The Effects of Gasoline Sulfur Level on Emissions from Tier 2 Vehicles in the In-Use Fleet

Appendix D
Discussion of Univariate and Multivariate Analysis of Variance

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NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments.

Appendix D. Discussion of univariate and multivariate analysis of variance

The univariate analysis of variance (ANOVA) uses the ordinary least squares to test the fixed effects. It requires equal time spacing of measurements, and assumes compound symmetry of covariance structure of equal variance and covariance across mileage. The assumptions made for ANOVA are not true for emission measurements in the current dataset and thus, it may use incorrect standard errors for the comparison of means at different mileages resulting in Type I error of rejecting the null hypothesis when it is true.[i,ii]

The multivariate analysis of variance (MANOVA) also uses ordinary least squares to test the fixed effects. It assumes an unstructured covariance structure, and may result in less powerful test by wasting information inherent in repeated measures data.[iii] Furthermore, it requires regularly spaced time intervals for all vehicles which were not the case in the "sulfur level" data where emissions were measured at different accumulated mileages. The actual mileage accumulated varied from vehicle to vehicle for several reasons. The most obvious is the modification to the L procedure during the test program, where evenly spaced mileage intervals occurring in emission tests were replaced with an alternating mix of on-road and test cell driving. Besides this, major adjustment differences also exist due to voided tests, long weekends or holidays necessitating additional re-preps prior to testing, and occasional errors in recording of odometer readings.

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[i] Littell, R.C., Henry, R.C., & Ammerman, C.B. (1998). Statistical analysis of repeated measures data using SAS procedures. *J. Anim. Sci.* 76:1216–1231.

[ii] Templeman, R.J., Douglass, L.W. & Craig, B.A. (2002). NCR-170 FASS Mixed Model Workshop 2002 ADSA-ASASCSAS National meetings, Quebec City, QC. 24–25.

[iii] SAS Institute, Inc. (2002). SAS course notes on Mixed Model Analysis Using SAS System. SAS Institute, Inc., Cary, NC.