISO 28580 because this standard includes alignment procedures and calculations to reduce the uncertainty due to lab-to-lab variation. The information needed to calculate the residual variation due to differences between machines or laboratories that may still be present after the alignment process will not be available until the ISO standard is adopted and implemented. If the RRF measurement system used at each of the candidate laboratories behaves linearly (i.e., the bias of the system relative to the reference laboratory is constant over the range of interest) and is stable and consistent, the alignment procedure should account for a sizable portion of the lab-to-lab variation. In this case, the residual lab-to-lab variation is expected to be substantially lower than the unaligned lab-to-lab variation. Data generated during development of the alignment procedure in the draft ISO standard may be used to estimate the residual lab-to-lab variation, but the actual level of residual variation will not be known until the draft ISO 28580 standard is adopted and implemented,.

3.1.4 Uncertainty Due to Rounding in the RFE Rating Calculation

Under the system described in the NPRM, the RFE rating for each SKU will be calculated from an RRF value provided by the manufacturer. The calculation involves rounding to the nearest integer; as a result, the resolution of the RFE rating system will be lower than the potential resolution of the RRF measurements. On average, rounding to the nearest integer value will change the RFE rating by ±0.25, which is almost 2 percent of the lowest RFE rating for the 149 SKUs in the CEC data set (13) but less than 0.3 percent of the highest RFE rating for the SKUs in the CEC data set (87). Thus, the amount of uncertainty introduced by rounding the calculated RFE value to the nearest integer is much higher for tires with low RFE ratings than for tires with higher ratings.

3.2 Total Uncertainty in the RFE Measurement System

The reliability of the measurement system described in the NPRM is dependent on the uncertainty associated with the RFE ratings assigned by the system. This uncertainty is due to the combined effects of the sources described in the preceding section. The variability observed in any particular data set may be due to multiple sources. Consider the CEC data set, which contains RRF measurements from five tires for each of 149 SKUs. Assuming that all of the measurements were made on one test machine, the variation in the five RRF values for a particular SKU is due in part to repeatability and in part to product variation. Under general conditions, the uncertainty contributed by the relevant sources is additive, as shown schematically in Figure 1. Applying this principle to the CEC data set, the variation among the five RRF values for a particular SKU might be substantially lower if the same tire had been tested five times because there would be no uncertainty due to product variation. Similarly, the variation among the five RRF values for a particular SKU might be substantially higher if the five tests were performed on different tires and on different machines.

The total uncertainty of the RFE ratings that will be assigned by the proposed measurement system cannot currently be determined due to the absence of data sets that reflect the residual lab-to-lab variation that may remain after the alignment procedures described in the draft ISO 28580 standard are applied. The CEC data set can be used, however, to establish a lower bound on the total uncertainty of the RFE ratings. This data set includes uncertainty due to the first two sources (repeatability and product variation), and the uncertainty due to rounding in the RFE calculation can be added by applying the RFE formula to RRF values in the CEC data set. The uncertainty associated with the RFE ratings derived from the CEC data set provides a lower bound for the total uncertainty of the RFE ratings that will be assigned under the proposed system. The uncertainty due to residual lab-to-lab variation may be substantial; if so, the total uncertainty of the RFE ratings developed under the proposed system will be substantially greater than this lower bound estimate.

3.3 Uncertainty of RFE Ratings Derived from the CEC Data Set

As noted above, the data set collected for the CEC contains five RRF measurements for each of 149 tire SKUs. These measurements were made using a single-load version of the SAE J1269 standard (not the draft ISO standard), and the difference between RRF values obtained using these two standards has not been determined. For the following discussion, ENVIRON has assumed that the difference between the RRF values produced by the two standards is linear and that all of the measurements in the CEC data set were obtained on the same test equipment. Under these assumptions, the uncertainty associated with RFE ratings developed from single RRF measurements in the CEC data set should be somewhat lower than the uncertainty associated with RFE ratings developed under the proposed system, which will be subject to an additional source of uncertainty (residual lab-to-lab variation).

As stated in Section 2.4, the uncertainty associated with a measurement is represented by the probability that the true value lies within a specified range derived from the measurement. A common way of quantifying this uncertainty is by constructing a confidence interval. A confidence interval is a statement of the probability that an unknown value of interest lies within a range of values. When a confidence interval is constructed for the population mean (in this case, the average RFE value for all tires with a specific SKU), the range of values is often written as the average value of the available measurements plus or minus a specified amount (for example, 10 ± 1). The specified amount is determined by the number of available measurements and the desired probability (e.g., 95 percent). This calculation is usually based on statistical assumptions regarding the distribution of the population of possible measurements. Because the proposed system would assign an RFE rating to many SKUs on the basis of a single RRF measurement, confidence intervals based on the average of multiple measurements were not used to characterize the uncertainty associated with the RFE ratings.

The uncertainty associated with the RFE rating that would be assigned to each of the 149 SKUs represented in the CEC data set was assessed by deriving an RFE rating from each of the five available RRF measurements. The variation of the five resulting RFE values provides an estimate of the uncertainty of the single rating that would be assigned under the proposed system. The coefficients of variation (CVs) calculated from the five RRF measurements for each SKU in the CEC data set are provided in Table 1. When all 149 SKUs are considered, the CVs for the RRF values range from 0.21 percent to 10.4 percent and average 1.94 percent. The CVs for the RFE ratings range from zero (no variation) to 25.5 percent and average 2.55 percent. The difference between the CVs for the RRF values and the CVs for the RFE ratings is due to rounding in the RFE calculation. For SKUs that have very little variation in the RRF values, this rounding reduces the variation. In general, however, rounding increases the variation of the RFE ratings relative to the variation of the RRF values.

Another statistic provided in Table 1 is the average absolute error for each SKU. The error for each of the five RFE ratings based on a single measurement was computed as the difference between the single-measurement RFE and the RFE rating derived for the average RRF. Some of these errors are positive and some are negative; the five errors available for each SKU would average to zero if the values were not rounded. The average absolute error is computed by treating all of the errors as positive values. As shown in Table 1, the average absolute errors for the 149 SKUs range from zero to 7.4, and 40 SKUs have average absolute errors greater than 1. In addition, 71 of the 149 SKUs have at least one absolute error of 2 or greater and 14 have an absolute error of 4 or more.

3.4 Implications of the Uncertainty Analysis of the CEC Data Set

The statistics in Table 1 demonstrate that the RFE ratings that would be assigned under the proposed measurement system are subject to substantial uncertainty. The 100-point scale implies a level of discrimination that cannot be provided by a single RRF measurement for each SKU. Errors of 3 points or more were found in the RFE ratings assigned to more than 20 percent (34 of 149) of the SKUs in the CEC data set. Under the proposed system, ratings must be assigned to thousands of SKUs. Thus, the statistics reported in Table 1 indicate that errors of at least 3 points should be expected in the RFE ratings assigned to many SKUs.

One way of reducing the uncertainty in the RFE ratings is to use multiple RRF measurements. The CV of RRF values computed as the average of four independent measurements is half as large as the CV of the individual measurements, and the CV of the RFE ratings would be reduced by a similar amount. The number of SKUs to be tested is very large and testing is expensive[5] and time-consuming, so the RFE ratings must be based on test data obtained from a relatively small number of tires.

A better way to reduce the number and extent of errors in the RFE ratings assigned to individual SKUs is to reduce the number of distinct categories. The 100-point scale RFE establishes a system of intervals (or bins) to which the SKUs are assigned. Because the range of RRF values covered by the scale is 20 pounds-force (lbf), each unit on the scale represents an interval of 0.2 lbf. Use of a scale with fewer, larger intervals (e.g., 10 intervals of 2.0 lbf) would greatly reduce the frequency and magnitude of errors in assigning RFE ratings to the thousands of tire SKUs.

[5] The cost estimates provided in the NPRM are based on one RRF measurement per SKU at a cost of approximately $180 per measurement.

4.0 CONSEQUENCES OF UNCERTAINTY IN THE PROPOSED RFE MEASUREMENT SYSTEM

Uncertainty is associated with all measurement systems, but the importance of the uncertainty is largely determined by the way in which the measurements are used. Under the system proposed in the NPRM, RFE ratings derived from RRF measurements performed under the ISO 28580 standard would be used by consumers to choose more fuel efficient replacement tires. For most consumers, this use will involve comparisons of the RFE ratings assigned to various SKUs within a narrow size range.[6] The NPRM also suggests that NHTSA may use the RRF data for compliance testing; this use would involve comparisons between RRF measurements made on different tires with the same SKU, most likely in different laboratories. The tire manufacturers will use RRF data from ISO 28580 tests to assign RFE ratings to each SKU. The RRF data may also be used by tire manufacturers for quality control or research and development purposes, or jointly by tire manufacturers and auto manufacturers to establish contract requirements and criteria for acceptance.

4.1 Resolution of the Proposed RFE Measurement System

As demonstrated in Section 3.3, the RFE ratings assigned on the basis of a single RRF measurement will be subject to error. The uncertainty analysis suggests that the RFE ratings assigned to many SKUs will be in error by more than one point; the use of a 100-point scale for this rating suggests a level of discrimination that will not be achieved. The CV values summarized in Table 1 for the 149 SKUs included in the CEC data set indicate that the minimum difference in fuel efficiency that can be reliably detected by the proposed measurement system is much greater than one. This problem can be addressed by using a much smaller number of rating values, as in the system proposed for the EU (seven categories, A to G).

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[6] In preparing this report, ENVIRON has assumed that a typical consumer purchasing replacement tires for a particular car will consider both P-metric and Euro-metric tires with the tire dimensions (section width, aspect ratio, and rim diameter) recommended by the car's manufacturer.

4.2 Analysis of Consumer Choice under the Proposed RFE Measurement System

An analysis was conducted to evaluate the consequences of uncertainty in the proposed RFE rating system for consumers and the public. This analysis was performed using the CEC data set, which contains five RRF measurements for each of 77 different SKUs in the (P)195/65R15 size group and 45 different SKUs in the (P)265/70R17 size group.[7] In this analysis, the sensitivity of the ranking (order) of the SKUs by their RFE ratings to uncertainty in the RRF measurements was evaluated. The steps in this analysis were as follows:

- The average RRF value and the RFE rating based on this average RRF value were calculated using the five available measurements for each SKU in each size group.
- The average RRF values and RFE ratings for the SKUs in each size group were ranked from low (rank 1) to high for the average RRF and from high (rank 1) to low for the average RFE. Thus, lower ranks indicate greater fuel efficiency in the rankings for both variables. The average of the five RRF values is the best available estimate of the true RRF value for each SKU, so the ranking based on these averages is considered to be correct in this discussion.
- The change in ranking of each SKU relative to others in the same size group due to substitution of each of the five RRF measurements was evaluated for one SKU at a time. For each SKU, the average RRF value was replaced by each of the individual RRF measurements in turn. After each replacement, the "new" RRF value and the corresponding RFE rating were ranked in relation to the averages for the other SKUs in the same size group. The changes in RRF and RFE rank due to each replacement were recorded.
- The changes in RRF rank and RFE rank for all of the SKUs in each size group were tabulated and analyzed. Summary statistics for these changes in ranking are

[7] The "(P)" used in these size descriptions indicates that both P-metric and Euro-metric tire sizes are included in these size groups.

provided in Table 2A for the (P)195/65R15 tires and Table 2B for the (P)265/70R17 tires. The variations in rank for each SKU in each size group are illustrated in Figures 2A and 2B.

The change in rank due to variation in the RRF value selected to represent a particular SKU is important because it indicates a likely error in the decision process. If a consumer wishes to select the most fuel efficient tire available for his car at a particular retailer, he will choose by comparing the RFE ratings. If the RFE ratings do not correctly reflect the order of the true (unknown) RRF values for the SKUs he is considering, the errors in the RFE ratings may lead him to choose a tire that is actually less fuel efficient. The greater the change in the RFE rankings, the more likely it is that this error will occur.

The changes in rank represent the number of SKUs that would erroneously be placed higher or lower in the ranking than the particular SKU being evaluated. As shown in Table 2, the changes in rank for the 77 (P)195/65R15 SKUs range from -23 to +29. A change of -23 indicates that assigning an erroneous RFE rating based on a single RRF measurement to one SKU has caused that SKU to be ranked below 23 SKUs that are actually less fuel efficient than the SKU with the erroneous RFE rating. The change of +29 indicates that a similar error would cause another SKU to be ranked higher than 29 other SKUs that are actually more fuel efficient. These changes in rank can also be expressed as a percentage of the SKUs tested in each size group. For example, the changes of -23 and +29 would correspond to about 30 percent and 38 percent of the 77 SKUs in the (P)195/65R15 size group, respectively. Similarly, the changes in rank for the 45 (P)265/70R17 SKUs range from -20 to +15. A change of -20 corresponds to about 44 percent and a change of +15 corresponds to about 33 percent of the 45 SKUs in this size group. These high percentages indicate that under the proposed system, the likelihood of error in trying to select the most fuel efficient tire within a specific size group will be quite high.

4.3 Consequences for Consumers and the Public

The quantitative analysis described in Section 4.2 demonstrates that the proposed RFE rating system is not reliable; an SKU with a high RFE rating may or may not be more fuel efficient than another SKU of the same size. As a result, consumers who want to purchase more fuel efficient tires will not have confidence in the ratings. Some consumers who pick tires based on the RFE ratings will get tires that are actually *less* fuel efficient. This reduces the fuel economy benefits to the individual and to the general public, and leads to skepticism regarding validity and usefulness of the ratings.

One remedy for this problem would be to advise consumers to consider differences in RFE rating of less than a certain amount (five, for example) as not meaningful. This approach would compensate for the fact that the resolution of the RFE measurement system is substantially greater than one. The likelihood that a consumer who selects replacement tires based on fuel efficiency actually gets more efficient tires would be much higher. This would increase the fuel savings realized by the individual consumer and the general public. As shown in Table 2, the correct RFE ratings for the 77 (P)195/65R15 SKUs range from 63 to 87. The corresponding range for the 45 (P)265/70R17 SKUs is 13 to 57. These values indicate that a consumer who wants to buy tires for a particular vehicle is likely to have a selection that covers only a portion of the full range of potential RFE ratings. Using a minimum difference in RFE of 5 as an indicator of meaningful differences in fuel economy would divide the range for the (P)195/65R15 size group into at least five bins and the range for the (P)265/70R17 size group into at least nine bins.

4.4 Consequences for Tire Manufacturers

The NPRM will require the tire manufacturers to conduct additional testing and labeling to ensure compliance with the tire fuel efficiency regulations. The NPRM states (page 29580) “For the fuel efficiency rating, the agency is proposing a tolerance for compliance purposes of plus and minus (±) 5.5 percent of the rating set by the manufacturer.” The NPRM further explains that compliance will be evaluated using RRF measurements (not

RFE ratings). The manufacturer will be required to submit the RRF value and RFE rating for each SKU to NHTSA. For compliance purposes, NHTSA may test any rated tire; if the rolling resistance test value falls outside of the specified tolerance range, "the agency will consider that rating a noncompliance."

The consequences of the proposed compliance standard cannot be precisely determined by quantitative analysis at this time. The NPRM (page 29580) identifies a number of factors that may contribute variability to the compliance testing program ("machine-to-machine tests, lab-to-lab tests, different manufacturing dates, different batches of material, and possibly different manufacturing plants") and notes "The agency does not have sufficient data to comprehensively establish tolerances considering these factors." While the effects of these factors cannot be determined precisely, these factors are all expected to increase the level of variation between tests conducted by the manufacturer for the purpose of assigning an RFE rating and tests conducted by NHTSA to determine whether the manufacturer is in compliance.

Assuming that all of the testing was done on one machine, the serial numbers provided for the tested tires indicate that the CEC data set is largely unaffected by the factors named in the NPRM. Therefore, the frequency of noncompliance in the CEC data set may provide a lower bound on the frequency to be expected if the proposed system is promulgated. ENVIRON calculated the percent difference in value between each pair of RRF measurements for each of the 149 SKUs in the CEC data set. Because there are five RRF measurements per SKU, there are ten pairs of RRF measurements to be considered for each SKU. Forty two of the 149 SKUs have at least one pair with a difference greater than 5.5 percent of the mean, and in total, more than nine percent (135 of 1,490) of the pairs have a difference greater than 5.5 percent of the mean. These statistics indicate that the rate of noncompliance may be substantially higher than suggested by the NPRM, which indicates that the tolerance was set at ±5.5 percent with the expectation that 95 percent of the compliance tests would meet this criterion. The NPRM does not explain the benefit of setting a tolerance that is expected to result in a finding of noncompliance in five percent of the tests, but analysis of the CEC data set indicates that the actual failure rate will be much higher than five percent.

One way of addressing the excessive failure rate that should be expected if the compliance system described in the NPRM is promulgated is to apply a one-sided tolerance limit rather than a two-sided tolerance band. Because the draft ISO 28580 standard has not yet been adopted and the number of test machines is limited, it will be very difficult for tire manufacturers to develop RFE ratings for all of their SKUs in a short time without estimating the RRF values for some tires. In addition, the analysis provided in this report indicates that a single test will not be sufficient to ensure that the RRF value for every SKU is within the proposed tolerance band. If the tolerance is specified as an upper limit, however, the tire manufacturers will be able to add a margin of safety to the RRF values used to calculate the RFE ratings for SKUs that have not been tested sufficiently to establish compliance. The proposed upper limit could be expressed as a percentage of the RRF value. For example, an upper limit of 5.5 percent would mean that to be in compliance, the RRF value of any tire tested for compliance purposes must be no more than 5.5 percent greater than the RRF value used by the manufacturer to assign the RFE rating. This would reduce the likelihood of noncompliance. Competition will provide an incentive to assign the highest possible RFE rating, but the manufacturers will have more control over their risk of noncompliance.

5.0 ANALYSIS OF AN ALTERNATIVE RATING SYSTEM

The RMA has developed and evaluated an alternative rolling resistance rating system for tires passenger car tires. This system is described in documents filed with the CEC, which are available in the California docket and at the web site listed in the NPRM.[8] The system proposed by the RMA assigns each tire SKU to one of five categories (also referred to as "bins") using RRC as the index of rolling resistance. The system described in the NPRM assigns each tire SKU to one of 100 categories using RRF as the index of rolling resistance. Thus the two most important differences between the two systems are in the index of rolling resistance (RRC or RRF) and the number of bins.

To allow a consumer to select the more fuel efficient of any two tires that fit his vehicle, the fuel efficiency rating system must place the appropriate tires in the proper order. In many cases, the available data may not be sufficient to reliably determine which of the tires is more fuel efficient; in these cases, the tires should be assigned to the same bin. The ability of the system proposed by RMA to rate tires in the proper order without suggesting differences in fuel economy that may not be real or significant is discussed below.

5.1 Comparison of RRC and RRF

The primary reason for using RRC to assign the SKUs to fuel efficiency bins is because consumers are more likely to select less efficient tires if the ratings are based on RRF instead of RRC. This point was illustrated in a presentation that described the RMA's proposed rating system at the CEC Workshop on April 8, 2009.[9] As shown in that presentation, the RRC value for a specific tire is nearly constant over a wide range of tire loads while RRF is a nearly linear function of load. The rolling resistance force (RRF)

8 http://www.energy.ca.gov/transportation/tire_efficiency/documents/index.html

9 This presentation was made by Tim Robinson of Bridgestone and can be downloaded from the CEC web site named above.

increases as the load on the tire increases; this is why the test load must be specified along with the RRF. The relationship between RRF and load is not restricted to test conditions; RRF also increases as a function of load when the tire is used on a vehicle.

Because it is nearly constant over a wide load range, RRC is a better predictor than RRF of the relative fuel efficiency of two tires that might be used on the same vehicle. This is illustrated by examples on slides 10 through 14 of the RMA presentation. In each example, the RRF of a smaller tire is lower (better) than the RRF of a larger tire because the two tires have been tested and rated at different loads. In fact, at any single load over the range of interest, the RRF of the smaller tire will be higher (worse) than the RRF of the larger tire. Thus, comparison of RFE ratings based on RRF values may lead the consumer to select a tire that will be less fuel efficient on his particular vehicle than another tire with a lower RFE rating.

Additional diagrams that illustrate this point are provided as Figures 3 and 4 in this report. Figure 3 compares the rolling resistance characteristics of two (P)195/65R15 tires. One tire is P-metric and has a load index of 89; the other is Euro-metric and has a slightly higher load index of 91. Based on tests conducted at 70 percent of the maximum load, the RRF values reported for these two tires are equal (9.96 lbf for each). The test load for the Euro-metric tire is higher, so this tire has a lower RRC value. More importantly, this tire also has a lower RRF value at a vehicle load of 1,000 pounds. Both tires would have an RFE rating of 75 under the system described in the NPRM, but the Euro-metric tire would certainly be more fuel efficient when mounted on a vehicle. In this example, the RFE ratings would not provide a basis for choosing the more efficient tire and some potential fuel savings would not be realized.

The example shown in Figure 4 compares the fuel efficiency of two (P)265/70R17 tires. Again, one tire is P-metric (load index 113); the other is Euro-metric and has a slightly higher load index (115). Based on tests conducted at 70 percent of the maximum load, the P-metric tire has a slightly lower RRF value (18.69) and a slightly higher RFE rating

(32). As in the previous example, however, the Euro-metric tire has a lower RRC value and a lower RRF value at a vehicle load appropriate for the tire size (2,000 pounds). In this example, the RFE ratings would lead a consumer to buy the P-metric tire, which would be less fuel efficient than the other tire when mounted on the same vehicle. Again, some potential fuel savings would not be realized.

Simply put, ratings based on RRF may not provide a reliable ranking of the fuel efficiency of various tires on a particular vehicle. This finding is relevant because each vehicle manufacturer determines the appropriate tire characteristics (size, pressure, load index, and speed rating) for each of his products after considering the vehicle's gross vehicle weight rating (GVWR) and other factors such as ride and handling, tire wear, pass-by noise, and fuel economy. For many vehicles, the manufacturer offers a number of rim diameters and tire sizes as options. In addition, many consumers and some tire retailers may ignore the difference between P-metric and Euro-metric tires of the same size. A consumer seeking to purchase replacement tires for a particular vehicle is likely to consider a number of size options, especially if he believes that switching tire sizes will provide substantial benefits. The consumer information programs for safety (traction), durability (tread wear), and fuel efficiency described in the NPRM are likely to increase the tendency of consumers to consider tire sizes other than the size supplied as original equipment by the vehicle manufacturer. In these circumstances, the fuel efficiency rating system should allow reliable comparisons among tires within a range of sizes.

There are other reasons for basing the tire fuel efficiency rating system on RRC instead of RRF. One reason is that the draft ISO standard is based on RRC and provides rolling resistance measurements in terms of RRC. The laboratory alignment procedures and data quality requirements of this standard are based on RRC data, and RRC will be used in the EU fuel efficiency rating system. Another reason is that use of fuel efficiency ratings based on RRF may lead some consumers to purchase smaller tires, which may cause safety problems. RRF is proportional to load, and smaller tires (with lower load index values) are tested at lower loads and tend to have lower RRF values. Consumers attempting to maximize their fuel economy may be tempted to buy tires that are too small to safely support the load of their vehicles.

5.2 Number and Size of Rating Bins

The number of possible ratings is directly related to the reliability of the fuel efficiency rating system. The reliability of a rating system can be evaluated by considering its ability to rate tires in the proper order without suggesting differences in fuel economy that may not be real or significant. The NPRM describes a rating system with 100 bins; although they are presented as point values, each RFE rating actually represents a range of possible RRF values. Rounding the RFE value calculated by the equation provided on page 29563 of the NPRM assigns each SKU to a bin identified by the integer RFE rating. As explained in previous sections of this report, the bins established by the proposed system are substantially smaller than the resolution of the RRF measurements that will be used to assign the ratings. As a result, many SKUs may be assigned to the wrong bin. The statistics presented in Table 1 indicate that errors of at least 3 points should be expected in the RFE ratings assigned to many SKUs under the rating system described in the NPRM.

The likelihood of error in assigning an SKU to the proper bin based on an RRC value is determined by the accuracy of the RRC value relative to the size of the bins. If the available data provide an accurate estimate of the true mean RRC for all tires in the SKU and the bins are large, the likelihood of error is small. Alternately, if the RRC value is not an accurate estimate and the bins are relatively small, the likelihood of error is large. The accuracy of the RRC value as an estimate of the mean for the SKU can be determined from multiple measurements and expressed as a confidence interval. Table 3 provides 95 percent confidence intervals for the mean RRC of all 149 SKUs in the CEC data set, which includes five measurements per SKU. The half-widths of these intervals range from 0.03 to 1.29 kN/N. If the rating bins proposed in the NPRM are converted for use with RRC values, each RFE rating interval represents an RRC range of approximately 0.081 kN/N. If the half-width of the confidence interval for the mean RRC is small (e.g., 0.03 kN/N) relative to the bin size (0.081 kN/N), the likelihood of assigning the SKU to the correct bin is relatively high; but if the half-width of the confidence interval is much higher (e.g., 1.29 kN/N) the likelihood is very low. The same principles apply if the bins are based on RRF values instead of RRC values, but the numbers are different. Table 3 also provides confidence intervals for the RRF values for the 149 SKUs in the CEC data set. The half-widths of the 95 percent confidence intervals for the mean RRF range from 0.03 to 2.29 pounds and the bin width for the proposed rating system based on RRF is just 0.2 pounds.

These comparisons demonstrate that the likelihood of error in assigning SKUs to fuel efficiency rating bins is very high when the bins are small relative to the uncertainty associated with the mean rolling resistance values. The consequences of such errors are discussed in Section 4 of this report. The likelihood of incurring these consequences can be reduced by using a smaller number of larger bins.

The rating system proposed by the RMA uses five bins with a width of 1.5 kN/N. Although the width is greater than the maximum half-width shown for the mean RRC in Table 3, there is still a meaningful possibility of error with this system, especially if the ratings are assigned on the basis of a single measurement per SKU. The likelihood of error for a specific SKU is determined in part by how close its average RRC is to one of the values that define the bins (7.5, 9.0, 10.5, and 12.0 kN/N in the system proposed by the RMA). An SKU with an average RRC value of 7.6 is more likely to be misclassified than an SKU with an average RRC of 8.25 kN/N. The relationship between the average RRC and the likelihood of misclassification is illustrated in Figure 5 for classification based on 1 measurement and on the average of 5 measurements per SKU. If only one measurement is available, the likelihood of error is considerably higher over most of the bin width.

The NPRM anticipates that approximately 20,000 SKUs will be assigned ratings. Because the number of SKUs is so large, some errors are inevitable. The likelihood of error is increased unnecessarily, however, when the bin size is much smaller than the resolution of the measurement system.

6.0 SUMMARY OF FINDINGS

The primary findings of this report include the following:

- The automotive industry has a well-developed procedure for analysis of measurement systems. This procedure should be applied to the classification of passenger car tires on the basis of fuel efficiency.
- There are four primary sources of uncertainty associated with the RFE measurement system described in the NPRM. These sources are: repeatability, product variation, lab-to-lab variation, and rounding. The levels of uncertainty due to repeatability and lab-to-lab variation are expected to change after ISO standard 28580 is adopted and implemented. At present, the level of residual lab-to-lab variation cannot be accurately predicted.
- The available data obtained from tests of multiple tires representing the same SKUs suggest that the coefficient of variation of RRF measurements for a typical product is about 2 percent, although some products are more variable.
- The resolution of the measurement system described in the NPRM is substantially greater than the RFE bin size. This will lead to misclassification and improper ranking of many SKUs.
- Because of misclassification and improper ranking, many consumers will not select the most fuel efficient tire for their vehicle. This will reduce fuel savings and other benefits that would otherwise be realized by the consumer and the general public.
- If the compliance program described in the NPRM is promulgated with a 5.5 percent tolerance, the frequency of noncompliance may be much higher than suggested by the NPRM. Use of a one-sided tolerance limit (rather than a two-sided tolerance band) would allow tire manufacturers to better control the likelihood of noncompliance without removing the incentive for manufacturers to assign high ratings to their fuel efficient tires.

- The fuel efficiency rating system should be based on RRC, not RRF, because rankings based on RRF may lead many consumers to purchase a less efficient tire. Tires selected based on RRF may also be less safe.
- The accuracy with which fuel efficiency ratings can be assigned to tire SKUs depends on the accuracy of the rolling resistance measurements and the number and size of the rating bins. The NPRM anticipates a single measurement per SKU; for many SKUs, the resulting rolling resistance measurement will not provide an accurate estimate of the mean value for all tires in the SKU. The solution to this problem is to use fewer, larger rating bins.
- The RMA has developed and proposed a system based on classification into five bins based on RRC. Adoption of such a system will mitigate the problems and negative consequences that should be expected if the system described in the NPRM is promulgated.

TABLES

TABLE 1

Variation of RRF Values and RFE Ratings in the CEC Data Set

CEC Group ID	average RRF	minimum RRF	maximum RRF	CV% for RRF	minimum RFE	maximum RFE	CV% for RFE	average absolute error in RFE	maximum absolute error in RFE
195-01	11.06	10.53	11.39	3.82	68	72	3.15	2	2
195-02	8.12	8.02	8.17	0.74	84	85	0.53	0.2	1
195-03	8.35	8	8.63	3.15	82	85	1.57	1	2
195-04	7.61	7.52	7.72	1.11	86	87	0.52	0.2	1
195-05	8.67	8.62	8.74	0.55	81	82	0.55	0.2	1
195-06	8.56	8.2	9.1	4.48	80	84	2.00	1.4	2
195-07	8.85	8.42	9.73	5.74	76	83	3.35	1.6	5
195-08	12.02	11.7	12.25	1.82	64	67	1.88	0.8	2
195-09	10.95	10.87	11.11	0.89	69	71	1.19	0.6	1
195-10	8.73	8.56	9.04	2.12	80	82	1.03	0.6	1
195-11	9.45	9.41	9.55	0.58	77	78	0.57	0.2	1
195-12	11.64	11.48	11.73	0.88	66	68	1.06	0.4	1
195-13	9.92	9.78	10.02	0.91	75	76	0.73	0.4	1
195-14	8.45	8.15	8.76	3.23	81	84	1.84	1.2	2
195-15	8.30	8.25	8.32	0.37	83	84	0.66	0.6	1
195-16	10.57	10.48	10.65	0.71	72	73	0.62	0.2	1
195-17	9.27	9.17	9.37	0.79	78	79	0.57	0.2	1
195-18	10.37	10.29	10.42	0.56	73	74	0.61	0.2	1
195-19	10.39	9.35	11.02	6.41	70	78	4.33	2.4	5
195-20	10.95	10.47	11.56	3.75	67	73	3.25	1.8	3
195-21	12.44	12.21	12.71	2.02	61	64	2.42	1.2	2
195-22	11.74	11.58	11.92	1.05	65	67	1.26	0.6	1
195-23	9.27	8.98	9.46	2.44	78	80	1.39	1	1
195-24	10.89	10.72	11.05	1.13	70	71	0.78	0.6	1
195-25	10.15	9.68	10.85	4.31	71	77	2.94	1.6	3
195-26	10.29	10.11	10.48	1.35	73	74	0.74	0.4	1
195-27	9.89	9.73	10.01	1.06	75	76	0.73	0.6	1
195-28	9.24	9.1	9.4	1.18	78	80	0.90	0.4	1
195-29	10.35	9.61	10.82	4.70	71	77	3.42	2	4
195-30	8.53	8.46	8.61	0.71	82	83	0.66	0.4	1
195-31	9.28	8.88	9.53	2.97	77	81	2.09	1.4	2
195-32	9.44	9.24	9.72	2.08	76	79	1.68	1	2
195-33	9.89	9.83	9.96	0.52	75	76	0.72	0.4	1
195-34	8.52	8.27	8.85	2.67	81	84	1.38	1	2
195-35	9.83	9.65	10.03	1.92	75	77	1.32	0.8	1
195-36	10.32	10.07	10.55	1.75	72	75	1.55	0.8	2
195-37	10.35	9.49	11.02	6.06	70	78	4.36	2.6	5
195-38	10.43	10.4	10.46	0.21	73	73	0.00	0	0
195-39	11.16	10.87	11.53	2.17	67	71	2.14	1	2
195-41	9.11	8.68	9.32	2.75	78	82	1.91	0.8	3
195-42	10.11	9.74	10.31	2.23	73	76	1.48	0.6	2
195-43	9.59	8.69	10.41	8.63	73	82	5.75	3.8	5
195-44	9.82	9.76	9.93	0.74	75	76	0.59	0.2	1
195-45	8.73	8.51	8.91	1.92	80	82	1.03	0.6	1
195-46	10.25	10.19	10.36	0.69	73	74	0.61	0.2	1
195-47	11.09	11.01	11.17	0.68	69	70	0.79	0.4	1
195-48	9.87	9.79	10	0.92	75	76	0.72	0.4	1
195-49	10.15	10	10.43	1.63	73	75	1.20	0.8	1
195-50	9.59	9.37	9.74	1.47	76	78	0.92	0.4	1
195-51	9.05	8.79	9.44	2.64	78	81	1.37	0.6	2
195-52	8.38	8.19	8.74	2.64	81	84	1.48	0.8	2
195-53	7.90	7.8	8.04	1.49	85	86	0.64	0.6	1
195-54	8.88	8.71	9.1	1.82	80	81	0.68	0.4	1
195-55	9.49	9.37	9.79	1.84	76	78	1.15	0.4	2
195-56	9.68	9.47	9.93	1.92	75	78	1.49	0.8	2
195-57	10.00	9.64	10.55	4.79	72	77	3.31	2.2	3
195-58	9.02	8.98	9.08	0.45	80	80	0.00	0	0
195-59	10.96	10.72	11.17	1.76	69	71	1.43	0.8	1
195-60	8.48	8.42	8.51	0.45	82	83	0.66	0.4	1
195-61	9.82	9.67	9.98	1.25	75	77	0.93	0.4	1
195-62	8.78	8.66	8.93	1.31	80	82	1.03	0.6	1
195-63	11.88	11.68	12.02	1.06	65	67	1.36	0.8	1
195-64	9.77	9.5	10.14	2.38	74	78	1.95	1	2
195-65	7.77	7.72	7.85	0.61	86	86	0.00	0	0
195-66	10.57	10.53	10.64	0.46	72	72	0.00	0	0
195-67	9.79	9.45	10.01	2.43	75	78	1.71	1	2
195-68	8.68	8.49	8.83	1.57	81	83	1.10	0.8	1
195-69	9.89	9.83	9.95	0.50	75	76	0.72	0.4	1
195-70	9.97	9.76	10.18	1.62	74	76	1.11	0.6	1
195-71	9.02	8.96	9.11	0.68	79	80	0.56	0.2	1
195-72	9.48	9.39	9.59	0.81	77	78	0.71	0.4	1
195-73	9.96	9.83	10.12	1.30	74	76	1.11	0.6	1
195-74	9.46	9.42	9.51	0.35	77	78	0.57	0.2	1
195-75	9.06	8.8	9.18	1.68	79	81	1.05	0.6	1
195-76	10.15	10.12	10.18	0.30	74	74	0.00	0	0
195-77	8.74	8.61	8.89	1.35	81	82	0.67	0.4	1
265-01	14.96	14.75	15.25	1.30	49	51	1.77	0.8	1
265-03	16.28	16.11	16.45	0.95	43	44	1.26	0.4	1
265-04	19.90	19.24	20.53	2.56	22	29	10.64	2	4
265-05	19.27	18.86	19.72	1.62	26	31	6.35	1.2	3
265-06	13.65	13.33	13.87	1.56	56	58	1.47	0.6	1

TABLE 1 Variation of RRF Values and RFE Ratings in the CEC Data Set									
CEC Group ID	average RRF	minimum RRF	maximum RRF	CV% for RRF	minimum RFE	maximum RFE	CV% for RFE	average absolute error in RFE	maximum absolute error in RFE
265-07	16.98	16.85	17.15	0.66	39	41	1.77	0.4	1
265-08	16.79	16.49	17.01	1.36	40	43	3.16	1	2
265-09	16.12	15.87	16.31	1.17	43	46	2.57	0.8	2
265-10	16.08	15.74	16.37	1.40	43	46	2.56	0.8	2
265-11	13.67	13.35	14.03	2.28	55	58	2.89	1.4	2
265-12	19.82	19.65	19.91	0.55	25	27	2.72	0.4	1
265-13	18.86	17.92	19.62	3.29	27	35	9.41	2	4
265-14	21.98	21.49	22.23	1.41	14	18	11.77	1.4	3
265-15	15.23	14.92	15.47	1.40	48	50	1.71	0.6	1
265-16	16.43	16.02	16.67	1.54	42	45	3.05	1	2
265-17	14.10	13.87	14.27	1.14	54	56	1.53	0.6	1
265-18	18.86	18.47	19.25	1.50	29	33	4.82	1	2
265-19	16.41	16.14	16.64	1.22	42	44	1.94	0.6	1
265-20	17.12	16.85	17.43	1.33	38	41	2.88	1	2
265-22	22.41	21.85	22.84	1.97	11	16	16.42	1.8	3
265-23	18.24	18.05	18.47	0.93	33	35	2.48	0.6	1
265-24	19.65	19.23	20.48	2.64	23	29	9.44	2	4
265-25	18.14	18.02	18.28	0.59	34	35	1.59	0.4	1
265-26	13.66	13.39	13.83	1.29	56	58	1.58	0.8	1
265-27	17.07	16.76	17.27	1.21	39	41	2.10	0.6	1
265-28	17.76	16.2	20.63	10.40	22	44	25.50	7.4	14
265-29	19.30	18.97	19.59	1.26	27	30	4.01	0.8	2
265-30	16.41	16.22	16.55	0.74	42	44	1.64	0.4	1
265-31	19.74	19.42	20	1.31	25	28	4.98	1	2
265-32	19.11	18.76	19.69	1.86	27	31	5.16	1.2	2
265-33	18.51	18.08	18.86	1.59	31	35	4.65	1	3
265-34	17.16	16.72	17.4	1.67	38	41	3.63	1.2	2
265-35	19.36	18.86	20.78	4.15	21	31	14.49	3	7
265-36	19.08	18.79	19.43	1.22	28	31	3.85	0.8	2
265-37	15.99	15.43	16.24	1.99	44	48	3.34	0.8	3
265-38	16.63	16.3	17.46	2.83	38	44	5.58	1.6	4
265-40	17.11	16.97	17.28	0.66	39	40	1.39	0.4	1
265-41	16.93	16.63	17.22	1.42	39	42	3.32	1.2	2
265-42	18.69	18.36	18.97	1.41	30	33	4.27	1	2
265-43	18.76	18.45	19.3	1.87	29	33	5.30	1.4	2
265-44	18.68	18.58	18.81	0.45	31	32	1.41	0.2	1
265-45	18.15	17.6	18.75	2.73	31	37	7.58	2	3
265-46	20.11	19.96	20.32	0.74	23	25	3.67	0.8	1
265-47	16.93	16.54	17.26	1.60	39	42	2.82	0.8	2
265-48	18.34	17.66	18.93	2.69	30	37	8.36	2.2	4
SIS-01	10.65	10.51	10.82	1.14	71	72	0.76	0.4	1
SIS-02	10.77	10.23	11.09	3.14	70	74	2.34	1.2	3
SIS-03	11.49	11.17	11.91	2.72	65	69	2.48	1.2	3
SIS-04	8.66	8.58	8.73	0.77	81	82	0.67	0.4	1
SIS-05	9.47	9.33	9.59	1.00	77	78	0.71	0.4	1
SIS-06	10.50	10.29	10.68	1.35	72	74	1.15	0.6	1
SIS-07	12.54	12	13.02	2.96	60	65	2.91	1.2	3
SIS-08	11.56	11.39	11.68	0.94	67	68	0.67	0.2	1
SIS-09	14.11	13.94	14.4	1.36	53	55	1.64	0.8	1
SIS-10	9.86	9.53	10.5	4.04	73	77	2.36	1.4	3
SIS-11	8.37	8.26	8.5	1.07	83	84	0.54	0.2	1
SIS-12	10.01	9.47	10.95	5.70	70	78	4.00	2	5
SIS-13	9.98	9.65	10.2	2.03	74	77	1.46	0.6	2
SIS-14	11.14	10.75	11.74	3.37	66	71	2.71	1.2	3
SIS-15	10.21	10.08	10.47	1.55	73	75	0.96	0.4	1
SIS-16	10.61	10.52	10.7	0.64	72	72	0.00	0	0
SIS-17	8.91	8.42	9.15	3.28	79	83	2.05	1	3
SIS-18	8.33	8.12	8.55	2.03	82	84	1.01	0.6	1
SIS-19	10.19	9.65	10.53	3.34	72	77	2.53	1.2	3
SIS-20	14.55	14.02	15.1	2.64	50	55	3.47	1.2	3
SIS-21	10.16	10.04	10.26	0.85	74	75	0.60	0.2	1
SIS-22	10.53	10.28	10.83	2.16	71	74	1.57	0.8	2
SIS-23	11.46	11.17	11.69	1.88	67	69	1.62	1	1
SIS-24	9.63	9.58	9.67	0.35	77	77	0.00	0	0
SIS-25	13.24	12.3	13.92	6.51	55	64	7.77	4	5
SIS-26	11.41	10.88	11.69	2.75	67	71	2.41	1	3
SIS-27	11.19	10.61	11.87	4.72	66	72	3.69	2	3
SIS-28	11.87	11.62	12.14	1.79	64	67	2.05	1.2	2

TABLE 2A

**Changes in Rank for RFE Ratings in the CEC Data Set:
77 (P)195/65R15 SKUs**

Group ID	average RRF Value	rank for average RRF	RFE Rating for average RRF	rank of RFE Rating for average RRF	maximum negative change in rank	maximum positive change in rank	average absolute change in rank
195-01	11.064	70	70	67	-5	4	4.6
195-02	8.122	4	84	4	0	2	0.4
195-03	8.346	6	83	6	-4	4	3
195-04	7.61	1	87	1	-1	0	0.2
195-05	8.674	13	82	10	-5	0	1
195-06	8.56	12	82	10	-11	7	6.6
195-07	8.852	19	81	15	-23	10	7.8
195-08	12.022	76	65	76	0	4	0.8
195-09	10.952	67	70	67	-5	2	1.8
195-10	8.732	15	81	15	-6	6	3.6
195-11	9.454	31	78	30	-5	0	1
195-12	11.644	73	67	73	-1	2	0.6
195-13	9.922	47	75	47	0	10	4
195-14	8.452	8	83	6	-9	3	4.8
195-15	8.296	5	84	4	-2	0	1.2
195-16	10.566	64	72	64	0	7	1.4
195-17	9.266	27	79	25	-5	0	1
195-18	10.37	61	73	58	0	8	1.6
195-19	10.392	62	73	58	-9	29	12
195-20	10.952	67	70	67	-6	10	5
195-21	12.438	77	63	77	0	2	0.8
195-22	11.738	74	66	74	-2	2	1.2
195-23	9.274	28	79	25	-5	5	5
195-24	10.89	66	71	66	-1	0	0.6
195-25	10.146	52	74	51	-15	17	8.4
195-26	10.286	57	74	51	-7	0	2.8
195-27	9.892	45	76	38	-9	0	5.4
195-28	9.24	26	79	25	-5	5	2
195-29	10.352	60	73	58	-8	24	11.2
195-30	8.534	11	82	10	0	5	2
195-31	9.276	29	79	25	-10	11	7.2
195-32	9.444	30	78	30	-8	6	5
195-33	9.89	44	76	38	-9	0	3.6
195-34	8.518	10	82	10	-5	7	4.4
195-35	9.826	42	76	38	-9	4	5.2
195-36	10.324	58	73	58	-6	12	5.2
195-37	10.35	59	73	58	-9	29	13.2
195-38	10.426	63	73	58	0	0	0
195-39	11.162	72	69	72	-1	7	2.8
195-41	9.108	25	79	25	-5	16	4.2
195-42	10.114	51	74	51	-7	14	4.2
195-43	9.586	35	77	35	-23	26	20.6
195-44	9.824	41	76	38	-9	0	1.8
195-45	8.732	15	81	15	-6	6	3.6
195-46	10.254	56	74	51	-7	0	1.4
195-47	11.094	71	70	67	-5	0	2
195-48	9.874	43	76	38	-9	0	3.6
195-49	10.15	53	74	51	-7	5	4.4
195-50	9.594	36	77	35	-3	6	1.8
195-51	9.05	23	80	21	-9	7	3.2
195-52	8.38	7	83	6	-9	3	3
195-53	7.902	3	85	3	0	2	1.2
195-54	8.882	20	81	15	-6	0	2.4
195-55	9.486	34	78	30	-8	0	1.6
195-56	9.68	37	77	35	-12	6	4.2
195-57	9.996	50	75	47	-17	13	13.4
195-58	9.024	22	80	21	0	0	0
195-59	10.964	69	70	67	-5	2	2.8
195-60	8.478	9	83	6	-4	0	1.6
195-61	9.816	40	76	38	-9	4	2.6
195-62	8.782	18	81	15	-6	6	3.6
195-63	11.878	75	66	74	-2	2	1.6
195-64	9.766	38	76	38	-13	9	5.2
195-65	7.774	2	86	2	0	0	0
195-66	10.574	65	72	64	0	0	0
195-67	9.792	39	76	38	-9	9	6.2
195-68	8.682	14	82	10	-5	5	4
195-69	9.894	46	76	38	-9	0	3.6
195-70	9.966	49	75	47	-4	10	4.8
195-71	9.018	21	80	21	-4	0	0.8
195-72	9.482	33	78	30	-5	0	2
195-73	9.964	48	75	47	-4	10	4.8
195-74	9.462	32	78	30	-5	0	1
195-75	9.056	24	80	21	-4	7	3
195-76	10.152	54	74	51	0	0	0
195-77	8.738	17	81	15	0	6	2.4
SIS-21	10.16	55	74	51	0	5	1

TABLE 2B Changes in Rank for RFE Ratings in the CEC Data Set: 45 (P)265/70R17 SKUs							
Group ID	**average RRF Value**	**rank for average RRF**	**RFE Rating for average RRF**	**rank of RFE Rating for average RRF**	**maximum negative change in rank**	**maximum positive change in rank**	**average absolute change in rank**
265-06	13.652	1	57	1	-2	1	1
265-26	13.656	2	57	1	-2	1	1.4
265-11	13.666	3	57	1	-3	1	1.8
265-17	14.096	4	55	4	0	2	0.4
265-01	14.964	5	50	5	-1	2	1.4
265-15	15.234	6	49	6	0	2	0.4
265-37	15.986	7	45	7	-2	2	0.8
265-10	16.078	8	45	7	-4	2	1.6
265-09	16.124	9	44	9	-2	4	1.8
265-03	16.282	10	44	9	-2	0	0.8
265-19	16.408	11	43	11	-3	3	1.8
265-30	16.414	12	43	11	-3	3	1.2
265-16	16.434	13	43	11	-3	5	2.8
265-38	16.634	14	42	14	-8	6	4.4
265-08	16.786	15	41	15	-1	5	1.8
265-41	16.926	16	40	16	-4	3	3
265-47	16.934	17	40	16	-4	3	1.8
265-07	16.984	18	40	16	-4	2	1.2
265-27	17.068	19	40	16	-4	2	2
265-40	17.114	20	39	20	0	5	2
265-20	17.12	21	39	20	-2	6	3.6
265-34	17.164	22	39	20	-2	6	3.4
265-28	17.762	23	36	23	-20	15	12.2
265-25	18.138	24	34	24	0	2	0.8
265-45	18.154	25	34	24	-7	3	3.2
265-23	18.242	26	34	24	-3	2	1.6
265-48	18.342	27	33	27	-7	6	4
265-33	18.514	28	32	28	-3	6	2.2
265-44	18.68	29	32	28	-3	0	0.6
265-42	18.69	30	32	28	-6	2	2.8
265-43	18.756	31	31	31	-4	5	3.6
265-18	18.856	32	31	31	-4	5	2.4
265-13	18.862	33	31	31	-8	9	4.6
265-36	19.08	34	30	34	-3	4	1.6
265-32	19.112	35	29	35	-4	5	2.6
265-05	19.266	36	29	35	-5	5	2.4
265-29	19.302	37	28	37	-2	4	1.8
265-35	19.36	38	28	37	-6	7	4.8
265-24	19.654	39	27	39	-4	5	3.6
265-31	19.744	40	26	40	-2	4	2
265-12	19.818	41	26	40	-2	2	0.8
265-04	19.902	42	25	42	-1	8	2.8
265-46	20.112	43	24	43	0	2	1.2
265-14	21.98	44	15	44	0	2	0.8
265-22	22.408	45	13	45	0	3	1

TABLE 3 Confidence Intervals for CEC Tire Test Data						
Group ID	**average RRC based on 5 replicates**	**standard deviation of RRC based on 5 replicates**	**half-width of 95% confidence interval on mean RRC based on 5 replicates**	**average RRF based on 5 replicates**	**standard deviation of RRF based on 5 replicates**	**half-width of 95% confidence interval on mean RRF based on 5 replicates**
195-01	12.36	0.472	0.59	11.06	0.423	0.52
195-02	9.07	0.067	0.08	8.12	0.060	0.07
195-03	9.32	0.293	0.36	8.35	0.263	0.33
195-04	8.50	0.094	0.12	7.61	0.084	0.10
195-05	9.69	0.053	0.07	8.67	0.048	0.06
195-06	9.56	0.428	0.53	8.56	0.383	0.48
195-07	9.89	0.568	0.71	8.85	0.508	0.63
195-08	13.43	0.244	0.30	12.02	0.219	0.27
195-09	12.23	0.108	0.13	10.95	0.097	0.12
195-10	9.75	0.207	0.26	8.73	0.185	0.23
195-11	10.56	0.061	0.08	9.45	0.055	0.07
195-12	13.01	0.114	0.14	11.64	0.102	0.13
195-13	11.08	0.101	0.13	9.92	0.091	0.11
195-14	9.44	0.305	0.38	8.45	0.273	0.34
195-15	8.74	0.032	0.04	8.30	0.030	0.04
195-16	11.80	0.084	0.10	10.57	0.075	0.09
195-17	9.70	0.076	0.09	9.27	0.073	0.09
195-18	11.58	0.065	0.08	10.37	0.058	0.07
195-19	11.61	0.744	0.92	10.39	0.666	0.83
195-20	12.23	0.459	0.57	10.95	0.411	0.51
195-21	13.89	0.280	0.35	12.44	0.251	0.31
195-22	13.11	0.138	0.17	11.74	0.123	0.15
195-23	10.36	0.253	0.31	9.27	0.227	0.28
195-24	12.16	0.138	0.17	10.89	0.123	0.15
195-25	10.69	0.461	0.57	10.15	0.438	0.54
195-26	10.84	0.146	0.18	10.29	0.139	0.17
195-27	10.42	0.111	0.14	9.89	0.105	0.13
195-28	10.32	0.122	0.15	9.24	0.109	0.14
195-29	10.91	0.512	0.64	10.35	0.486	0.60
195-30	9.53	0.067	0.08	8.53	0.060	0.07
195-31	10.36	0.308	0.38	9.28	0.275	0.34
195-32	10.55	0.219	0.27	9.44	0.196	0.24
195-33	11.05	0.057	0.07	9.89	0.051	0.06
195-34	9.51	0.254	0.32	8.52	0.227	0.28
195-35	10.98	0.211	0.26	9.83	0.189	0.23
195-36	10.88	0.190	0.24	10.32	0.180	0.22
195-37	11.56	0.700	0.87	10.35	0.627	0.78
195-38	10.98	0.023	0.03	10.43	0.022	0.03
195-39	11.76	0.255	0.32	11.16	0.242	0.30
195-41	9.60	0.264	0.33	9.11	0.251	0.31
195-42	11.30	0.252	0.31	10.11	0.225	0.28
195-43	10.10	0.871	1.08	9.59	0.827	1.03
195-44	10.97	0.082	0.10	9.82	0.073	0.09
195-45	9.75	0.187	0.23	8.73	0.167	0.21
195-46	10.80	0.075	0.09	10.25	0.071	0.09
195-47	11.69	0.079	0.10	11.09	0.075	0.09
195-48	11.03	0.102	0.13	9.87	0.091	0.11
195-49	11.34	0.185	0.23	10.15	0.165	0.21
195-50	10.11	0.148	0.18	9.59	0.141	0.17
195-51	9.53	0.252	0.31	9.05	0.239	0.30
195-52	8.83	0.233	0.29	8.38	0.221	0.27
195-53	8.83	0.131	0.16	7.90	0.118	0.15
195-54	9.92	0.181	0.22	8.88	0.162	0.20
195-55	10.60	0.195	0.24	9.49	0.174	0.22
195-56	10.81	0.208	0.26	9.68	0.186	0.23
195-57	11.16	0.535	0.66	10.00	0.479	0.59
195-58	10.08	0.045	0.06	9.02	0.040	0.05
195-59	11.55	0.203	0.25	10.96	0.193	0.24
195-60	9.47	0.043	0.05	8.48	0.038	0.05
195-61	10.96	0.137	0.17	9.82	0.123	0.15
195-62	9.81	0.129	0.16	8.78	0.115	0.14
195-63	12.51	0.133	0.17	11.88	0.126	0.16
195-64	10.91	0.260	0.32	9.77	0.232	0.29
195-65	8.19	0.050	0.06	7.77	0.048	0.06
195-66	11.81	0.054	0.07	10.57	0.048	0.06
195-67	10.32	0.250	0.31	9.79	0.238	0.30
195-68	9.70	0.153	0.19	8.68	0.137	0.17
195-69	10.42	0.052	0.06	9.89	0.049	0.06
195-70	10.50	0.170	0.21	9.97	0.162	0.20
195-71	10.07	0.069	0.09	9.02	0.061	0.08
195-72	10.59	0.086	0.11	9.48	0.077	0.10
195-73	11.13	0.144	0.18	9.96	0.129	0.16
195-74	10.57	0.037	0.05	9.46	0.033	0.04
195-75	10.12	0.170	0.21	9.06	0.152	0.19
195-76	10.70	0.032	0.04	10.15	0.030	0.04
195-77	9.21	0.125	0.15	8.74	0.118	0.15
265-01	8.43	0.110	0.14	14.96	0.194	0.24
265-03	9.18	0.087	0.11	16.28	0.154	0.19
265-04	11.22	0.287	0.36	19.90	0.509	0.63

TABLE 3

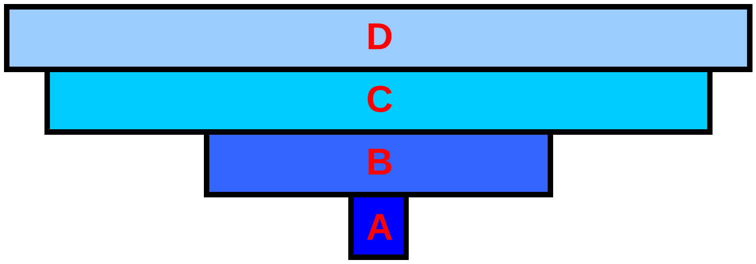
Confidence Intervals for CEC Tire Test Data

Group ID	average RRC based on 5 replicates	standard deviation of RRC based on 5 replicates	half-width of 95% confidence interval on mean RRC based on 5 replicates	average RRF based on 5 replicates	standard deviation of RRF based on 5 replicates	half-width of 95% confidence interval on mean RRF based on 5 replicates
265-05	10.86	0.176	0.22	19.27	0.312	0.39
265-06	7.69	0.120	0.15	13.65	0.213	0.27
265-07	9.57	0.063	0.08	16.98	0.112	0.14
265-08	9.46	0.129	0.16	16.79	0.228	0.28
265-09	9.09	0.106	0.13	16.12	0.189	0.23
265-10	9.06	0.127	0.16	16.08	0.225	0.28
265-11	7.70	0.175	0.22	13.67	0.311	0.39
265-12	11.17	0.061	0.08	19.82	0.109	0.14
265-13	10.63	0.349	0.43	18.86	0.620	0.77
265-14	12.39	0.174	0.22	21.98	0.309	0.38
265-15	8.58	0.121	0.15	15.23	0.214	0.27
265-16	9.26	0.143	0.18	16.43	0.254	0.31
265-17	7.94	0.090	0.11	14.10	0.160	0.20
265-18	10.63	0.159	0.20	18.86	0.282	0.35
265-19	9.25	0.113	0.14	16.41	0.200	0.25
265-20	9.65	0.128	0.16	17.12	0.227	0.28
265-22	12.63	0.249	0.31	22.41	0.442	0.55
265-23	10.28	0.095	0.12	18.24	0.169	0.21
265-24	11.08	0.292	0.36	19.65	0.518	0.64
265-25	10.22	0.060	0.07	18.14	0.107	0.13
265-26	7.70	0.100	0.12	13.66	0.177	0.22
265-27	9.62	0.117	0.14	17.07	0.207	0.26
265-28	10.01	1.041	1.29	17.76	1.848	2.29
265-29	10.88	0.137	0.17	19.30	0.243	0.30
265-30	9.25	0.069	0.09	16.41	0.122	0.15
265-31	11.13	0.146	0.18	19.74	0.259	0.32
265-32	10.77	0.200	0.25	19.11	0.355	0.44
265-33	10.43	0.166	0.21	18.51	0.295	0.37
265-34	9.67	0.162	0.20	17.16	0.287	0.36
265-35	10.91	0.453	0.56	19.36	0.803	1.00
265-36	10.75	0.132	0.16	19.08	0.234	0.29
265-37	8.52	0.170	0.21	15.99	0.318	0.39
265-38	9.37	0.265	0.33	16.63	0.471	0.58
265-40	9.64	0.064	0.08	17.11	0.113	0.14
265-41	9.54	0.136	0.17	16.93	0.241	0.30
265-42	10.53	0.149	0.18	18.69	0.264	0.33
265-43	10.00	0.187	0.23	18.76	0.350	0.43
265-44	9.96	0.045	0.06	18.68	0.084	0.10
265-45	10.23	0.279	0.35	18.15	0.495	0.61
265-46	11.33	0.084	0.10	20.11	0.148	0.18
265-47	9.54	0.153	0.19	16.93	0.272	0.34
265-48	10.34	0.278	0.34	18.34	0.493	0.61
SIS-01	10.30	0.117	0.15	10.65	0.121	0.15
SIS-02	10.19	0.320	0.40	10.77	0.338	0.42
SIS-03	10.79	0.293	0.36	11.49	0.312	0.39
SIS-04	10.49	0.081	0.10	8.66	0.067	0.08
SIS-05	12.28	0.123	0.15	9.47	0.094	0.12
SIS-06	11.53	0.156	0.19	10.50	0.142	0.18
SIS-07	10.28	0.304	0.38	12.54	0.371	0.46
SIS-08	10.63	0.100	0.12	11.56	0.108	0.13
SIS-09	10.76	0.147	0.18	14.11	0.193	0.24
SIS-10	12.06	0.488	0.61	9.86	0.399	0.50
SIS-11	12.47	0.133	0.17	8.37	0.089	0.11
SIS-12	11.58	0.660	0.82	10.01	0.570	0.71
SIS-13	11.06	0.225	0.28	9.98	0.203	0.25
SIS-14	11.75	0.396	0.49	11.14	0.376	0.47
SIS-15	10.42	0.161	0.20	10.21	0.158	0.20
SIS-16	10.11	0.065	0.08	10.61	0.068	0.08
SIS-17	12.15	0.399	0.50	8.91	0.292	0.36
SIS-18	11.48	0.233	0.29	8.33	0.169	0.21
SIS-19	12.46	0.416	0.52	10.19	0.340	0.42
SIS-20	10.25	0.270	0.34	14.55	0.384	0.48
SIS-21	11.35	0.096	0.12	10.16	0.086	0.11
SIS-22	10.75	0.232	0.29	10.53	0.228	0.28
SIS-23	10.17	0.191	0.24	11.46	0.215	0.27
SIS-24	12.87	0.045	0.06	9.63	0.034	0.04
SIS-25	11.37	0.741	0.92	13.24	0.863	1.07
SIS-26	10.20	0.280	0.35	11.41	0.314	0.39
SIS-27	9.87	0.466	0.58	11.19	0.528	0.66
SIS-28	11.07	0.198	0.25	11.87	0.212	0.26

FIGURES

FIGURE 1

Sources of Uncertainty in RFE Ratings



Level	added source of uncertainty
D	rounding error
C	lab-to-lab variation
B	product variation
A	measurement repeatability

FIGURE 2A
Variation in RFE Ranks for 77 (P)195/65R15 SKUs
(Five RRF Measurements per SKU)

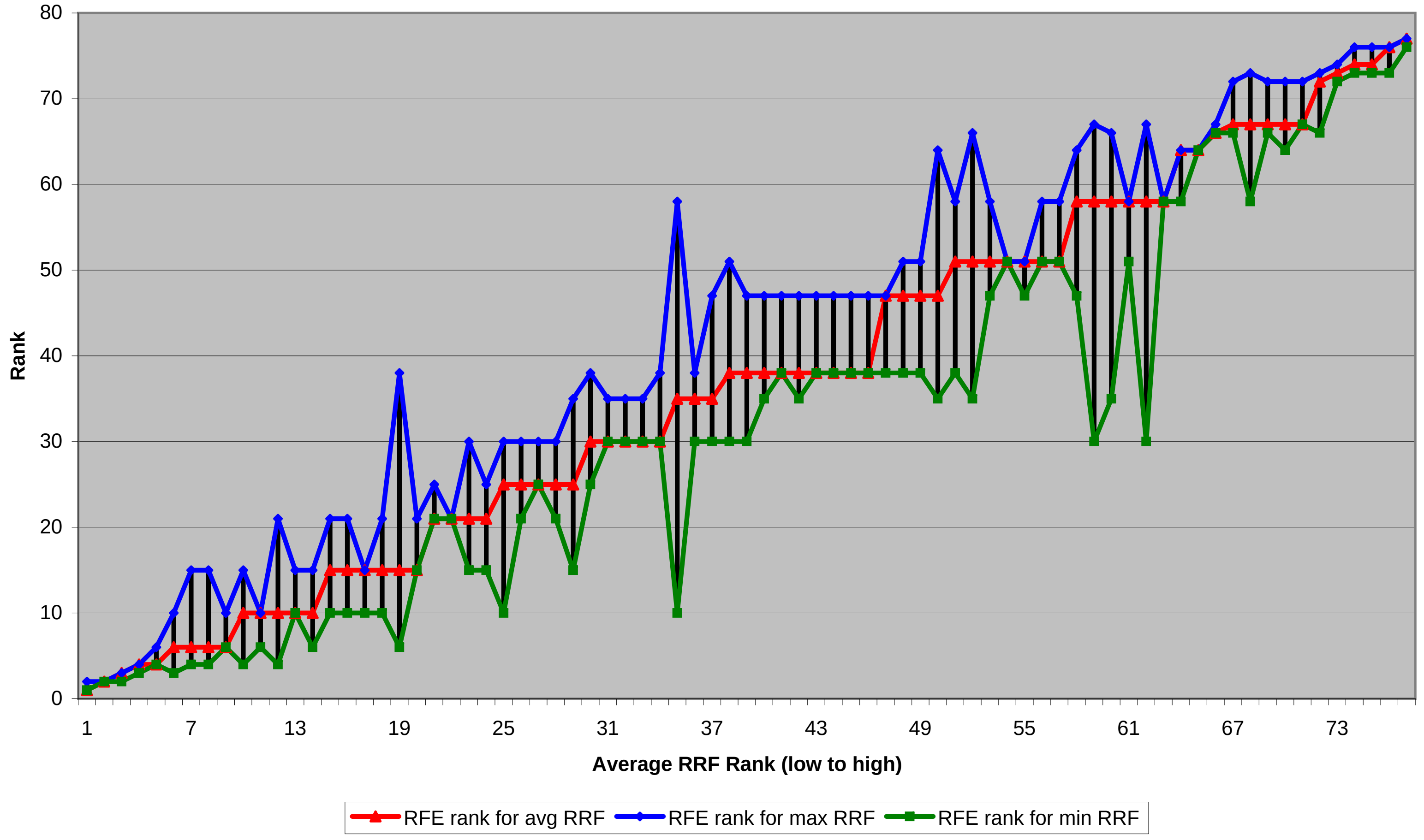


FIGURE 2B
Variation in RFE Ranks for 45 (P)265/70R17 SKUs
(Five RRF Measurements per SKU)

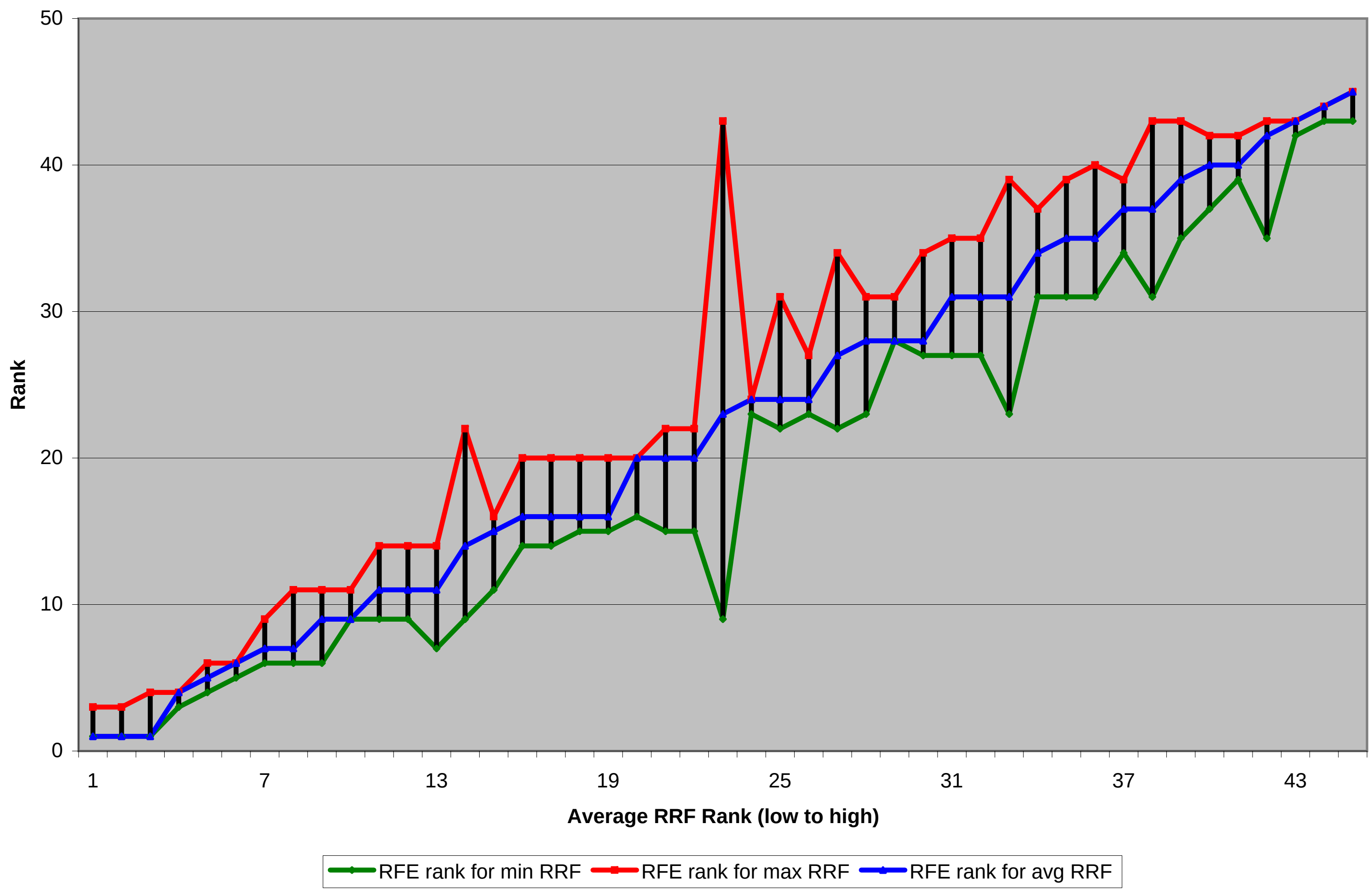
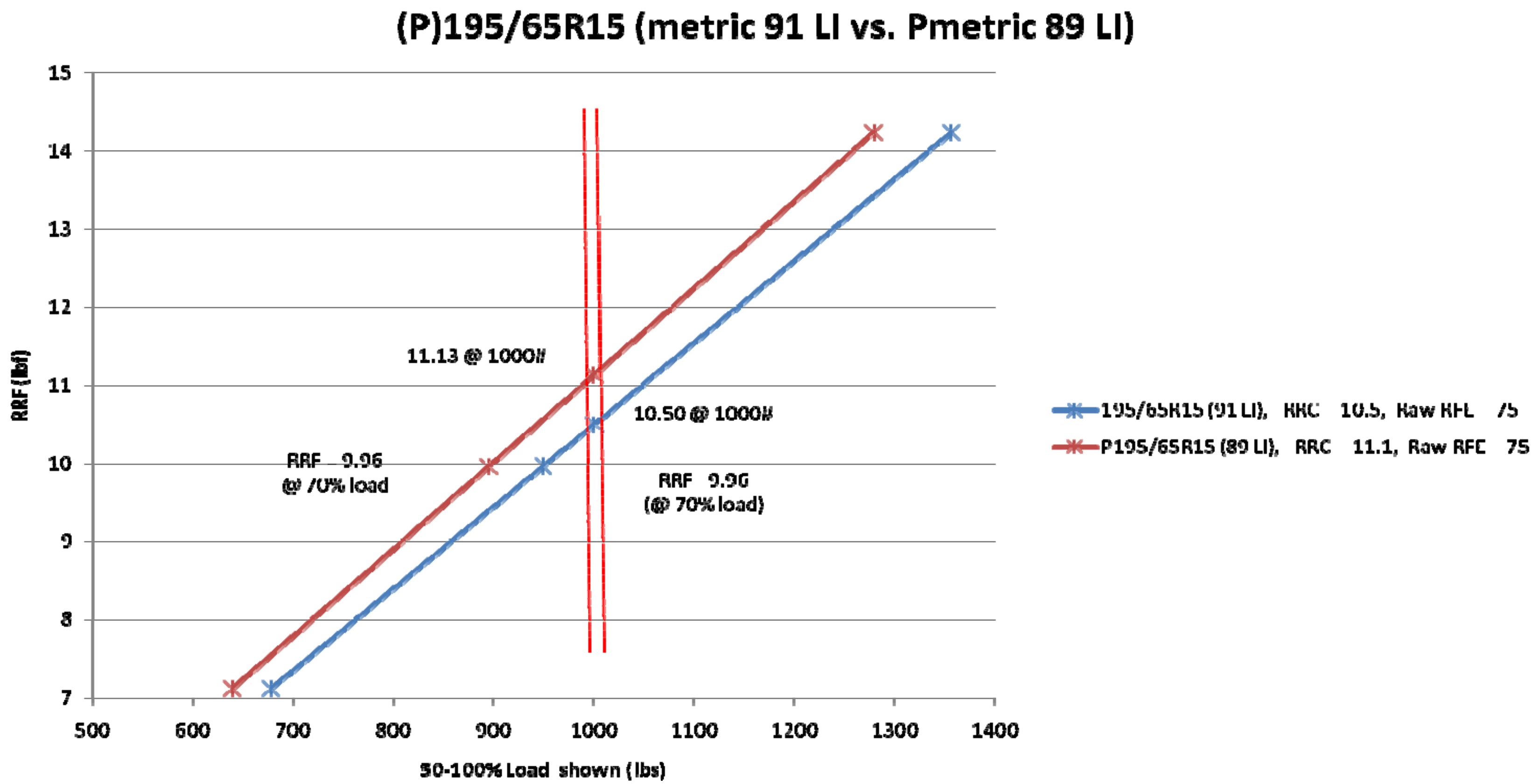


FIGURE 3

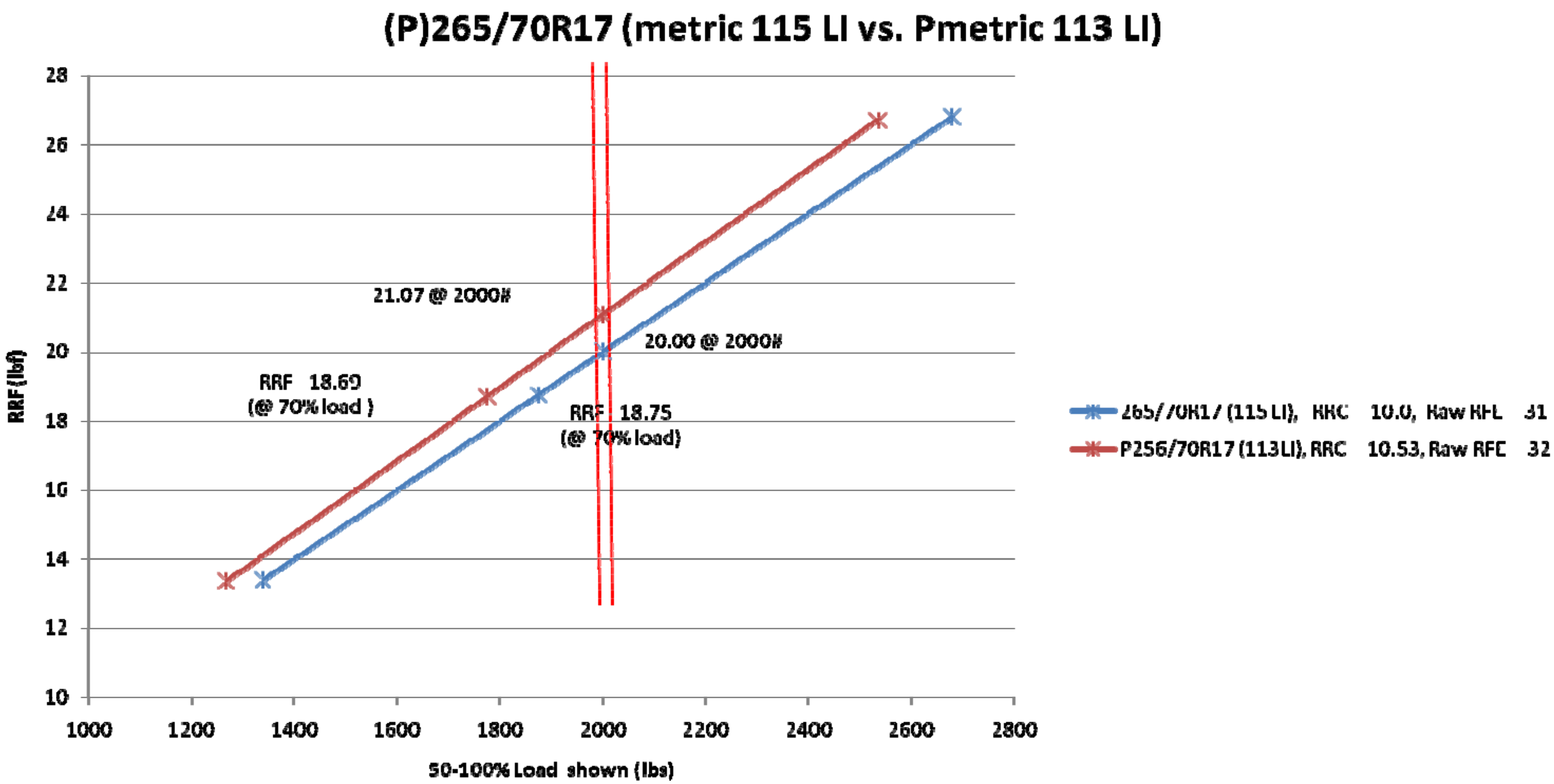
Ratings by RRF and by RRC



size	Load Index	RRC	RRF (70%), lbf	RFE rating	RRF at 1000 lb
195/65R15	91	10.50	9.96	75	10.50
P195/65R15	89	11.13	9.96	75	11.13

FIGURE 4

Ratings by RRF and by RRC



size	Load Index	RRC	RRF (70%), lbf	RFE rating	RRF at 2000 lb
265/70R17	115	10.00	18.75	31	20.00
P265/70R17	113	10.53	18.69	32	21.07

FIGURE 5
Probability of Error in Bin Assignment as a Function of Mean RRC Value