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APBF-DEC NOx Adsorber/DPF Project: SUV / Pick-up Truck Platform

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INTRODUCTION

The objective of this project is to determine the influence of diesel fuel composition on the ability of NOX adsorber catalyst (NAC) technology, in conjunction with diesel particle filters (DPFs), to achieve stringent emissions levels with a minimal fuel economy impact. The test bed for this project was intended to be a light-duty sport utility vehicle (SUV) with a goal of achieving light-duty Tier 2 – Bin 5 tailpipe emission levels (0.07 g/mi. NOX and 0.01 g/mi. PM). However, with the current US market share of light-duty diesel applications being so low, no US 2002 model year (MY) light-duty truck (LDT) or SUV platforms equipped with a diesel engine and having a gross vehicle weight rating (GVWR) less than 8500 lb exist. While the current level of diesel engine use is relatively small in the light-duty class, there exists considerable potential for the diesel engine to gain a much larger market share in the future as manufacturers of heavy light-duty trucks (HLDTs) attempt to offset the negative impact on cooperate average fuel economy (CAFE) that the recent rise in market share of the SUVs and LDTs has caused. The US EPA Tier 2 emission standards also contain regulation to prevent the migration of heavy light-duty trucks and SUV's to the medium duty class. This preventive measure requires that all medium duty trucks, SUV's and vans in the 8,500 to 10,000 lb GVWR range being used as passenger vehicles, meet light-duty Tier 2 standards.

In meeting the Tier 2 emission standards, the HLDTs and medium-duty passenger vehicles (MDPVs) will face the greatest technological challenges. Because the MDPV is the closest weight class and application relative to the potential upcoming HLDTs and SUV's, a weight class compromise was made in this program to allow the examination of using a diesel engine with a NAC-DPF system on a 2002 production vehicle. The test bed for this project is a 2500 series Chevrolet Silverado equipped with a 6.6L Duramax diesel engine certified to 2002 MY Federal heavy-duty and 2002 MY California medium-duty emission standards. The stock vehicle included cooled air charge (CAC), turbocharger (TC), direct fuel injection (DFI), oxidation catalyst (OC), and exhaust gas recirculation (EGR).

DISCUSSION

The plan for this project is to focus the evaluation on two fuels with differing sulfur levels (8 and 15 ppmS fuels). Some limited testing at 30 ppmS level will also be performed to examine possible effects of fuel sulfur level excursions.

The baseline engine-out (without EGR) emissions test produced 5.3 grams/mile NOx over the urban dynamometer driving schedule (UDDS) cycle. When compared to the Tier 2 Bin 5 NOX emissions goal of 0.07 grams/mile, the base emissions needed to be reduced by over 98%. Aggressive EGR calibrations to reduce the engine-out NOX were created and tested to lower the NOX reduction requirements of the NAC system. Engine-out NOX was reduced by 65 percent to 1.7 grams/mile, but the PM mass doubled. The final PM - NOX trade-off was adjusted to a reasonable and driveable level which resulted in engine-out NOX emissions of approximately 2.6 g/mile.

Baseline testing also indicated that the engine exhaust at the catalyst inlet location was at a very low temperature (average 153°C) over the UDDS test cycle. Information supplied by the emissions system manufacturer indicated that the NAC would require between 300 and 400°C to achieve maximum catalyst efficiency, and the DPF would require exhaust temperatures >300°C for continuous regeneration. A large portion of calibration work through the first year focused on generating heat at the catalyst efficiently, to reduce the fuel economy penalty associated with doubling the exhaust temperature. Tools that were developed and calibrated included: post fuel injection (in-cylinder), EGR and intake throttling, turbocharger bypassing, supplemental in-exhaust fuel injection, air gap exhaust manifolds, crossover pipes, and down pipes, and a diesel-fueled burner. Combinations of engine management techniques (post injection, EGR, intake throttling and turbocharger bypassing) proved inadequate in providing sufficient supplemental heat and were very inefficient in transferring the supplemental heat generated to the catalyst system (only about 15-25 percent efficient in conversion and transfer of fuel energy). The burner system achieved the thermal goals and proved to be 90 percent efficient in conversion and transfer of the supplemental energy. The burner also offers a wide range of fuel and airflow operation, and can be operated rich during emissions system regeneration to provide reductant for regeneration and to consume excess oxygen.

The emission control systems (ECS) were installed and control strategy development started. Throughout the course of the year, the NOx and thermal management strategies were created and applied. The control strategies were first developed under steady-state operation and were later converted into transient control approaches. The first transient operation strategy was based heavily on the approach developed for steady-state (a rich/lean time method). This approach worked well, but a more refined, realistic approach based on a NAC NOx mass storage model was developed and applied. Using the strategies developed, tailpipe NOx mass was reduced by about 98% from baseline, at low hours on low sulfur fuel for the Hot LA-4 cycle. Figure 1 shows a summary of the integration control results.

The second task of the project involves aging the ECS using fuels with varying sulfur levels. Since this is a light-duty program, an aging cycle that focused on heavy-duty operation was determined to be inappropriate. Also, since the primary function of the NAC is to adsorb, desorb, and reduce NOx, it was not known exactly how the aging of this device could be accelerated. Aging at elevated temperature is known to deactivate the NAC, but a correlation of elevated temperature operation to miles was not known, also it was not clear that thermal acceleration of aging alone would adequately simulate the aging process of the NAC. Therefore, the aging cycle was not intended to be an accelerated-type aging cycle; instead the cycle was to focus on exercising the ECS in a manner similar to what would be expected in-use. Additionally, it was felt that steady-state modes rather than transient operation would be safer to operate for extended periods.

The aging cycle was created to match the operating modes of this application over the light-duty LA-92 cycle (also referred to as the unified cycle). To determine the modes that should be run, and the percentage of time each mode should represent, the test cycle was run and an analysis of the frequency of time spent in combinations of engine speed and accelerator pedal position (a surrogate for engine load) was conducted. The top ten most frequently occurring modes were extracted and used to define the steady-state modes of the aging cycle. The aging cycle is shown in Figure 2.

During the next task, the emissions control system will be tested on 8 and 15 ppmS fuel. Emissions testing will be conducted at "zero" hours, and then at 50-hour increments, with more complete unregulated emissions sampling conducted at 100-hour intervals. A 15 ppmS refinery fuel will also be used to examine the unregulated emissions at the 50 hour and the 300-hour point of the 15-ppmS testing. At the close of the preliminary aging task, one system will be selected for extended durability testing, and the aging will continue out to 1500 hours, with emissions testing at 100-hour increments. The results of this evaluation will be reported at the end of 2004.

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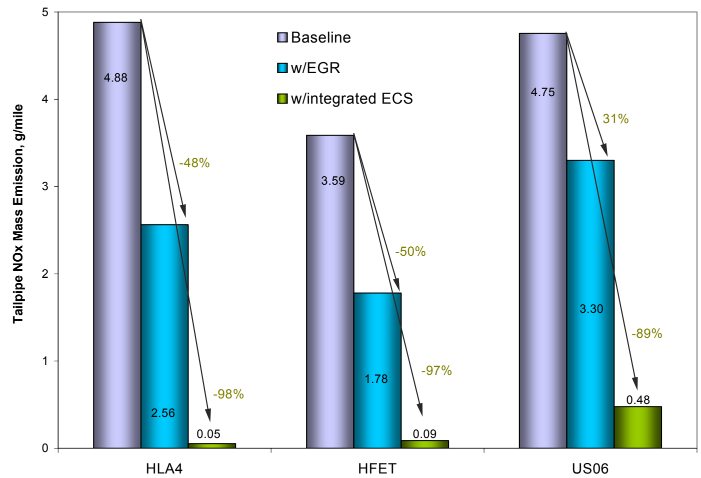

FIGURE 1. SUMMARY OF NAC INTEGRATION RESULTS - LOW HOUR, "ZERO" SULFUR FUEL

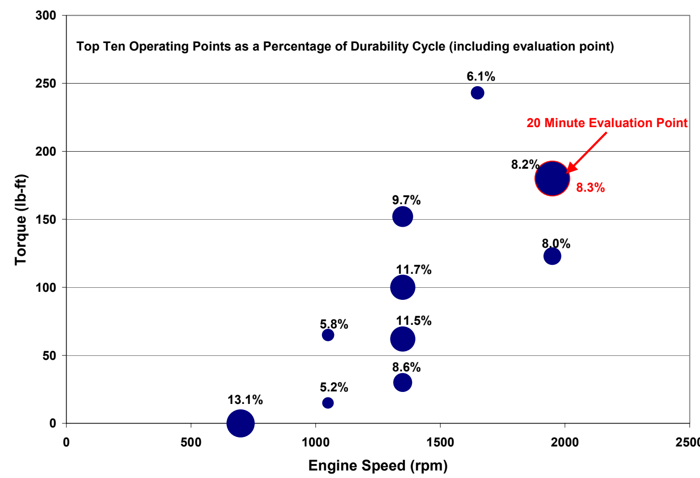

FIGURE 2. AGING CYCLE OPERATING POINTS