5/24/05

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Review of report entitled: **"Fuel Effects on Emissions from Modern Gasoline Vehicles Part 1 - Sulphur Effects,"** 2003, CONCAWE Report No. 5/03

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Description of CONCAWE Study

The above-named study reports the short-term sensitivity of four cars to the emission effects of fuels containing sulfur at four concentrations ranging from 4mg/kg to 148 mg/kg sulfur (4 ppm to 148 ppm sulfur). Two of the test vehicles were certified to Euro-4 emission standards (0.1 g/km HC, 0.08 g/km NOx, and 1.0 g/km CO) and the two others to Euro-3 emission standards (0.2 g/km HC, 0.15 g/km NOx, and 2.3 g/km CO). Model year and mileage accumulation were not provided. However, it was reported that vehicles possessed at least 8000 km accumulation, and it was ascertained that all four vehicles were of approximate 2002 model year. Tests were conducted with the New European Driving Cycle (NEDC). Descriptions of the four vehicles are given below:

Veh A - stoichiometric DI, TWC (Euro-3)
Veh B - MPI, variable valve actuation, TWC (Euro-4)
Veh C - lean DI, TWC+NOx trap (Euro-3)
Veh D - lean DI, TWC+NOx trap (Euro-4)

A summary of the limitations seen in this study is given below. Additional details and expanded comments follow.

Limitations of the CONCAWE Study

- One CONCAWE conclusion is that: "Reductions in sulphur level from 150 to 10 mg/kg seem unlikely to bring substantial emissions benefits for current Euro-3 & 4 vehicle technologies." The design and results of this study are too limited to support this conclusion. The statement represents a "jump" from the specific to the general.

- Because the vehicle exposure to a particular fuel was only 37 minutes in duration, the CONCAWE study shows only a snapshot in time relative to sulfur's effect on tailpipe emissions. Thus, no conclusions can be drawn from this study with respect to long-term studies. In addition, the desulfurization procedure performed prior to testing increases the likelihood that sulfur effects would not be detectable, especially in a 37-minute test.

- Because the mileage accumulation on the CONCAWE test vehicles is relatively low (presumably on the order of 8000 - 12000 km), no conclusions can be drawn from this study with respect to high-mileage vehicles.

- Conclusions drawn from the CONCAWE test results apply only to those vehicles possessing the same technologies as those in the test fleet. Application of the test results is thus limited, since gasoline direct injection and NOx adsorbers are relatively new technologies.

- The CONCAWE conclusion that "fuel sulfur sensitivity is influenced by catalyst system design rather than by emissions level," is not valid within the context of this study since the experimental design was not conducive to testing that hypothesis.

Expanded Comments re: the CONCAWE Study

(a) Desulfurization - The CONCAWE testing includes a desulfurization procedure immediately prior to emission testing. This procedure typically allows the vehicle to run rich at high temperatures, thereby converting the sulfur oxides to hydrogen sulfide. Desulfurization is not a procedure that is routinely conducted in standard emission testing. Different desulfurization procedures were conducted for the different vehicle technologies. It is thus not clear how relevant this mode of operation is to actual on-road operation, especially since the two vehicles possessing a NOx adsorber are likely to have active desulfurization whereas the other two vehicles are not.

(b) Catalyst durability - The *Introduction* of the CONCAWE report states: "Although sulfur reduction is mainly aimed at long-term durability and fuel efficiency with advanced after-treatment systems, short-term effects are also important…." Yet the overall tenor of the report seems to discount the long-term effects by concluding that: "Reductions in sulphur level from 150 to 10 mg/kg seem unlikely to bring substantial emissions benefits for current Euro-3 & 4 vehicle technologies." This "blanket statement" does not logically follow, i.e., it is an extended generalization of the results. To the contrary, there have been many studies showing statistically significant effects of fuel sulfur on tailpipe emissions, up to 100Kmi of operation.

(c) Duration of catalyst exposure to sulfur - Prior to vehicle emission testing over the NEDC cycle, the vehicle was subjected to a desulfurization procedure, followed by one ECE prep cycle and two EUDC prep cycles (totaling 1000 sec of prep cycles). The combined NEDC and prep cycles totaled only 37 minutes, thereby subjecting the catalyst bed to only 37 minutes of exhaust. Although there were no statistically significant increases in NEDC emissions with increasing fuel sulfur, there were some statistically significant increases over the EUDC portion of the cycle, i.e., when the catalyst is hot and fully functional. This increase was seen for the HC and CO in the two vehicles without NOx traps. This suggests that statistical significance for the full NEDC cycle might have been observed had the testing been performed over several NEDC cycles.

(d) Emission control technology - The fuel-management and emission control systems used on three of the four test vehicles were somewhat unique. Three of the four vehicles employed direct injection. In California, there are only a few DI engine families certified for the 2005/2006 model year. Two of the four vehicles possess a NOx adsorber. Only a very small number of vehicles in California, or the U.S. in general, are certified with this emission control device. NOx adsorber technology is a confounding variable in that NOx adsorbers are particularly sensitive to sulphur. Therefore, vehicles possessing this technology are designed to include operation parameters which desulfurize the catalyst bed. Discussions with ARB staff knowledgeable in certifying these vehicles indicate that it is only infrequently that the desulfurization regime is triggered in the vehicle. This would support the contention that the short exposure (a total of 37 minutes) of the vehicle to a particular fuel is not likely to subject the NOx adsorber to significant sulfur exposure from the perspective of affecting tailpipe emissions.