ADDENDUM

To:

ARB's Study of Emissions from "Late-model" Diesel and CNG Heavy-duty Transit Buses

REPORT OF PARTIAL RESULTS: EMISSIONS FROM TWO OXIDATION CATALYST-EQUIPPED CNG BUSES

August 22, 2002

Preface

This document offers interpretation of available new results summarized in the accompanying presentation slides from a follow up study that expanded on last year's bus emissions testing. Information is available at http://www.arb.ca.gov/research/cng-diesel/cng-diesel.htm. This latest study includes testing of two CNG-fueled buses: 1) the same CNG bus evaluated last year, but now equipped with an original equipment manufacturer (OEM) oxidation catalyst, and 2) a new and state-of-the-art CNG transit bus equipped by the OEM with oxidation catalyst. This report provides a synopsis of partial test results available to date. Data or analyses have not been subject to full external peer review and as such are subject to revision and change. Additional data reduction and analysis are in progress. Therefore, interpretations are not definitive or exhaustive. The data is being presented at this time because of general interest. The report is intended to facilitate further review and discussion of the available new information.

Project Summary

Last year, ARB led a multi-agency research effort and gathered tail-pipe emissions data from two in-use, late-model public transit buses. From this study, we learned that no single tested alternative to diesel is clearly superior to the others for every pollutant or pollutant indicator measured. 2001 results suggest that, in their tested configuration, neither the CNG-fueled nor the trap-equipped diesel option is clearly superior in all aspects to the other. But, most importantly, feasible improvements were identified for both.

In this latest effort, a "snap-shot" of two CNG buses equipped with additional emissions controls was obtained. No diesel buses were tested. The test vehicles were 1) a new 2001 bus powered by a Cummins Westport C Gas Plus engine and OEM-equipped with oxidation catalyst and 2) a 2000 bus powered by a DDC Series 50G engine. This is the same DDC CNG bus from last year. This time, the DDC bus was tested with and without oxidation catalyst. DDC assisted in the catalyst retrofit. Fuel for both buses came from the LACMTA refueling station. Testing over two driving cycles: 1) the Central Business District (CBD) cycle and 2) Steady-state (SS) cruise at 55 mph was conducted at ARB's Heavy-duty Emissions Testing Laboratory. Identical testing, sampling, and analytical protocols observed in the original project were followed again.

Project Status

Dynamometer testing was completed in June 2002. Collection of total PM over multiple cycles was performed for subsequent chemical analyses. Emission factors for regulated pollutants (i.e., nitrogen oxides (NO_X), total hydrocarbons, total PM, and carbon monoxide (CO)) and unregulated pollutants (i.e., carbon dioxide (CO_2), nitrogen dioxide (NO_2), non-methane hydrocarbons (NMHC), toxic hydrocarbons, and carbonyl compounds) are reported in the presentation accompanying this document. Also included are preliminary results from two Scanning Mobility Particle Sizers (SMPS) that were used to characterize ultrafine particle emissions in the range of 6 to 230 nm. Analyses for metals, elemental carbon, organic carbon, polycyclic aromatic hydrocarbons, and Ames bioassay activity are in progress with results expected by end of year. Staff are currently involved in interpretation of results. All of the data reported to date passed internal quality control.

Interpretations

This report provides an analysis of available new data and identifies possible conclusions that may emerge from this study. Plausible interpretations of the data in terms of a comparison between the emission profiles of the different vehicles are offered with some of the same caveats for the 2001 study, repeated here for emphasis:

1- Work is in progress to generate technical documents for external peer review. It is possible that peer review may offer a different interpretation of results.
2- The study was limited to in-depth testing of only two buses and three configurations. While we believe the emissions from these vehicles typify the emissions differences between the tested technologies, it may eventually be determined that results are not quantitatively representative for some pollutants for the fleet as a whole.
3- Interpretation of the data and comparisons of the properties of the vehicle emissions are still works in progress and additional and/or different conclusions may emerge later.
4- Testing of the CNG technologies challenged the sampling and analytical methodologies to the limits of detection. Further data analysis and evaluation of the conventional sampling protocols may be required before final conclusions can be reached. For example, the dilution tunnel background effects have not been rigorously quantified. These can have a significant impact on results and will be extensively evaluated.

Summary of Results

Partial findings from this new study indicate that the emissions impact from oxidation catalyst control for CNG applications is as follows:

1- Oxidation catalyst on CNG bus reduced formaldehyde emissions by over 95% for both CBD and SS cycles.

2- Comparison of results on relative basis suggests some BTEX emission reductions by the catalyst. Accurate determination of total BTEX emission levels cannot be made due to high tunnel blank results.
3- 1,3-Butadiene emissions from CNG were reduced by the catalyst to levels below detection limit.
4- Oxidation catalyst on CNG bus reduced NMHC emissions by over 88% for both CBD and SS cycles.
5- The problem of high NO_2 emissions from trap-equipped diesels is not present for CNG-fueled buses with or without oxidation catalyst.
6- Oxidation catalyst on CNG bus shows reduction of total PM, CO, and total HC.
7- Oxidation catalyst on CNG bus shows potential for reduction of ultrafine particle number concentrations across the size range of 6nm to 230nm. Concentrations show dependence on engine operating condition.
8- No significant effect of oxidation catalyst on CH_4, CO_2, and NO_X was determined.
9- Catalyst durability was not addressed in this study. Both catalysts were relatively low-mileage.

Perspective

The regulated emissions of PM and NO_X from the tested CNG buses continue to be lower relative to a "conventional" heavy-duty vehicle fueled by California diesel and not equipped with an aftertreatment device. With regards to the toxic emissions, the oxidation catalyst appears to offer significant reductions. In terms of total PM mass, this study shows that CNG with or without oxidation catalyst is significantly superior to the current and conventional diesel bus, including the catalyst-equipped bus fueled with very low sulfur diesel tested last year. This alone continues to represent a clear advantage. Finally, particle numbers in CNG exhaust appear to be reduced by the catalyst under some engine operating conditions.

In conclusion, these partial results suggest that oxidation catalyst for CNG applications offers significant benefits. These interpretations are presented to inform interested parties of the new study findings to date and to facilitate further review and discussion. For comments or questions, please contact Mr. Jack Kitowski, Chief, On-road Controls Branch, Mobile Source Control Division at (916) 445-6102 or jkitowsk@arb.ca.gov.