D. Additional Elements Contributing to Engine Load

As part of the Non-LA4 Emission Test Program, EPA conducted an evaluation of emission impacts from road grade by simulating a two percent grade through increased inertia weight at the dynamometer during testing of three vehicles over the three representative cycles. The road grade effect, weighted by the percentages of the driving types in-use, showed a consistent HC increase of 0.04 g/mile, a highly variable CO increase averaging 3.2 g/mile, and a NO_X increase (due largely to one vehicle) of 0.19 g/mi. Due to the absence of comprehensive in-use survey information, EPA did not calculate adjustments to these numbers to reflect in-use frequency of grade or modifications to driving behavior over grades.

IX. Cause and Control of Emissions

Three candidate areas for emission control are aggressive driving behavior, intermediate soak periods, and A/C operation. Microtransient driving behavior carries over and is addressed withing these candidate areas. The following discusses each of these areas, the causes of emission, and potential strategies for controlling the emission.

A. Aggressive Driving Emissions

Both agencies and the vehicle manufacturers anticipated that a primary cause of higher emissions during aggressive operation would be "commanded enrichment," which is done by programming the vehicle's computer to change the air/fuel ratio to the rich side (more fuel for the same air) of stoichiometric operation, typically in response to high loads on the engine. Aggressive driving, positive road grade, increased vehicle loading, and air conditioning operation all generate increased load on the engine. Further, the effect of these factors are cumulative. Manufacturers currently employ commanded enrichment in essentially all applications when high load at the engine (regardless of the source) is detected, both to provide increased power and to cool the engine or catalyst.

Using data from EPA's Non-LA4 Test Program, supplemented by AAMA/ AIAM data,²³ the Agency concluded elevated HC and CO emissions during aggressive driving are due primarily to enrichment, both commanded and transient. High NO_x emissions during aggressive driving, EPA believes, are due both to an increase in engine out NO_x (from higher temperatures) and to relatively poor catalytic conversion. Poor catalytic conversion is due to lean events resulting from erratic A/F control and to an A/F control strategy which is not biased rich. The Agency also recognizes that catalyst breakthrough is a potential contributor to CO and NO_x emissions during aggressive driving.

The Agency considered five strategies that manufacturers might employ for addressing the causes of high emissions from aggressive driving: improved control of the A/F ratio (fuel control) through calibration; improved fuel control by upgrading fuel injection systems to sequential firing; upgrading to electronic throttle control; improvements to catalyst design; and reapplication or refinement of conventional NO_x emission control systems. These strategies are discussed in detail in the Technical Reports.

Of these strategies, the various recalibration options appeared to be the least costly, because each of the remaining strategies involved pervehicle hardware modifications. In addition, data from the Non-LA4 test program indicated that recalibrations would probably control the vast majority of aggressive driving emissions.

B. Intermediate Soak Periods

The Agency examined the causes of post-soak emissions using data from the EPA Soak/Start Test Program and a preliminary program called the Albany Cooldown Study that gathered realworld engine and catalyst cooldown profiles. The data from these programs indicated that increased emissions following intermediate soaks arise in three ways:

• Rapid catalyst cooldown following keyoff,

• Slow catalyst thermal recovery following a restart, and

• Manufacturer calibration strategies in response to the startup condition.

The Agency data indicate the catalyst cools to below the temperature needed to sustain significant catalytic activity ("light-off" temperature) within 20–30 minutes of vehicle shutoff, while the engine is still near its normal operating temperature. Data also indicated a significant delay in achieving light-off temperature upon restart, apparently due to the cool initial temperature of the engine-out exhaust. Because tailpipe emissions increase dramatically when the catalyst is below light-off temperatures, the relatively long delay in achieving light-off results in disproportionately high emission increases over intermediate soaks.

The current FTP provides no incentive for manufacturers to retard the rapid cooldown of the catalyst during intermediate soaks. In addition, testing found differences in engine-out emissions determined by the manufacturer's calibration strategy upon restart. Following intermediate-duration soaks, one vehicle had a lean calibration strategy which increased NO_X emissions. Here again, the test results indicate that significant emissions may be occurring in-use because of a lack of incentive for manufacturers to optimize startup calibrations following intermediate soaks.

In general, strategies for reducing post-intermediate soak emissions are catalyst-based and either focus on the retarding of catalyst cooldown through insulation after the vehicle is shut off or the enhancement of catalyst light-off upon restart.

Of the potential approaches considered for control of intermediate soaks, EPA is focusing on catalyst insulation as the primary control strategy. Use of insulation results in greater emission reductions over intermediate soaks than strategies which focus on improving catalyst light-off through conventional means and provides more cost-effective emission benefits than advanced cold start approaches. Although intermediate soak emissions will likely be reduced to some extent due to directional improvements in cold start performance, EPA believes that on Tier 1 vehicles intermediate soak emissions will continue to be relatively significant because the primary cause of intermediate soak emissions-rapid cooling of the catalyst-will remain unaddressed. Because insulation directly addresses catalyst cooldown, EPA anticipates that this approach will incur significant emission reductions over intermediate soaks on Tier 1 vehicles, including those which will incidentally reduce intermediate soak emissions through improved cold start performance.

C. Air Conditioner Operation

The Agency focused on the NO_X impacts from A/C use because of the large observed increases. The increases in tailpipe NO_X with the A/C operating seen in the ACR Test Program could clearly be linked to large increases observed in engine out NO_X , which are probably caused primarily by higher combustion temperatures due to the additional load of the A/C system. Tailpipe NO_X can be improved by

²³ AAMA/AIAM spotlighted commanded enrichment by retesting a portion of the vehicles in their test program in a stoichiometric configuration, as well as in the "production" configuration and provided second-by-second data acquisition capability for emissions and a variety of engine and emission control parameters, allowing fine scrutiny of individual driving events.