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CRC E-56 Study Response for USEPA

Prepared for:

U.S. Environmental Protection Agency

February 2005

This material is in response to concerns expressed by the USEPA about our remote sensing technology's ability to measure particulate mass for the heavy duty trucks that will be monitored at the Nogales, Arizona border crossing. The CRC E-56 study report and a follow-up analysis by Bob Slott have been cited as confirming the inadequacy of the technology.

Comments are provided in a bullet format.

1. The E-56 study was performed in February 2001; hence, does not reflect advances over the last 4 years.
2. The Desert Research equipment tested consisted of two separate instruments (one of our RSD3000's to measure CO_2 and the UV Lorax Backscatter instrument to measure particulate matter) that were loosely tied together to deliver a fuel specific measurement. The Denver University FEAT unit had been recently modified to include a HeNe visible light channel, but was found to be noisy. DU also had UV opacity, but they were not using the best available UV source for low noise results. What is more, DU had not refined their measurement algorithms to operate in dense smoke situations. This resulted in much data loss for a technology assessment (DU did not have many large smoke readings because their algorithms rejected those conditions).
3. Nevertheless, based on the data obtained from the tests, Bob Slott concluded that the technology could, at best, distinguish between 2.5-grams/ kg and 4.0-grams/kg.
4. These values correspond approximately to RSD4000 instrument smoke factor values of 0.25 and 0.40. The typical smoke factor noise for our instrument is 0.05, which means we can distinguish a 0 reading from 0.05 (i.e. 0 from 0.5 gram/kg). This is many times better than the results of the E-56 testing.
5. The E-56 study was conducted on light-duty vehicles rather than the heavy-duty vehicles that will be measured at Nogales. There will be much more exhaust to sample from these vehicles than there was from the light-duty vehicles tested in the E-56 study. Basic error analysis for remote sensing technology indicates that the larger the plume size, the smaller the measurement error in general.
6. There is a fairly large body of evidence that shows that the advanced RSD4000 UV Smoke Factor measurement is a sound reliable measurement that has precision and clearly identifies "smoking vehicles" (Attachment 1 contains excerpts from various reports).
7. However, there has been no credible study performed that correlates (proves the theory) that our reported number Smoke Factor is approximately (grams-particulate/kg-fuel)/10. For this reason, I completely agree with the importance of trying to obtain this information at the Riverside Test Facility using the West Virginia University mobile heavy-duty test lab in the near future. To this end Dana Lowell (M. J. Bradley and Assoc.) and Gary Full are visiting the Riverside test facility on 10-Feb-05 in order to establish a testing protocol to obtain this information. If all goes well, we will be conducting some correlation testing the following week.

Attachment 1

"Excerpts from various studies and reports concerning Smoke Factor"

Virginia Remote Sensing Device Study Addendum – Vehicle Opacity, February 2003 **(full report available at http://www.deq.virginia.gov/air/pdf/air/opacityAdd.pdf)**

The Virginia Report Figures 3-3 and 3-5 indicate that RSD 4000 smoke opacity readings can discriminate very small differences between vehicles and between fuel types.

Figure 3-3 is very comparable to the equivalent data from British Columbia (see later) comparing RSD 4000 readings to the British Columbia I/M readings. The diesel fleet becomes more and more smoking on average as the vehicles get older, and even the oldest fleet average is only about 0.4 opacity units. The gasoline fleet is almost smoke free when new and their average smoke readings increase only slowly with increasing age, always remaining below the diesels. Even more impressive is the apparent impact of the Virginia I/M program on observed smoke opacity readings of gasoline-powered vehicles. Figure 3-5 shows that as older and older model years are observed on-road there is a steadily increasing difference in smoke factor between the lower smoke from the I/M fleet and the higher smoke from the non-I/M fleet. Furthermore, these statistically significant differences are on the order of 0.01 RSD 4000 opacity units. This impressive discrimination cannot be the result of chance or of instrument noise because the model year determination and the fuel determination are totally independent of the smoke opacity readings.

Figure 3-3 Average Smoke Emissions by Model Year

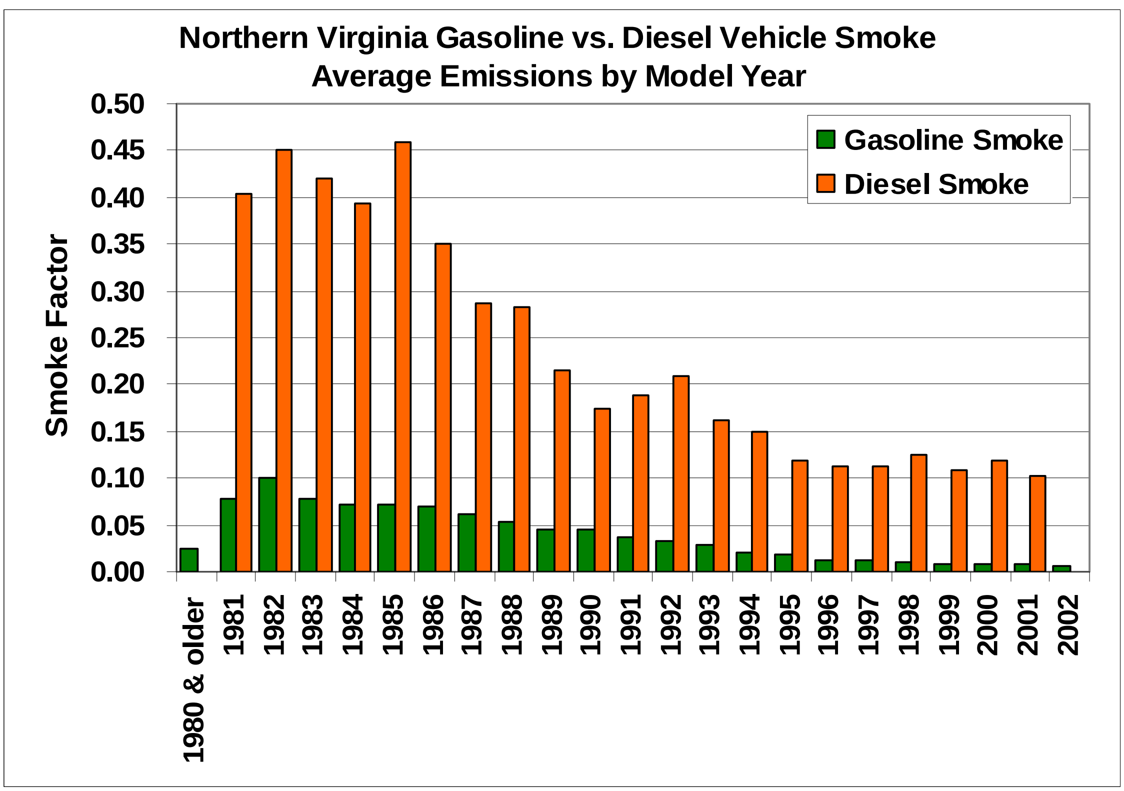
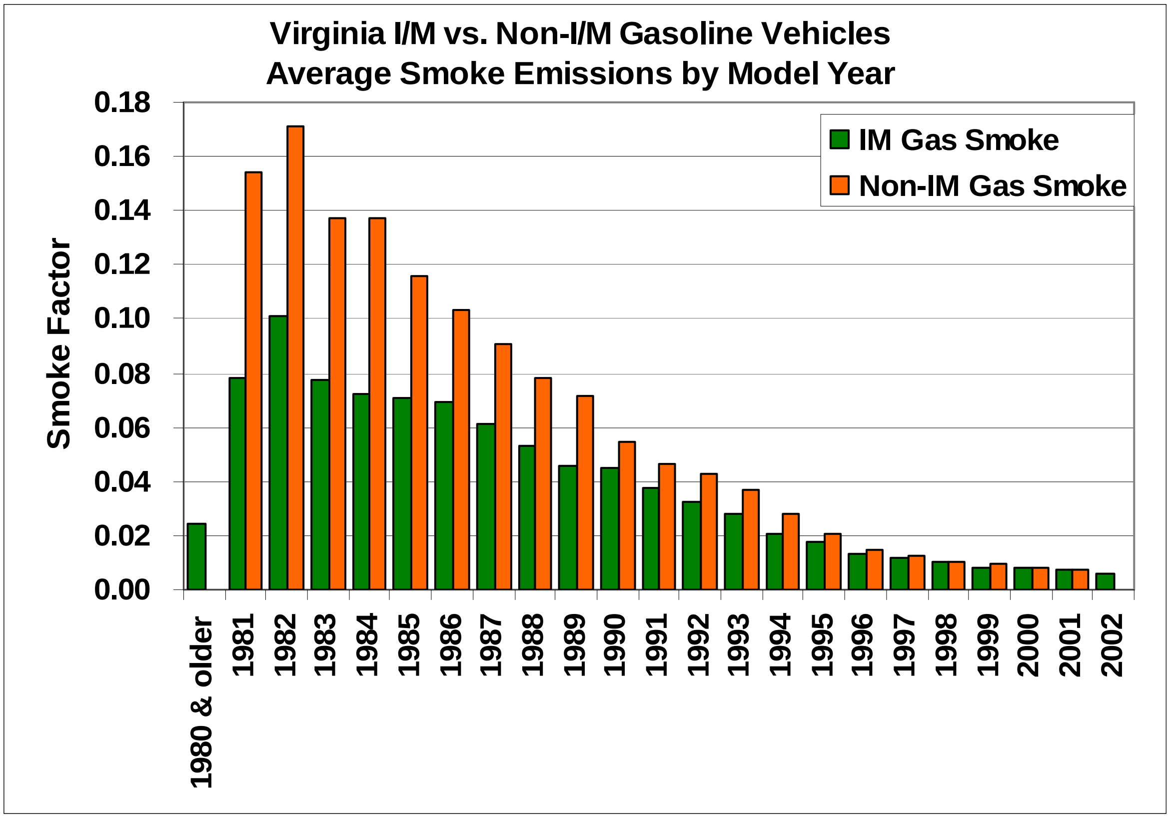


Figure 3-5 I/M vs. Non-I/M Vehicles Average Smoke Emissions

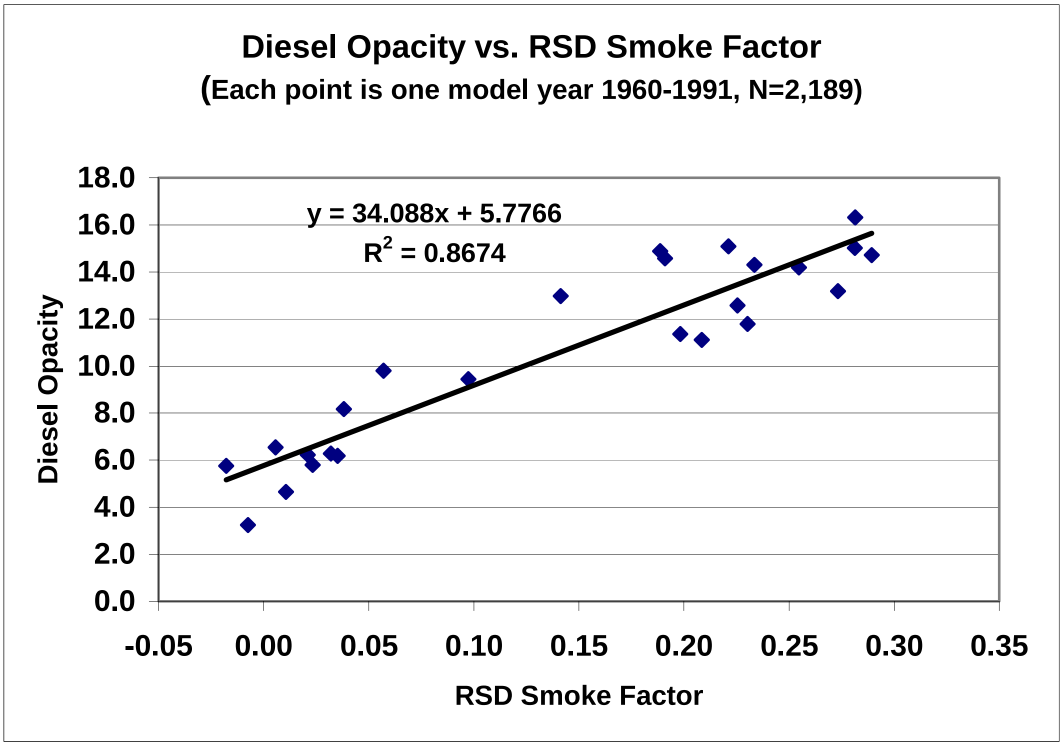


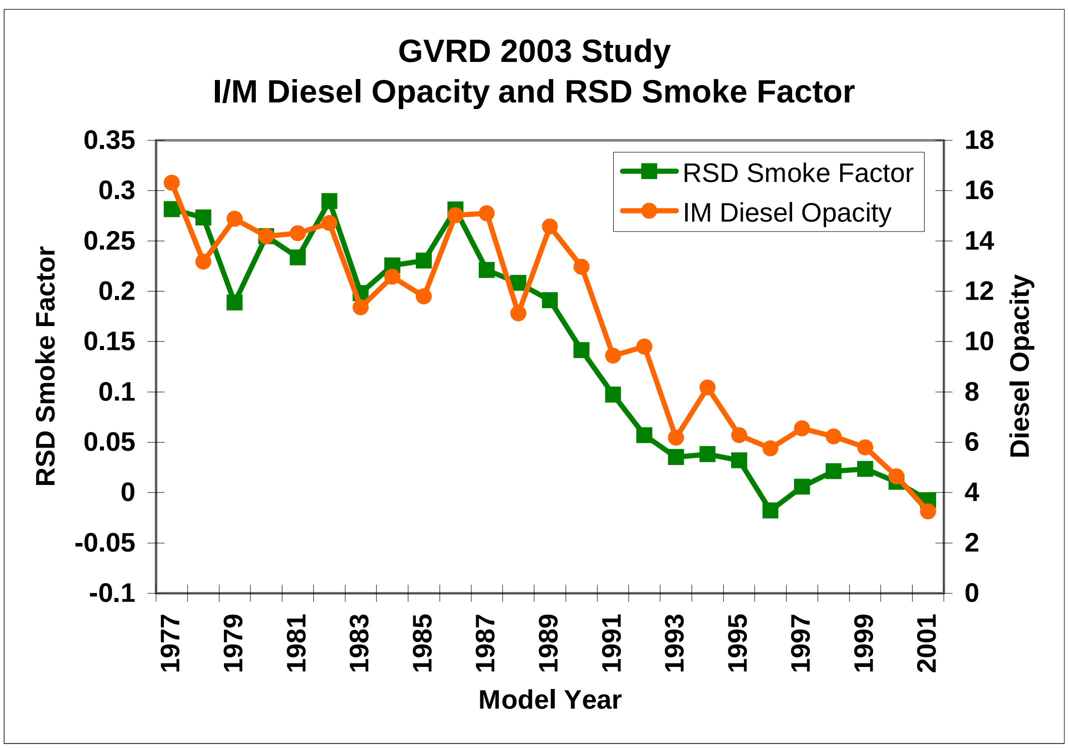
AIRCARE TECHNICAL REVIEW PHASE 1, Levelton Consultants Ltd, November 2004 **(full report available at http://www.aircare.ca)**

A study in Vancouver British Columbia compared RSD4000 smoke factor readings against the Greater Vancouver I/M program D147 diesel opacity test. The D147 test measures the maximum opacity reading over a transient cycle that is the last 147 seconds of the IM240 trace.

The figures below from Appendix A-2 of the Aircare Technical Review show that the average correlation by model year is excellent and indicate that the RSD4000 readings and the independent I/M opacity readings are indeed measuring quantitatively the same phenomenon from these, relatively low smoke, diesel fleets.

Appendix A-2 Correlation Between I/M Readings and RSD





Heavy Duty Truck UV Smoke Measurement

On November 12, 2004 as preparation for a study for Raytheon, ESP measured four trucks in different modes of operation at the Raytheon facility in Tucson, Arizona. During idle and snap-idle modes, the RSD unit was run in a continuous measurement mode that reports results every second. Results for two trucks, a 2002 Chevy C6500 and a 1987 Ford L8000 are shown in Figure 1. Although there were some set-up and calibration issues to be resolved, the RSD4000 was clearly able to differentiate between the clean 2002 Chevy C6500 and the much smokier 1987 Ford L8000. The characteristics of the traces for all pollutants are consistent with the events of a snap idle procedure; 1) sudden enrichment, 2) an increase in engine speed with declining fuel air ratio, and 3) a sudden drop in engine speed and fuel. Figure 2 shows the RSD4000 opacity trace from the study of both the Chevy and the 1987 Ford. The Chevy data show low smoke readings and the snap idle increases are hardly discernable. By contrast the Ford data show three clearly defined snap idle opacity increases. The Ford data also show opacity at the beginning greater than 0.5 and at the end averaging about 0.4. This trace shows how well individual smoke factor readings can see smoking truck exhaust and the rapid variation of same.

It is trucks like this that we expect to see and intend to report on at the Nogales border crossing.

Figure 1

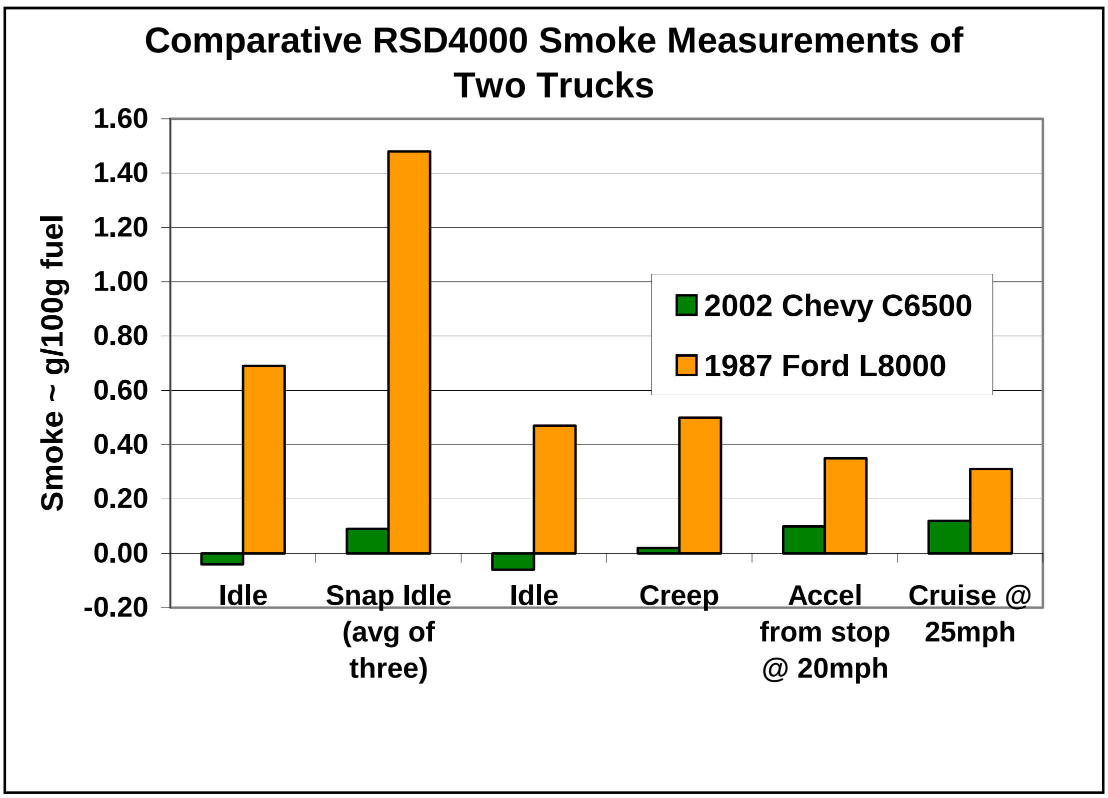
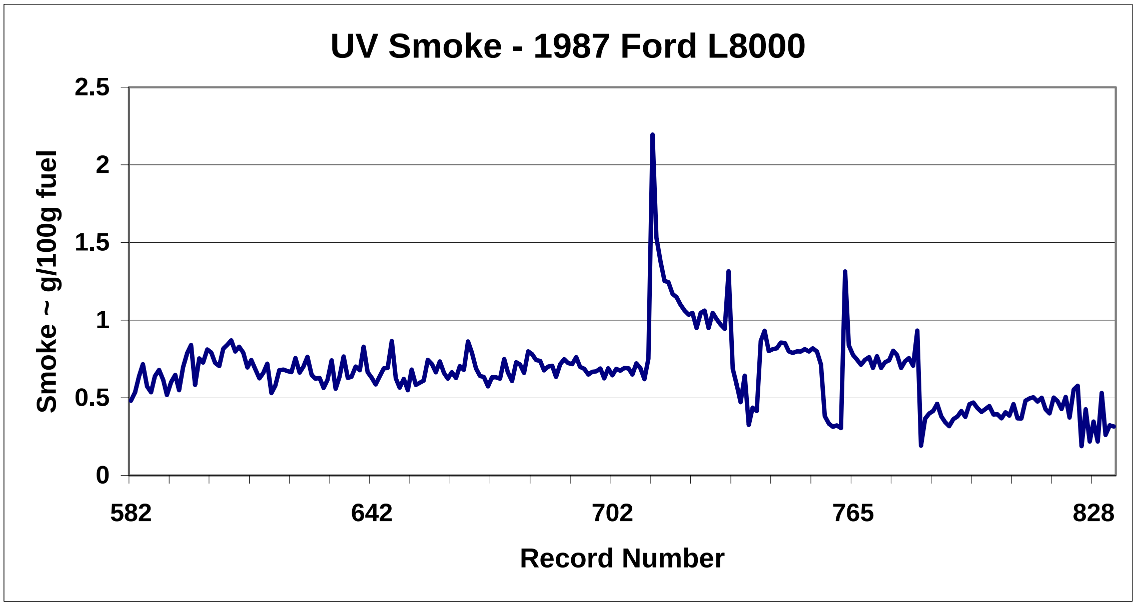
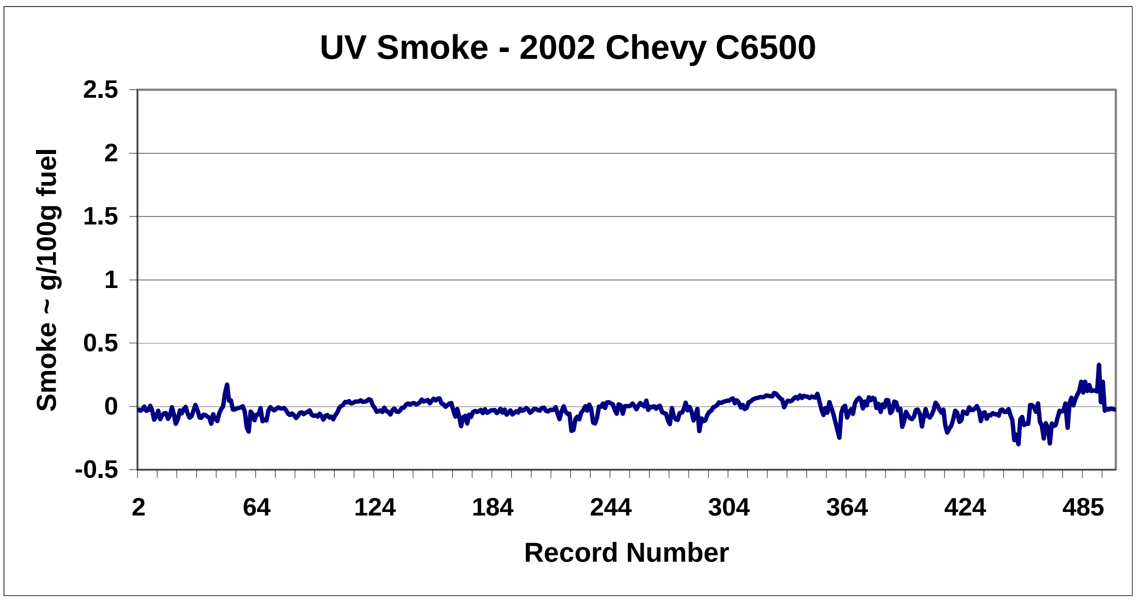


Figure 2



UV Smoke - 1987 Ford L8000
Smoke ~ g/100g fuel
2.5
2
1.5
1
0.5
0
582
642
702
765
828
Record Number



UV Smoke - 2002 Chevy C6500
Smoke ~ g/100g fuel
2.5
2
1.5
1
0.5
0
-0.5
2
64
124
184
244
304
364
424
485
Record Number