Support Document to the Proposed Regulations for Revisions to the Federal Test Procedure: Detailed Discussion and Analysis

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Office of Air and Radiation
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I. Introduction

Cars and trucks produce hydrocarbons (HC), carbon monoxide (C0), and oxides of nitrogen (NOx), all of which have documented impacts on public health. HC and NOx contribute to the formation of ozone, a powerful oxidant which irritates the respiratory system and reduces lung function. Some studies indicate that ozone may permanently damage lung and other tissues. Elevated levels of CO decrease the ability of blood to transport oxygen throughout the body, which tends to exacerbate cardiovascular stress. High ambient levels of CO can also adversely affect the central nervous system, and the presence of CO in even moderate levels in the bloodstream may impact the health of fetuses and newborns.[1] The Agency believes that the changes proposed today would result in meaningful reductions in the pollution due to automobiles.

The Agency has established a number of emission standards for motor vehicles and engines, designed to control air pollution by reducing in-use emissions of motor vehicles. Compliance with these standards is typically measured using a test procedure that simulates in-use driving, including the driving cycle (speed, time, acceleration, and the like), ambient conditions (such as temperature, humidity), and fuel (such as gasoline volatility). In 1990, Congress amended the Clean Air Act (CAA) and required that EPA review these test procedures and revise them as appropriate to reflect current in-use conditions. The Agency's review focused on the procedures for light-duty motor vehicles, especially FTP, the procedure used to measure tailpipe and evaporative emissions when determining compliance with motor vehicle emission standards.

As part of this review, EPA, in conjunction with auto manufacturers and the California Air Resources Board (CARB), conducted an extensive review of in-use driving behavior, obtaining a wealth of data on how vehicles are driven during trips, the length of trips, the length of time between trips, and so on. The Agency then generated representative driving cycles from these data and conducted testing to compare emissions over these cycles with emissions over the driving cycle used for

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Regulatory Impact Analysis for FTP Revisions, U.S. EPA Office of Air and Radiation. Available in the public docket for review.

tailpipe emission testing in the current FTP (the "LA4" or "Urban Dynamometer Driving Schedule"[UDDS]). These results confirmed that revisions were needed, as significant emissions were seen under conditions not represented by the current FTP.

From these results and other analysis, EPA developed various changes to the FTP, focusing on new driving cycles to add to the current FTP. The Agency also investigated possible control technologies that could be used to control emissions over these new cycles. Today's proposal includes these various changes in the test procedure for tailpipe emissions, as well as the emission standards related to them. The basic approach used for today's proposal is to extend FTP control comparable to that for the FTP across all in-use driving behavior and conditions that significantly impact in-use emissions. Additional control is not proposed because the main focus of this proposal is to update and correct the test procedure, and control previously unregulated areas to the level of stringency of the existing requirements. Proper incorporation of the full range of in-use driving conditions and behavior will allow future standards to assess feasible increases in stringency.

The rest of this section provides a summary of the existing FTP, as well as identifying various pollutant-specific test procedure components that EPA is not proposing to change.

The procedure used to measure emissions from light-duty vehicles (LDVs) and light-duty trucks (LDTs) is the FTP. The current version of the FTP (40 CFR 86.130-96) consists of a series of preparatory steps to ensure the vehicle has been properly preconditioned on the test fuel, periods when the engine is off between vehicle operation (called "soaks"), and emission tests which measure tailpipe and evaporative emissions. Tailpipe emissions are measured while the vehicle is operated according to a specified driving cycle on a dynamometer. With the exception of running losses, which are measured during dynamometer operation, evaporative emissions are measured in a sealed enclosure while the vehicle is turned off. An additional cold temperature CO test procedure measures tailpipe emissions at 20°F following a cold soak. Compliance determinations are made by comparing the emission test results from the FTP and the cold CO test procedure to emission performance standards applicable to a given vehicle class, combustion cycle, and motor fuel.[2]

The current evaporative emission procedures, including refueling, and cold temperature CO requirements were promulgated following passage of the Amendments. Thus, the test procedures in these rules were recently developed to reflect the actual current driving conditions under which motor vehicles are used (58 FR 16002; 57 FR 31888). The Agency is not proposing to change these test procedures and the remainder of this section and the subsequent proposals focus on the light-duty tailpipe emission testing procedures of the FTP.

The FTP simulates on-road vehicle operation using a dynamometer in a laboratory test cell held between 68°F and 86°F. The vehicle is driven on the dynamometer over cycles that prescribe the vehicle operator's speed as a function of time. The method for measuring tailpipe emissions of HC, CO, and NOx requires filling a bag with exhaust drawn from the tailpipe and diluted with background air while the vehicle is driven over the appropriate cycle. The bagged sample is analyzed for the concentrations of exhaust constituents, which serve as inputs to subsequent emission calculations. Additional procedures apply to the sampling of particulate matter from diesel-cycle vehicles and organic gases from alternative-fueled vehicles.

The LA4 was designed to represent in-use driving behavior over a typical urban commuter trip.[3] The original LA4 was a road route developed in the mid-1960's by the California Vehicle Pollution Laboratory. The route matched the average speed/engine-load distribution of Los Angeles commuter trips driven by a sample of the lab's employees. The current LA4 is a

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The Agency has historically relied on emission performance standards because they directly limit production of exhaust constituents that affect attainment of the National Ambient Air Quality Standards, while providing maximum flexibility to the vehicle manufacturers in determining cost-effective strategies to meet the requirements. Other basic compliance program approaches include system performance standards, which set bounds on measurable performance parameters of the engine or emission control system rather than actual emission levels, and design standards, which prescribe primary design elements of the engine or control system.

In this report, "driving behavior" refers to the measurable consequences of the operator's action on the accelerator pedal, including vehicle speed, throttle variation, acceleration, and power.]

truncated version of speed/time chart recorder output from one of six EPA drivers that operated a single vehicle over the original LA4 route. The Agency discarded one of the six traces for unrepresentatively high accelerations and then chose the one trace of the remaining five with the driving time closest to the average.[4]

The resulting LA4 is a driving cycle that lasts 1371 seconds and is 7.46 miles long, with a peak speed of 57 mph, average speed of 19.6 mph, and maximum acceleration rate of 3.3 mph/sec2. The first 505 seconds of the LA4 are usually referred to as the "505 Cycle"; the balance of 866 seconds, which is frequently called "hot stabilized" driving, is referred to here as the "866 Cycle." A speed versus time trace of the LA4 is shown in Figure 1.

Additional detail about the development of the driving cycle can be found in an SAE paper, "Development of the Federal Urban Driving Schedule", Ronald E. Kruse and Thomas A. Huls, EPA, 1973, #730553.

INSERT FIGURE 1 - NOT AVAILABLE IN THIS ELECTRONIC VERSION

Superimposed on the LA4 representation of driving behavior are representations of in-use soak periods, A/C operation, and vehicle loading. Thus, vehicle compliance determinations are based on emission testing over the LA4 Cycle in a "cold start" condition (following a 12- to 36-hour soak) as well as in a "hot start" condition (following a 10-minute soak). However, because hot stabilized driving is essentially identical following either the 12- to 36-hour or the 10-minute soak, EPA requires testing on the full LA4 only for the cold start; the hot start test terminates following the 505 Cycle. Thus, the current test sequence is (1) a 12- to 36-hour soak; (2) a 505 Cycle ("Bag 1" or the "cold start"); (3) an 866 Cycle ("Bag 2," or "hot stabilized" driving); (4) a 10-minute soak; and (5) a repeat of the 505 Cycle ("Bag 3" or the "hot start"). Fixed weights are applied to the three-bag results to represent the in-use frequency of the starts.

Load on the engine from A/C operation is simulated on the current FTP by increasing the dynamometer road-load horsepower by ten percent, to a maximum of 1.4 horsepower, for any test vehicle where A/C penetration in the engine family will exceed 33 percent. An FTP test vehicle is loaded by adjusting the dynamometer to represent its curb weight, plus 300 lbs for passengers and cargo. No provision is made for extra load to represent road grade or trailer towing.

Fuels for emission testing, referred to as certification test fuels, are specified by regulation (40 CFR 86.113-94). The regulations prescribe allowable levels for octane or cetane rating, portions of the distillation curve of the fuel, the HC composition, and sulfur. The gasoline specification includes limits on fuel volatility. The limited penetration to date of non-petroleum fuels into the market made developing a representative, commercially available specification for alternative fuels more problematic than for petroleum fuels. In general, EPA regulations for these certification test fuels simply require that they be "representative of commercially available fuels" (40 CFR 86.113-94(a)(3)). As discussed later, EPA is not proposing to change these requirements.

Current regulations do not limit the altitudes at which FTP testing may be performed. As a consequence, EPA tests light-duty vehicles and trucks at both low and high altitude for compliance with the emission standards.

With this background on the current FTP, the discussion in

Section III now shifts to a summary of the central proposal and alternative proposals. Sections IV and V to follow provide background on the statutory requirement, the FTP Review Project, and the FTP elements that were the focus of the review effort. Section VI covers EPA's data gathering efforts on in-use driving and other behaviors related to the focus areas in the review. Section VII details the development of driving cycles that were representative of these behaviors and Section VIII provides emissions inventory assessments of candidate areas for emissions control. Sections IX through XI examine the candidate areas of control in greater detail, identifying the causes of emissions shortfalls in the FTP, possible manufacturer abatement strategies, and EPA control programs to address the shortfalls. Section XII brings together the results from the individual areas of control into the SFTP. The remaining sections of this preamble address several changes to the conventional FTP, and analysis of environmental and economic impacts.

III. Summary of the Proposal

Today's proposal deals primarily with five areas of driving behavior that have not previously been regulated: aggressive driving behavior (such as high acceleration rates and high speeds); microtransient driving behavior (that is, the degree of throttle movement or speed variation over short timescales); start driving behavior; intermediate soak times (engine-off times between 10 minutes and 2 hours prior to vehicle start); and actual A/C operation. The Agency is proposing new requirements for these areas, separate from the existing FTP requirements. Also included in this proposal are changes to improve the simulation of actual road load forces across all speed ranges and to revise the speed tolerances for a valid test, which would be applicable both to the new provisions proposed in this NPRM and the existing FTP.

As most of the proposal deals with areas that have not previously been regulated, the Agency is proposing a broad range of alternative proposals for comment. While both the central proposal and the alternatives are EPA's own design, they incorporate some concepts put forth both by the CARB and the Ad Hoc Panel on Revisions to the FTP (Ad Hoc Panel), a joint committee of the American Automobile Manufacturers Association (AAMA) and the Association of International Automobile Manufacturers (AIAM).

While EPA is offering a central proposal, there is sufficient merit in various alternative approaches that EPA is specifically soliciting additional data, analysis, or evaluation of these alternatives. If appropriate, EPA may include these alternatives in the final rule or an appropriate combination of the central proposal and alternatives, or logical outgrowths of these. Interested parties may also submit comment on alternatives not specifically identified or analyzed by EPA for this proposal.

The proposed additions and revisions to the tailpipe emission portions of the FTP would apply to all LDVs and LDTs certifying on all current motor fuels. The proposed changes would apply to testing conducted during certification, Selective Enforcement Audits, and in-use enforcement (recall).

The central proposal relies on a new SFTP that addresses various conditions under which vehicles are actually driven and used, which are not adequately represented in the current FTP. The SFTP includes: (1) aggressive driving (characterized by high speeds and/or high accelerations); (2) driving immediately following vehicle start-up; and (3) microtransient driving (the degree of small timescale speed or throttle fluctuations), which occurs across the majority of the normal ranges of operating speeds and accelerations. The proposed SFTP incorporates conditions that are designed to more accurately reflect actual engine load due to A/C operation under typical ozone exceedance conditions. A new intermediate-duration (60-minute) soak period is also included.

Two additional changes proposed in this notice have wider impacts than just the SFTP. The first is to more accurately simulate real on-road loads at the tire/dynamometer interface, which is an element of the proposal that affects dynamometer operation throughout both the FTP and SFTP. The second would remove language specifying "minimal throttle movement" when conducting emission tests and replace it with "appropriate throttle movement" and require a specification of allowable speed variation, which also impacts both SFTP and FTP testing. The Agency is also requesting comment on whether the increased sophistication of vehicle computers necessitates replacing existing defeat device language with a requirement for proportional emission control under conditions not directly represented by the FTP and the SFTP.

The SFTP includes three single-bag emission test cycles: a hot stabilized 866 Cycle run with a new simulation of in-use A/C operation; a new Soak Control Cycle (SC01), which is run following the new 60-minute soak and with the new simulation of in-use A/C operation; and a new Aggressive Driving Cycle (US06) run in the hot stabilized condition. The cycles of the SFTP can be run as a sequence to save on preconditioning and setup time; however, separate runs of the cycles are permissible with the appropriate soak or preconditioning steps appended. Each of the test cycles is run on a system providing accurate replication of real road-load forces at the interface between drive tires and the dynamometer over the full speed range. While EPA intends to use a large-diameter single-roll dynamometer with electronic control of power absorption to meet this requirement, any system would be allowed that yields equivalent test results.

Elements of the proposed A/C simulation include a 95°F ± 5°F test cell ambient temperature, A/C set to "maximum A/C" with air recirculation (introduction of little or no exterior air), high interior fan setting, coldest setting on the temperature slide, driver's window down, and front-end supplemental fan cooling. The Agency proposes these conditions as a cost-effective surrogate for testing in a fully controlled environmental chamber set to simulate ozone-exceedance conditions of ambient temperature, humidity, solar load, and pavement temperature, although the use of a fully controlled environmental chamber would also be permitted.

With the exception of changes prompted by use of new dynamometers and an additional driver speed variation tolerance, no changes are proposed for the driving cycle of the conventional FTP. Similarly, EPA proposes to retain unchanged the method of determining compliance with the existing FTP. However, an additional "composite" calculation is proposed that brings together elements of the conventional FTP with results from the SFTP. In the composite calculation, emissions from the range of in-use driving are appropriately weighted, summed, and compared to the proposed emission performance standards. For total hydrocarbons (THC), non-methane hydrocarbons (NMHC), organic material hydrocarbon equivalents (OMHCE), organic material non-methane hydrocarbon equivalents (OMNMHCE), and CO, these proposed standards are the same as the standards applicable under the conventional FTP; for NOx, an adjustment factor of 1.15 is applied to that standard to account for the intrinsic emission response of vehicles to the new A/C test conditions. Due to the absence of relevant test data on which to base a decision, no supplemental test procedures or standards are proposed for diesel particulate. The proposed standards for applicable vehicle and fuel types, including the adjustments to the current FTP standards discussed above, are shown in Tables 1 to 6.[5]

Table 1: Proposed Intermediate Useful Life SFTP Standards (g/mi) for LDVs

Fuel	THC	NMHC	OMHCE	OMNMHCE	CO	NOx
Gasoline	0.41	0.25			3.4	0.46
Diesel	0.41	0.25			3.4	1.15
Methanol			0.41	0.25	3.4	0.46

Table 2: Proposed Full Useful Life SFTP Standards (g/mi) for LDVs

Fuel	THC	NMHC	OMHCE	OMNMHCE	CO	NOx
Gasoline		0.31			4.2	0.69
Diesel		0.31			4.2	1.44
Methanol				0.31	4.2	0.69

Table 3: Proposed Intermediate Useful Life SFTP Standards (g/mi) for Light Light-Duty Trucks

Fuel	LVW* (lbs)	THC	NMHC	OMHCE	OMNMHCE	CO	NOx
Gasoline	0-3750		0.25			3.4	0.46
Gasoline	3751-5750		0.32			4.4	0.8
Diesel	0-3750		0.25			3.4	1.15
Diesel	3751-5750		0.32			4.4	
Methanol	0-3750				0.25	3.4	0.46
Methanol	3751-5750				0.32	4.4	0.8

* Loaded Vehicle Weight

Table 4: Proposed Full Useful Life SFTP Standards (g/mi) for Light Light-Duty Trucks

Fuel	LVW* (lbs)	THC**	NMHC	OMHCE**	OMNMHCE	CO	NOx
Gasoline	0-3750	0.80	0.31			4.2	0.69

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[5] Standards are proposed to apply to the vehicle at both the intermediate and full useful life, which are defined by regulation in 40 CFR 86.096-2. For LDVs and light LDTs the intermediate useful life is 5 years or 50,000 miles, whichever first occurs, and the full useful life is 10 years or 100,000 miles, whichever first occurs.

Gasoline	3751-5750	0.80	0.40			5.5	1.11
Diesel	0-3750	0.80	0.31			4.2	1.44
Diesel	3751-5750	0.80	0.40			5.5	1.11
Methanol	0-3750			0.80	0.31	4.2	0.69
Methanol	3751-5750			0.80	0.40	5.5	1.11

* Loaded Vehicle Weight
** Applicable useful life is 11 years or 120,000 miles, whichever occurs first.

Table 5: Proposed Intermediate Useful Life SFTP Standards (g/mi) for Heavy Light-Duty Trucks

Fuel	ALVW* (lbs)	THC	NMHC	OMHCE	OMNMHCE	CO	NOx
Gasoline	3751-5750		0.32			4.4	0.8
Gasoline	</=5750		0.39			5.0	1.26
Diesel	3751-5750		0.32			4.4	
Diesel	</=5750		0.39			5.0	
Methanol	3751-5750				0.32	4.4	0.8
Methanol	</=5750				0.39	5.0	1.26

* Adjusted Loaded Vehicle Weight

Table 6: Proposed Full Useful Life SFTP Standards (g/mi) for Heavy Light-Duty Trucks

Fuel	ALVW* (lbs)	THC	NMHC	OMHCE	OMNMHCE	CO	NOx
Gasoline	3751-5750	0.80	0.46			6.4	1.13
Gasoline	</=5750	0.80	0.56			7.3	1.76
Diesel	3751-5750	0.80	0.46			6.4	1.13
Diesel	</=5750	0.80	0.56			7.3	1.76
Methanol	3751-5750			0.80	0.46	6.4	1.13
Methanol	</=5750			0.80	0.56	7.3	1.76

* Adjusted Loaded Vehicle Weight

Included in the composite calculation are a cold start bag (based on Bag 1 of the conventional FTP) and the three bags of the SFTP (called Bag4, 5 and 6). The weighting factor for each of the four bags is adjusted as appropriate to reflect the proposed level of control for each type of driving in the SFTP. Because the exhaust constituents respond differently to the loads and speeds of the new SFTP cycles, the proposed levels of control and, thus, the weighting factors of the composite calculation differ somewhat for different pollutants. The proposed weighting factors are:

	HC	CO & NOx
Bag 1 (cold start from FTP)	21%	15%
Bag 4 (866 Cycle from SFTP)	24%	37%
Bag 5 (SC01 from SFTP)	27%	20%
Bag 6 (US06 from SFTP)	28%	28%

The Agency is proposing that changes in the achievable levels of control over the SFTP tests would track changes in the underlying FTP standards and, thus, adoption of the central proposal would have the effect of automatically reducing the composite standards in step with any future declines in the FTP standards.

Flexibilities are proposed to allow manufacturers to reduce their testing burden, particularly during development testing. Manufacturers may forgo hot stabilized testing (Bag 2) on the FTP if they substitute the results from the analogous SFTP hot stabilized 866 Cycle ("Bag 4") into the conventional FTP calculation. Similarly, results of the post-soak SFTP test ("Bag 5") may be substituted for the warm soak (Bag 3) FTP results. Criteria are being considered to permit manufacturers to forgo the data submittal requirement for SC01 testing following a 60-minute soak, allowing manufacturers to reduce the SFTP soak duration to 10 minutes.

The proposal recognizes that adoption of emission standards more stringent than current Federal Tier 1 standards will likely result in emission control strategies that reduce catalyst light-off times. This could have a significant impact on the costs and benefits of the warm start requirement. As Tier 1 standards are the current legal requirement and the status of future standard changes is uncertain at this time, this proposal presumes Tier 1 applicability. The Agency invites comments and data addressing the cost/benefit calculation under a Federal Tier 2 (or equivalent) program and the concurrent applicability of Tier 1 and the proposed intermediate soak requirement promises to be more limited.

The Agency is proposing to phase-in the proposed requirements for aggressive and microtransient driving and A/C control prior to implementing the intermediate soak requirements. It is proposed that the standards apply to 40 percent of each manufacturers' combined production of LDVs and LDTs for the 1998 model year, 80 percent in 1999, and 100 percent in 2000. Small volume manufacturers would not have to comply until the 2000 model year. All the proposed requirements would apply during this phase-in period, except that Bag 5 could be conducted with a 10-minute soak instead of the proposed 60-minute soak for control of intermediate soak emissions. The 60-minute soak would be required for all vehicles starting with model year 2001, including small volume manufacturers.

The improved road load simulation and the new criteria for allowable speed variation for FTP testing are proposed to be implemented in the 1998 model year. Manufacturers could elect to use improved road load simulations prior to 1998, at their option. The Agency is also proposing a minor procedural change that would remove the current 5500 lb test weight cap, a proposal that would also be implemented in the 1998 model year with the improved road load simulations.

The Agency is also seriously considering a number of alternatives to several critical elements of the central proposal, the most important of which are summarized immediately below. Depending on comments and data received and analyses conducted subsequent to today's proposals, EPA may include some of the alternatives, in whole or in part, in the final rule.

The Agency is considering two alternatives to the proposed FTP/SFTP composite and the related standards: (1) promulgating three separate sets of standards, one set each for aggressive and microtransient driving, post-soak startup emissions, and A/C impacts; and (2) promulgating a single set of standards, based on a simple weighted average of separate standards for each control area. Both of these alternatives would use the same cycles and test procedures as the composite approach discussed above. However, instead of weighting them with Bag 1 of the FTP and using bag weights to establish appropriate compliance procedures and standards, the alternative approaches would establish emission standards specifically for each new control area.

The Agency did not select either of these alternatives as the central proposal primarily because of difficulties encountered in determining the appropriate amount of in-use compliance margin to allow when establishing emission standards. Also, the proposed concept of indexing the SFTP standards to any future changes in FTP standards probably would not work with either of the two alternatives. If data are submitted that could help establish appropriate in-use margins, EPA would reevaluate the most appropriate compliance structure and, if appropriate, may select one of the alternatives in the final rule. The Agency is also considering the alternative of establishing a single standard for NMHC+NOx, instead of separate standards, and invites comments on the cost and emission impacts of this alternative.

One issue was identified too late for EPA to properly evaluate it -- a concern that the proposed level of CO control may significantly interfere with the ability for vehicles to comply with the proposed level of NOx control. Should further data and analyses substantiate that tradeoffs between CO and NOx control would preclude meeting the proposed level of NOx control, EPA would consider reducing the stringency of the CO standards for the new control areas in the final rule.

On October 20, 1994, EPA representatives received a joint vehicle manufacturer proposal from the Ad Hoc Panel that addressed emissions arising from aggressive and microtransient driving and A/C operation and proposed emission standards for each of these two areas. The Agency has not had sufficient time to fully analyze the concepts offered by the panel or to incorporate the manufacturer proposal as an explicit, complete alternative to the central Agency proposal presented today. Nevertheless, the manufacturers' specific proposals fall within the scope of the options and alternatives discussed by EPA in today's notice. Significant points of overlap between the manufacturers' October 20, 1994, submission and this proposal are identified subsequently by footnote. The Agency has submitted materials supplied by the panel on October 20, 1994, to the rulemaking docket.[6] Analysis of these elements by the Agency, as well as any related material supplied in the future, will also be docketed. In order that the Agency may make the most informed and appropriate judgments in any final rulemaking, EPA encourages interested persons and organizations to evaluate and comment upon these materials.

In the area of A/C emissions control, EPA is considering an alternative to the proposed test simulation of A/C operation, as well as the alternative of requiring A/C testing across the cold start (that is, Bag 1 of the FTP). The alternative A/C simulation would leave the A/C off in the test cell, but would increase the dynamometer load curve across the range of vehicle speeds to reflect the additional load imposed by an A/C

"Industry Proposal on FTP Revisions," October 20, 1994.

compressor during ozone exceedance conditions.[7]

In the intermediate soak area, the effect of in-use emissions of the alternatives depends on future changes to the stringency of the FTP standards, the control strategies manufacturers would employ to meet such future standards, and the impacts those strategies might have on post-soak emissions. The central proposal is based on known quantities--a national fleet certified to Tier 1 standards with emission control strategies that have minimal impact on post-soak emissions. Future changes in standards, such as penetration into the national fleet of vehicles meeting California Low Emission Vehicle (LEV) standards or Tier 2 standards, might affect the cost-benefit calculation for post-soak emission control, as emission control strategies to meet such future standards might also lead to greater control emissions from soaks of intermediate duration. Thus, alternatives to the central proposal might include exemptions of vehicles from the 60-minute soak requirement or even deletion of the soak requirement in its entirety.

IV. Legal Analysis and Interpretation

A. Analysis of Statute and Scope of Agency Authority

This proposal is based on the U.S. Environmental Protection Agency's (EPA) general rulemaking authority under Sections 206 and 301(a) of the Clean Air Act (CAA), as amended in 1990 (Act), 42 U.S.C. 7525 and 7601(a). Section 206(a) authorizes the Administrator to "test, or require to be tested in such manner as [s]he deems appropriate, any new motor vehicle or new motor vehicle engine submitted by a manufacturer to determine whether such vehicle or engine ... conforms with the regulations prescribed under section 202 of this Act." Section 206(b) authorizes the Administrator to test vehicles and engines that have been produced by a manufacturer to determine whether they in fact conform with a certificate of conformity issued by the agency under section 206(a)(1). Section 301(a) of the Act authorizes EPA to "prescribe such regulations as are necessary to carry out his functions under this Act."

The Ad Hoc Panel has submitted a proposed methodology for such a dynamometer simulation of A/C load, dubbed "Nissan-II." Manufacturers are pursuing additional refinements to address Agency concerns with the approach, such as the ability to simulate air compressor cycling and A/C loads at idle, which cannot be simulated on a dynamometer.

In 1990, Congress expressed its concern over the test procedures issued by EPA under this general authority, and mandated that EPA:

> Review and revise as necessary the regulations under subsection (a) and (b) of this section regarding the testing of motor vehicles and motor vehicle engines to insure that vehicles are tested under circumstances which reflect the actual current driving conditions under which motor vehicles are used, including conditions relating to fuel, temperature, acceleration, and altitude. CAA Section 206(h).

For this rulemaking, EPA's authority stems from Section 206(a)'s delegation of authority to establish appropriate test procedures, as revised by section 206(h). While Section 206(h) provides general criteria to direct agency action, it delegates to the agency the authority to reasonably interpret the broad and ambiguous requirements of that provision. The text of Section 206(h), for example, requires that EPA review test procedures and make such revisions "as necessary." In addition, EPA is to "insure" that the "circumstances" under which vehicles are tested "reflect the actual current driving conditions" under which vehicles are "used." These terms are undefined and ambiguous. Congress did not identify exactly what test procedure revisions were required. Other than directing that EPA specifically consider certain testing conditions, such as fuel and temperature, the text of the Act indicates that Congress provided discretion to the agency to reasonably interpret and implement these provisions.

The legislative history confirms that Congress provided the Agency broad discretion with little specific guidance on how to exercise it. Section 206(h)'s provisions originated in the Senate. The Committee on Environment and Public Works reported a bill containing provisions nearly identical to those found in the current section 206(h), with certain additional requirements.[8] For example, the Committee bill required that EPA continue to review and revise these test procedures every four years. In addition, it required that the revised test procedures include

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S. Rep. No. 101-228, 101st Cong., 1st Sess. 633-4 (1990); reprinted at 5 A Legislative History of the Clean Air Act Amendments of 1990 at 8973-4 (1993) ("Leg. Hist."). This legislative history is reprinted as Committee Print, S. Prt. 103-38, 103d Cong., 1st Sess.

testing for evaporative emissions, and testing of trucks with a gross vehicle weight rating of six thousand pounds or more in a loaded mode approximating that rating. The bill passed by the Senate did not change these provisions.[9]

The Senate Committee Report provides a relatively limited discussion of this provision, describing in general terms the basic concerns motivating congressional action but providing little specific guidance on how the agency should conduct its task. First, the Report focuses solely on concerns over inadequacies with the chassis dynamometer test procedure used to test light duty motor vehicles, such as passenger cars and trucks, identified as the Federal Test Procedure (FTP). Second, the emission impacts from these inadequacies is a central focus. "Unfortunately, it has become apparent that emissions during vehicle operation in modes other than the ones on the test are not adequately accounted for in current test procedures." Finally, the primary remedy for this is reliance on more representative test conditions, through a requirement that "the Administrator ... revise the Federal test procedures (FTP) ... to assure that the FTP incorporates representative driving conditions throughout the nation." Other than these general indications of congressional intent, the Report contains no additional discussion clarifying the kind of test procedure review and revision required of EPA. This supports the view that the Senate bill provided EPA with discretion to reasonably interpret and implement this provision, with the agency to be guided by the concerns noted in the Report.

The subsequent legislative history further supports this interpretation. In Conference Committee, the Senate bill was revised to Section 206(h)'s current form. The ongoing four year review cycle was dropped, as were the specific references to evaporative emissions testing and testing of trucks with gross vehicle weight rating above six thousand pounds. The Conference Committee report does not discuss these changes, and the limited floor debate on this provision emphasizes the importance of emission control as a basic goal of this requirement.[10]

In these circumstances EPA has authority to adopt a

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3 Leg. Hist. 4373-4

1 Leg. Hist. 890, 1024.

reasonable interpretation of Section 206(h). Under Chevron U.S.A. Inc. v. Natural Resources Defense Council, Inc., 467 U.S. 837 (1984), a court reviewing an agency's construction of a statute it administers must first determine "whether Congress has directly spoken to the precise question at issue. If the intent of Congress is clear, that is the end of the matter." Id. at 842. If, however, "the statute is silent or ambiguous with respect to the specific issue" the question is whether EPA's interpretation "is based on a permissible construction of the statute." Id. at 843. In addition, "[i]f Congress has explicitly left a gap for the agency to fill, there is an express delegation of authority to the agency to elucidate a specific provision of the statute by regulation." Id. at 843-44. If the delegation is implicit, the agency may adopt a reasonable interpretation of the statute. Id. at 844. See also Natural Resources Defense Council, Inc. v. Reilly, 983 F.2d 259, 266 (D.C. Cir. 1993). Given the delegation of legislative rulemaking authority in Sections 206 and 301, and the lack of clear and unambiguous direction on the kind of review and revision that EPA must conduct, EPA's interpretation of section 211(h) should be upheld unless manifestly contrary to the Act. Chevron, 467 U.S. at 843-44.

Recognizing its discretion under Section 206(h), EPA believes that the following factors are of primary importance in implementing this provision, and properly reflect Congress' concerns over assuring increased in-use emissions control through reliance on test procedures that are more representative of real world conditions.

First, it must be recognized that any test procedure will induce manufacturers to design their product to pass the test under that procedure. However, emissions control over the conditions contained in the test procedure may or may not lead to adequate emissions control over conditions not covered by the test procedure.

Second, the primary goal of agency action under this provision is to obtain better in-use emissions control. The Agency's main goal is not controlling emissions in the lab, but controlling them in-use, under real world conditions. The Agency believes that in-use emissions will be controlled most effectively when the test procedures induce manufacturers to adopt control strategies that are effective over a broad range of representative in-use conditions, covering all of the major in-use conditions that significantly affect emissions from the fleet of motor vehicles. This would include, for example, driving patterns, ambient conditions, and fuel. Another important focus should be achieving emissions control under those circumstances when it is most needed, for example summertime conditions for ozone control, wintertime conditions for Carbon Monoxide (CO) control.

Third, EPA recognizes that no test procedure can be perfect, and should also reasonably reflect a wide variety of considerations such as time, expense, and repeatability. It should also reflect various additional concerns such as harmonization with the state of California, which also regulates motor vehicle emissions.

In light of these factors, EPA believes that its review and revision of the FTP under section 206(h) should lead to a test procedure with the following attributes: (1) a driving cycle that is representative of all major driving conditions that occur in-use and have a significant emissions impact, as well as representative of important driving events that have a significant impact on overall emissions even if they occur in only a small portion of in-use driving; (2) test conditions that are generally representative of ambient conditions that significantly affect emissions; (3) test fuel that is generally representative of in-use fuel in ways that significantly affect emissions. Achieving such a result would, in certain cases, call for removing test procedure flexibility to ensure that certain conditions are included in the test. The actual driving trace for a chassis dynamometer test uses that approach. In other cases, the test procedure would more appropriately be flexible and provide a range of potential conditions, allowing a valid test to be run under any condition within that range. The requirements for test fuel generally use that approach, adopting a maximum or minimum level for various fuel qualities, but allowing several different test fuels that fall within those ranges. EPA's review and proposal to revise the test procedure for motor vehicles reflects these various considerations.

The Agency's proposal is also based on two additional interpretations. The first of these is that Section 206(h) only addresses test procedures for light duty motor vehicles, and does not require that EPA review and revise the engine dynamometer test procedure used to test heavy duty engines. The second is that EPA has authority to adopt various emissions standards under section 202(a) along with the revised test procedure changes.

With respect to the kinds of vehicles addressed by Section 206(h), this provision requires that EPA review and revise test procedures "to insure that vehicles are tested" under appropriate conditions (emphasis added). The plain meaning of this is that EPA's review and revision should be directed at those procedures used to test vehicles, for example the chassis dynamometer procedures used for light-duty cars and trucks. Compliance with emission standards for heavy duty engines is measured by testing the engine on an engine dynamometer. Vehicles are not tested to determine compliance with these engine standards. The plain meaning of this text is reinforced by the legislative history, which indicates that Congress wanted EPA to review and revise those chassis dynamometer test procedures (the "FTP") described in the Report by the Senate Committee on Environment and Public Works.[11] The Agency, of course, retains authority to review and revise the heavy-duty engine test procedure as appropriate. That procedure was reviewed most recently when EPA determined that it need not revise the test procedure for heavy duty engines used to power urban buses.[12]

With respect to emission standards, Section 206(h) is silent on the impact, if any, that test procedure changes should have on emission standards. There is no indication in the text of this paragraph that Section 206(h) limits or restricts EPA's authority to establish emissions standards. The legislative history is also silent on this matter. The Agency therefore believes that it may propose emission standards along with test procedure changes, to the full extent otherwise authorized in the Act.

Section 202 provides EPA with broad general authority to adopt standards for emissions of air pollutants from motor vehicles. Section 202(a)(1) provides that:

> [t]he Administrator shall by regulation prescribe (and from time to time revise) in accordance with the provisions of this section, standards applicable to the emission of any air pollutant from any class . . . of new motor vehicles . . . , which in his judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare.

See fn. 1

CITE to Fed. Reg. for UB rulemaking, § 219(e)

This is a broad grant of authority to the Administrator to prescribe standards to regulate emissions that contribute to air pollution. There is no issue here whether the emissions regulated, hydrocarbons (HC)s, CO and Oxides of Nitrogen (NOx), contribute to air pollution, or whether this air pollution may reasonably be anticipated to endanger public health or welfare.

Emissions standards issued under Section 202(a) must, under Section 202(a)(2), provide appropriate lead time for technology development. Section 202(a)(2) mandates that any regulation under Section 202(a)(1) may only "take effect after such period as the Administrator finds necessary to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period." The appropriate lead time for the emissions standards proposed herein is addressed in a later section of this notice.

The emissions standards proposed today are not in conflict with Section 202(b)(1)(C), which prohibits EPA from changing the Tier 1 numerical emissions standards prior to model year (MY) 2004. Section 202(b)(1)(C) states that "[i]t is the intent of Congress that the numerical emission standards specified in subsection (a)(3)(B)(ii), (g), (h), and (i) shall not be modified by the Administrator . . . for any model year before the model year 2004." On its face this language does no more than prohibit modification of these specific numerical emissions standards. Other than this express limitation, it does not restrict the agency's authority and discretion under Section 202(a).

Under this proposal the Tier 1 numerical emissions standards are not revised, they continue in full force and effect. The new standards proposed today are in addition to, and not instead of, the Tier 1 standards. In combination with the test procedures used to measure compliance with these procedures, they address emissions not otherwise addressed by the Tier 1 standards and cannot be viewed as implicitly revising the Tier 1 standards.

The Agency is also proposing revisions to the test procedures used to measure compliance with the Tier 1 standards. The Agency believes that Section 202(b)(1)(C) limits EPA's ability to modify the Tier 1 numerical emissions standards to reflect a change in the effective stringency of the Tier 1 standards caused by any of the test procedure changes proposed herein. Section 202(b)(1)(C) would prohibit any relaxing of the Tier 1 standards based on test procedure modifications. This flows directly from the dual requirement that EPA review and revise the test procedures used to measure compliance with the Tier 1 and other standards, and that EPA not revise the Tier 1 numerical emissions standards prior to a set time. Congress clearly envisioned that the test procedure used to measure compliance with the Tier 1 standards could change. Congress did address the issue of changes to the Tier 1 standards, and instead of directing EPA to adjust the standards to account for any test procedure changes, Congress prohibited EPA from changing the numerical emission standards prior to MY2004.

The Agency does retain considerable discretion in establishing the appropriate effective date for the test procedure changes. Any impact on the stringency of Tier 1 standards is properly addressed through consideration of the appropriate effective date for the test procedure changes.

V. The Federal Test Procedure Review Project and Areas of EPA Concern

In response to the review requirement of the Clean Air Act Amendments (CAAA), the Certification Division of EPA's Office of Mobile Sources (OMS) initiated the FTP Review Project (the FTP Review) in November 1990. The first action of the project team was to perform an initial review of existing information to identify elements of the current FTP that might be of concern (justifying additional focus) and others that might not justify concern at this time.

Of immediate concern to EPA at the time were the LA4 representation of one element of in-use driving behavior: aggressive (high-speed and/or high-acceleration) driving. It was clear that the LA4 maximum speed of 57 mph excluded a significant fraction of higher-speed, in-use operation. Similarly, EPA suspected that an important fraction of in-use accelerations were more severe than those found in the LA4. The exclusion of one higher-acceleration driving trace as "unrepresentative" during the LA4 development effort ignored the potential for disproportionate emissions impact of such operation. A 1990 California Air Resources Board (CARB) study found much higher emissions, particularly for CO, during operation at high acceleration rates relative to those seen during FTP-level accelerations. One possible explanation of these emission increases is that the engines were not calibrated for emission control during the higher engine loads associated with aggressive driving, as these loads are not encountered during current FTP testing. However, insufficient data existed at the time to quantify the in-use frequency of aggressive driving events or the actual emission impacts. There were also concerns about other aspects of driving behavior that were not represented in the current test procedures for which no data existed, where engineering judgement indicated cause for concern. Thus, the Agency concluded that further information was necessary to properly represent actual driving conditions and began extensive research into driving behavior and conditions and their emission implications.

During the course of the research a number of other concerns with the current FTP were identified, including two additional concerns with the LA4 representation of in-use driving behavior. The first concern was start driving behavior, that is, behavior immediately following vehicle start up and initial idle. Start driving was suspect because truncation of the prototype LA4 trace brought the most aggressive operation close to the beginning of the cycle; driving survey data suggest this is atypical of in-use operation. The second concern was microtransient behavior (short timescale speed or throttle fluctuations). In-use driving survey data contain more frequent speed fluctuations than the FTP. The Agency speculated that speed fluctuations on the LA4 may not be representative because the resolution of the chart recorders used to generate the original LA4 traces was insufficient to show the true speed variation.

The Agency identified four elements of the current FTP in addition to concerns with the LA4 reflection of driving behavior: the duration of the soaks; the representation of air conditioner (A/C) load; representation of additional loads on the engine due to factors such as road grade, extra cargo, or trailer towing; and the adequacy of the dynamometer specification for representation of real road load.

With respect to soaks, EPA sought to determine if significant levels of emissions are missed by the current FTP because only very short- and long-duration soaks are reflected in the current structure. One related hypothesis was that differences in the cooling rates of catalysts and engines might lead to excessive emissions during intermediate-duration soaks.

Several aspects of the A/C load simulation were problematic. The current FTP adds load as a percentage of the base road-load horsepower curve, which means the FTP A/C load decreases with decreasing speed, while real A/C system loads relative to road-load horsepower are highest at low speed. Also, vehicles with different base horsepower curves end up with different FTP A/C load simulations, even if they have identical A/C systems. As in the case of aggressive driving behavior, incorrect representation of A/C loads during the FTP risks incorrect simulation of the emissions these loads would generate from an engine in-use.

Road grade, vehicle towing, and cargo also represent a load effect on the engine. Some driving situations, especially for trucks, substantially exceed the 300 lb passenger-plus-cargo allowance on the FTP. Also, the absence of road grade or vehicle towing simulations on the FTP means these actual in-use loads are not a factor in determining compliance with the emission standards.

Three aspects of the current FTP dynamometer configuration have the potential to misrepresent the actual road load experienced by vehicles in-use. First, the shape of the speed/load curve on current certification dynamometers is fixed and cannot be changed; the magnitude of the speed/load curve is adjusted by periodically calibrating the dynamometer at a single speed (currently, 50 mph). As a consequence, loads at speeds other than the calibration point can be misrepresented. Second, current FTP dynamometers cradle the vehicle drive wheels between two small (8.65-inch) rolls. Heating effects and pinching of the tire result in an unrepresentative simulation of road "surface." Third, the dynamometer rolls are currently uncoupled and the front roll (which bears the power absorber) spins somewhat more slowly than the rear (which provides the vehicle speed signal); this tends to bias the system towards underloading the vehicle.

The Agency analyzed three other elements of the FTP, and believes revising the current procedures is unnecessary at this time. The first such area is the altitude of testing. Given that EPA has the authority to perform vehicle testing at any altitude, and it currently exercises that authority, the Agency is not proposing to supplement by further regulation the altitude testing flexibility in current law. While it is possible that driving behavior may differ at high altitudes, EPA believes that any emission controls required for aggressive and microtransient driving will also be effective during high altitude driving.

The Agency's test procedure regulations include specifications for the test fuel used in emissions testing. This provision applies to emissions testing for purposes of certification, the Selective Enforcement Audit program, and in-use compliance testing. See 40 CFR 86.113-94. This regulation includes specifications for gasoline, methanol, and diesel test fuel. In addition, EPA's regulations specify that service accumulation fuel used during the certification process must be representative of commercial fuel available through retail outlets.

The specifications for gasoline test fuel address octane, sensitivity, lead, phosphorous, various distillation parameters, sulfur, Reid Vapor Pressure (RVP), and levels of olefins, aromatics, and saturates. In certain cases a range is allowed, as with distillation characteristics, and for other parameters a maximum or minimum is provided. For diesel test fuel, the regulation addresses cetane number and index, gravity, sulfur, levels of aromatics and paraffins, flash point, and viscosity. For methanol test fuel, the regulation addresses percentage of methanol, and requires that the methanol fuel be representative of commercially available methanol fuel.

An analysis of the gasoline specifications must take into account two major factors that have occurred since the 1990 Amendments of the CAA. First, several major fuel regulations have been implemented with significant impact on the characteristics of in-use fuels. For example, the second phase of summertime RVP controls went into effect in 1992, reducing summertime RVP to either 9.0 psi or 7.8 psi. The reformulated and conventional gasoline requirements have also recently been implemented. Reformulated gasoline, affecting about 30 percent of the nation's gasoline, will lead to further reductions in summertime RVP, as well as reductions of benzene, aromatics, olefins, and sulfur. The conventional gasoline requirements affecting the remainder of the nation's gasoline supply will in large part preclude degradation in these qualities from their 1990 levels. Finally, various states have implemented a wintertime oxygen content requirement to reduce emissions of CO from motor vehicles.

A second major factor is that EPA's understanding of the emissions impact of various gasoline parameters has significantly improved. The Agency promulgated a complex model for use in the reformulated and conventional gasoline program, reflecting the results of several major testing programs conducted by EPA, and automobile and oil industries. This model predicts the in-use emissions from 1990 type motor vehicles, based on the gasolines levels of oxygen, sulfur, RVP, various distillation characteristics, and levels of benzene, aromatics, and olefins.

See 40 CFR 80.45. (59 FR 7818, February 16, 1994).

The reformulated and conventional gasoline regulations also contain a baseline gasoline, based on a statutory summertime baseline and EPA's analysis of average 1990 wintertime gasoline. See 40 CFR 80-91(c)(5). (59 FR 7862, February 16, 1994). While this baseline may not exactly represent average 1990 gasoline, it does provide a valuable benchmark for purposes of this analysis.

An analysis of the specifications contained in the existing regulations for gasoline test fuel shows that in general they provide the Agency and industry with the flexibility to use a test fuel that is fairly representative of in-use fuel, without adopting the post-1990 fuel requirements directly into the specifications. For example, the allowable range for the distillation characteristic T-50 includes the baseline value for T-50, while the range for T-90 is slightly below the baseline value. The Agency does expect the average in-use values of T-50 and T-90 to be reduced in reformulated gasoline. The specifications for aromatics and sulfur are set as maximums, and these maximums appear to be clearly above the baseline levels. The specification for olefins is slightly below the baseline, although EPA believes the baseline for olefins may be somewhat below the actual average levels in 1990 on an industry wide basis.

The only complex model parameters not specified for gasoline test fuel are benzene and oxygen. Benzene, an aromatic, was specified in the complex model for purposes of toxics control, which is not directly relevant to this particular rulemaking. The impact of oxygen content in the fuel will in large part be incorporated through dilution in the values of other parameters, such as sulfur, olefins, or aromatics. Furthermore, the levels in oxygenated fuels are typically such that an average oxygen content for certification fuel would be inappropriate.

At this time, EPA is not proposing any changes to the regulatory specifications for gasoline test fuel. The current specifications appear to provide the Agency with the flexibility to use a variety of test fuels, ranging from gasoline that reflects the average qualities of in-use gasoline, to gasoline reflecting some of the less typical in-use fuels with qualities that could significantly affect emissions. As in-use fuels change over time, this flexibility will allow the Agency to change the qualities of the test fuel used if appropriate. Specifically, the specified range for RVP includes average summertime RVP levels for those areas outside of the program. This covers a large percentage of the nation's gasoline, and will ensure that in-use emissions reductions from reformulated gasoline will be in addition to, and not instead of, reductions based on the motor vehicle emissions standards. For sulfur and aromatics, the test fuel specifications are set at maximums that clearly allow a range of fuels from very "clean" to "dirty." The maximum for olefins is closer to the average, but is still fairly representative of expected in-use averages.

The Agency has reviewed the specifications of the gasoline test fuel typically purchased by EPA and industry for emissions testing. This fuel, called Indolene, does appear to be significantly different from average in-use fuels in certain parameters that can significant impacts on emissions. For example, changes to sulfur levels can affect CO, HC, and NOx emissions; different olefin content can affect NOx levels, and the concentration of aromatics can affect HC and NOx. The Agency will continue to review this issue to determine whether any changes should be made in the kind of gasoline that is purchased for certification testing. However, as noted above, the current regulations provide the flexibility needed in this kind of situation. A change in the regulations themselves would not appear warranted at this time.

The specifications for methanol test fuel are much less detailed, based in large part on the different characteristics of that fuel and the relatively limited penetration of this fuel into the marketplace. However, as with gasoline, the regulations require the use of a fuel that is representative of commercially available methanol fuel. This continues to be a reasonable specification given the above circumstances.

For diesel test fuel, the fuel specifications are like those for gasoline in that they specify various ranges, maximums and minimums for several fuel characteristics. As with the specifications for gasoline test fuel, these appear to allow Agency flexibility to use test fuels that are representative of in-use diesel fuel, recognizing the requirements for in-use diesel fuels that went into effect in October 1993. See 40 CFR 80.29. The Agency is therefore not proposing any regulatory changes to the diesel test fuel specifications at this time.

Finally, EPA believes that it is unnecessary to further address the direct impacts of ambient temperature on FTP tailpipe emissions in this proposal. At the time the Amendments were adopted, the FTP evaluated tailpipe emissions performance in the midrange of temperature (68°F to 86°F), but omitted both cold and hot temperature testing. The emissions concern following cold temperature soaks and during cold temperature operation is increased CO emissions. This concern was addressed through EPA's Cold Temperature CO rulemaking[13]. The direct emissions impact during hot temperature operation is increased fuel evaporation.[14] This concern was addressed through the Agency's Evaporative Emissions rulemaking (footnote: 58 FR 16002). Ambient temperature also produces indirect emissions effects through increased operation of the vehicle A/C, which affects the load on the engine; this indirect aspect of temperature was addressed in EPA's detailed review of the FTP and is reflected in today's proposal.

The FTP Review project team found that existing information was clearly inadequate for evaluating potential revisions to the test procedures. Consequently, a number of new data gathering and analytical efforts were undertaken in connection with the project. In several of these efforts, EPA resources were supplemented by significant cooperative investments from other sources, including the American Automobile Manufacturers Association (AAMA), the Association of International Automobile Manufacturers (AIAM), and CARB. These studies provided EPA with unprecedented data on which to base its comparative review with the FTP and to construct the options presented in today's proposal.

VI. Survey of In-Use Driving, Soak Behavior, and Air Conditioner Usage.

The first critical need in reviewing the FTP was a current database on in-use driving and vehicle soak behavior. The Agency quickly determined that existing data for this purpose were far from adequate. Consequently, EPA collaborated with AAMA, AIAM, and CARB over the spring and summer of 1992 to conduct surveys of in-use driving and soak behavior in four major U.S. cities. The

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17 FR 31888 (July 17, 1992)

Hot ambient temperatures should not otherwise affect tailpipe emissions, as the engine and combustion temperature are not directly affected in any significant way by temperatures exceeding 86°F.

following provides a summary of EPA's conclusions.

A. In-Use Driving Behavior

The Agency employed two survey methods to gather basic data on the speeds and accelerations found in actual in-use driving. In the "instrumented vehicle" approach, digital dataloggers were installed in private owner vehicles to record second-by-second speed and engine parameter data over a period of seven to ten days. Separate "chase car" studies used laser rangefinder technology in a "patrol" vehicle to calculate vehicle speed of targeted in-use vehicles operated over predetermined routes.

Instrumented vehicle surveys sponsored by EPA, AAMA, and AIAM were conducted on a sample of 150 vehicles in Baltimore, Maryland, and 144 vehicles in Spokane, Washington. An additional 101 vehicles were instrumented in Atlanta, Georgia, in a cooperative effort between EPA's Office of Research and Development and the Georgia Institute of Technology. Chase car studies funded by EPA were conducted on 218 routes in Baltimore and 249 routes in Spokane; CARB-funded chase-car work was performed on 102 routes in Los Angeles.

In May of 1993, EPA published its initial findings regarding driving behavior in the "Federal Test Procedure Review Project: Preliminary Technical Report"[15]. The discussion below focuses on aspects of in-use driving behavior not represented by the LA4, including start driving, aggressive driving, and microtransient driving behavior.

The Preliminary Technical Report analyses were largely based on the Baltimore survey data. Subsequent analysis has been completed on the larger, three-city instrumented vehicle database, and the three-city results were found to be consistent with the Baltimore-only results. The three-city analysis showed that while the majority of in-use driving is similar to LA4 driving, nearly 13 percent of vehicle operation time occurs at combinations of speed and acceleration that fall outside the matrix of speeds and accelerations found on the LA4 driving cycle. The maximum observed in-use speed was 95.5 mph, compared to the LA4 maximum speed of 56.7 mph, and slightly more than

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U.S. Environmental Protection Agency, Federal Test Procedure Review Project: Preliminary Technical Report, EPA 420-R-93-007, May 1993 seven percent of in-use vehicle operation time was spent at speeds greater than 60 mph. Average speed from the three-city in-use data was 25.9 mph compared to 19.6 mph over the LA4.

Another speed-based measure, specific power, is useful when analyzing aggressive driving behavior.[16] Measures of power also indicated that in-use driving behavior was more aggressive than reflected in the LA4. Specific power in the three-city sample ranged up to 723 mph^2/sec and averaged 47.0 mph^2/sec. The LA4 has maximum power of 192 mph^2/sec, and an average of 38.6 mph^2/sec.

The Agency analyzed the in-use survey data to determine how the above findings on speeds, accelerations, and power measures were affected by other factors, including vehicle type (car/truck), transmission type, vehicle performance level, time of day, and day of the week. The first three vehicle-related factors are relevant to this rulemaking and the findings are summarized below.[17]

Trucks falling in EPA's light, light-duty classification (LLDTs, or trucks with gross vehicle weight [GVW] less than 6000 lbs) were found to have speed-acceleration profiles that were similar to light-duty vehicles. However, heavy, light-duty trucks (HLDTS, or trucks between 6000 lbs GVW and 8500 lbs GVW) spend less time at higher speeds than LLDTs and Light-Duty Vehicles (LDV)s, and during that limited time, they are driven less aggressively.

The Agency compared the 60 manual transmission vehicles from the combined Spokane and Baltimore databases to the 106 vehicles with automatic transmissions by analyzing the fraction of vehicle operation time spent in a high power mode. The

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The power needed from an engine to move a vehicle is proportional to both the vehicle speed and the acceleration rate. Neither variable, by itself, is a good measure of the load placed on the engine. The joint distribution of speed and acceleration is probably the best measure, but it must be examined in three dimensions, which is difficult to visualize and comprehend. The concept of specific power provides a two-dimensional measure which is roughly equal to 2*speed*acceleration and has the units of mph^2/second

For a more detailed discussion of the analysis see US06 Technical Report analysis suggested that manual transmission vehicles are driven more aggressively and that control programs for aggressive driving emissions might need to treat vehicles differently according to their transmission type.

In order to evaluate the relationship between vehicle performance and driving behavior, EPA focused on specific power as a measure of driving aggressiveness and the ratio of equivalent test weight to peak horsepower (W/P) as a measure of vehicle performance. While the amount of aggressive driving behavior is similar for the majority of vehicles at moderate performance levels, the Agency found that there is a correlation between vehicle performance and aggressive driving behavior at the ends of the performance distribution; high performance vehicles tended to be driven more aggressively, while low performance vehicles tended to be among the least aggressively driven.

In addition to looking at the nature of aggressive driving in-use, EPA also separately examined start driving behavior. Based on the instrumented vehicle survey data, EPA determined that the start driving (operation following the initial idle and before coolant temperature exceeded 140°F) in the survey data generally did not exceed 240 seconds. Further analysis showed that the speeds of start driving did not change substantially following soaks of different durations, but they did differ from those found in hot stabilized driving. The results for in-use initial idle time and start driving are different than the representation of these elements in the FTP. The LA4 Cycle has atypical high speeds over the first four minutes of a vehicle trip. On the other hand, the LA4 has substantially less aggressive accelerations than the first 80 seconds or so of typical in-use start driving, while it is substantially over-aggressive when compared to the succeeding 160 seconds. For initial idles, the FTP presumes 20-second durations for both cold and hot starts, whereas the in-use averages from EPA's data were 28 seconds for cold starts and only 12 seconds for hot starts.

The previous discussion of in-use speeds and accelerations presents a snapshot of driving behavior. Although the acceleration measure, which looks at the <u>change in speed</u> from one second to the next, partially characterizes the transient nature of driving, there are other measures which expand the time interval to examine the small-scale deviations in speed, or microtransients. One measure, referred to as jerk, is equal to the <u>change in acceleration</u>. A related measure is the second-to-second change in specific power. Conceptually, this measure captures the change in the power requirement imposed by the driving behavior.

The Agency used the three-parameter instrumented vehicle data from Baltimore, Spokane, and Atlanta to calculate these microtransient measures for in-use driving behavior and compared the results to the LA4's representation. The measures of jerk and change in power are shown in Table 7 below.

Table 7: Measures of Microtransient Driving from Instrumented Vehicle data/sec

Source	Jerk		Change in Power	
	Mean of the absolute values (mph/sec)	STD Deviation (mph/Sec)	Mean of Absolute Values (mph^2/sec)	STD Deviation (mph/Sec)
In-Use Driving	0.47	0.89	20.48	34.36
LA4	0.36	0.63	14.96	22.96

For both jerk and change in power, the mean of the absolute values was used in order to incorporate both the positive and negative values (the mean of the signed values of jerk is always equal to zero). The in-use means were higher than those for the LA4, indicating larger in-use changes in acceleration and power, as well as reflecting, in part, the LA4's acceleration rate cutoff of 3.3 mph/sec and the maximum speed of 57 mph. The standard deviations of jerk and change in power are probably a better measure of microtransient behavior. Again, in-use data show larger values for both measures. The greater variation around the mean demonstrated by the in-use data suggests that the LA4 does not adequately represent the microtransient nature of in-use driving behavior.

B. Soak Behavior

The survey data were also analyzed to determine the frequencies at which soaks of different durations occurred in-use. The Agency found that soaks of less than ten minutes and greater than eight hours occur with the highest frequencies in use. However, EPA also found that a significant portion of in-use soaks are of intermediate duration. For example, nearly 40 percent of all soaks in the Baltimore survey data were between ten minutes and two hours. Given that the current FTP employs only two soaks (the 10-minute hot soak and the 12- to 36-hour cold soak) to represent the range of soaks in-use, EPA was concerned that the current FTP might not adequately control for emissions following these intermediate-duration soaks.

C. Air Conditioning

A number of variables affect the range of A/C usage, particularly temperature, sun load, and humidity, all of which vary by season, time of day, and geographic location. Given that the overall goal of the Act is to help bring localities and regions into compliance with the National Ambient Air Quality Standards (NAAQS), the Agency chose to focus attention on the contribution of A/C to vehicle emissions during typical high ozone situations. Analyses revealed that ozone exceedances typically occur on days with a mean ambient temperature of 95°F, 30-40 percent relative humidity, and limited cloud cover.

In August and September 1994, the Agency conducted an instrumented vehicle study in Phoenix, Arizona. Twenty vehicles were instrumented for periods of up to two weeks, and data pertaining to vehicle and A/C operation were gathered on a trip basis. The mean daily high temperature during the study was 98°F, with highs typically occurring at about 4:00 p.m. Preliminary analyses of the survey data indicate that the average A/C usage was 77 percent for days that reached a peak temperature between 90°F and 100°F. The compressor was actually engaged 79 percent of the time the A/C was in-use. Thus, the compressor was engaged 61 percent of the time for days with a peak temperature between 90°F and 100°F.

D. Additional Elements Affecting Engine Load

A comprehensive evaluation of additional elements affecting engine load would require surveys of the frequency of occurrence of the elements in-use, as well as evaluation of interactive effects with driving behavior. For road grade, a 1980 EPA report[18] indicated that positive road grades average 1.66 percent nationally and that roughly six percent of national vehicle miles traveled (VMT) is spent on grades of four percent or higher. The Agency sought to supplement this information with driving behavior data over road grade, gathered during the chase car portion of the in-use driving surveys. Unfortunately, problems with noise and insufficient resolution on the measure of grade rendered the data inadequate, and no alternative data source was available. In addition, EPA was unable to conduct in-use surveys in the areas of passenger/cargo loading and trailer towing, due to the scope and nature of the necessary survey instrument. As a consequence, EPA has insufficient data for use in evaluating the additional elements affecting engine load that were originally identified as areas of concern.

VII. Representative Driving Cycles

In order to evaluate the emission impacts of in-use driving and soak behavior, EPA designed driving cycles that were representative of the in-use survey results using segments of actual in-use driving survey data. To maintain a high level of coordination between the EPA and CARB, the data set used in developing the in-use cycles was the combined driving survey data from EPA's Baltimore instrumented vehicle study and CARB's Los Angeles chase car study. The Agency developed separate cycles for start driving and aggressive driving. To complete the representation of in-use driving behavior for emission assessment purposes, a third cycle, the Remnant Cycle, was developed to characterize in-use driving behavior not represented by either the start or aggressive driving cycles. Concurrently, EPA determined weighting factors to reflect the fraction of in-use operation represented by each cycle; these factors are used to properly weight the emissions from the cycles when doing an emission assessment.

"Passenger Car Fuel Economy: EPA and Road.", US EPA, Report No. EPA 460/3-80-010, September 1980, p. 119.

The Agency chose to develop individual cycles rather than a single "representative" cycle in order to evaluate EPA's areas of concern independently. This is most critical in the case of aggressive driving where both capturing the diversity of aggressive driving behavior and representing it proportionally in a single cycle covering all in-use operation would lead to a very long cycle.

The Agency used the same basic cycle development methodology for each of the three representative cycles. A database covering the desired subset of in-use driving (non-LA4 operation, for example) was isolated from the survey data.[19] A distribution of the observed combinations of speed and acceleration was constructed from the database. This joint distribution of speed and acceleration became the design target for the new cycle. The cycles themselves were assembled from actual idle-to-idle driving segments (microtrips) drawn from the survey data. The approach was to iteratively select idle to idle segments from the database to improve the fit between the speed/acceleration distribution of the developing cycle and the target distribution based on the in-use data. Thousands of candidate cycles were generated and the "winning" cycle was the one with the best fit for a desired cycle duration. The software development and the necessary computer runs were performed by Sierra Research, Inc., under contract with EPA.

For the Start (ST01) Cycle, three target surfaces were developed from the database, representing three successive 80-second segments of in-use driving immediately following the initial idle. The combinations of speed and acceleration found in these distributions could largely be found in the LA4 Cycle, but with different percentages and in a different sequence. The microtrips that produced the best fit to these surfaces, together with an initial idle period that best matched in-use initial idles, generated a start cycle that was 257 seconds long. Testing using ST01 allowed separate determination of start driving emissions; ST01 was also used to quantify the emissions effects of varying soak duration.

The second cycle was the Aggressive Driving Cycle, also known as REP05. This cycle targeted speeds and accelerations, as

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"Federal Test Procedure Review Project: Preliminary Technical Report", US EPA, 420-R-93-007, May, 1993 well as microtransient effects, not covered by the current LA4. The in-use data points used in developing the REP05 target surface were those with combinations of speed and acceleration that were not represented on the LA4 Cycle (non-LA4) and, in addition, were not part of the ST01 target surfaces. These points tended to be either high-speed or high-acceleration (or both). By assembling the cycle from actual idle-to-idle driving segments, however, the cycle necessarily included some speed/acceleration combinations that were represented on the LA4, amounting to about 30 percent of the cycle's 1400 seconds. The average speed of REP05 is 51.5 mph, the maximum speed is 80.3 mph, and the maximum acceleration rate is 8.5 mph/sec.

The Remnant Cycle was intended to represent the balance of in-use driving not already covered by ST01 or REP05. Thus, the remnant target surface was obtained by using the remaining speed/acceleration distribution after subtracting that found in the in REP05 and STO1. Though much of the 1237 seconds in the Remnant cycle is LA4-like driving, there are some non-LA4 segments (at low speeds, with high acceleration rates) which were not captured by the REP05 cycle. In addition, the Remnant Cycle has greater speed variation than is found on the LA4.

Speed versus time traces of the three EPA representative driving cycles are reproduced in Figures 2 through 4.

INSERT FIGURE 2 - NOT AVAILABLE IN THIS ELECTRONIC VERSION

INSERT FIGURE 3 - NOT AVAILABLE IN THIS ELECTRONIC VERSION

INSERT FIGURE 4 - NOT AVAILABLE IN THIS ELECTRONIC VERSION

It seemed clear from the in-use survey data that the issue of accurately representing microtransient driving behavior cuts across start, aggressive and remnant driving. That is, small timescale speed fluctuations, including ones not well represented on the LA4, could be found in all types of in-use vehicle operation. The Agency's use of actual microtrips as the building blocks for the three representative cycles directly incorporated in-use microtransient driving behavior into all three cycles.

The Agency has assumed that driving behavior is not affected significantly by A/C operation and that the representative driving cycles developed from the in-use driving survey data are equally applicable to testing with the A/C system on and off. In fact, even though the Atlanta driving survey was the only one of the three surveys conducted during the summer, that city had the most aggressive driving of the three cities. Thus, it does not seem likely that A/C operation could have a significant impact on driving behavior. Nonetheless, the Agency welcomes data and comment on the relationship between A/C operation and driving behavior.

VIII. Emission Inventory Assessments

An assessment of emissions from four areas for potential emission control was conducted using the representative test cycles developed from the survey data. A full description of the test programs and the results can be found in the Technical Support Document. The first section on in-use driving behavior includes both aggressive and microtransient driving behavior. This is followed by sections on intermediate soak, air-conditioning, and other elements which affect engine load.

A. In-Use Driving Behavior

The FTP Review's emissions assessment of in-use driving behavior was based on a vehicle emissions test program conducted cooperatively by EPA, CARB, AAMA, and AIAM during 1993 and early 1994 (referred to subsequently as the Non-LA4 Emissions Test Program).[20] In the EPA portion of the program, completed in August 1993, eight well-maintained, 1991-1993 model year, fuel-

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EPA's assessment was limited to EPA's and the AAMA/AIAM data. Due to differences in testing hardware, CARB's emission results were not directly comparable.

injected vehicles completed testing over the LA4 (505 plus 866) and the three representative in-use cycles (REP05, ST01, and the Remnant Cycle). All tests were run in hot stabilized condition so that the effects of speed and acceleration could be separated from soak effects. The in-use weighting factors, determined as part of the cycle development effort, were applied to the bag results to generate predictions of hot stabilized emissions based on the EPA representative cycles for comparison to the LA4 cycle. For example, the REP05 cycle represents about 28 percent of miles driven for Baltimore and Los Angeles dataset; thus, emissions from REP05 were multiplied by 28 percent for inclusion in the total in-use emissions. The factors used for ST01 and the Remnant Cycle were 24 percent and 48 percent, respectively.

On the basis of the EPA data, the project team concluded that the LA4 underpredicts actual in-use hot stabilized emissions by 0.043 g/mi NMHC, 2.8 g/mi CO, and 0.083 g/mi NOx on modern-technology, properly operating vehicles.[21] These numbers do not have any direct bearing on the FTP standards. They are simply an estimate of the additional amount such vehicles actually emit in-use, compared to the FTP test results.

Table 8 shows the percentage contribution to the in-use emission increase from the ST01, Remnant, and REP05 Driving Cycles, weighted by their respective proportion of in-use driving. As expected, the aggressive driving of REP05 contributed significantly to the difference. More surprisingly, however, significant contributions to the increase also came from the Start and Remnant Cycles, particularly for NMHC and NOx. Table 9 provides analysis of the same database on gram-per-minute basis, which eliminates the effects of speed differences between the cycles. These data still show that start and remnant driving are significant contributors to the FTP's shortfall with respect to in-use driving behavior.

Table 8: Contributions to the In-Use g/mi Increase by Three Types of Driving

Driving	NMHC	CO	NOx
All (In-Use Increase)	0.043 g/mi	2.784 g/mi	

These estimates are only for the emission under-prediction related to driving behavior. Other factors such as soak are addressed in the sections to follow.

			0.083 g/mi
Start	30.2%	17.1%	23.0%
Remnant	33.8%	25.0%	45.6%
Aggressive	36.0%	57.8%	31.4%

Table 9: Contributions to the In-Use g/min Increase by Three Types of Driving

Driving	NMHC	CO	NOx
All (In-Use Increase)	0.018 g/min	1.131 g/min	0.041 g/min
Start	25.6%	15.2%	14.9%
Remnant	28.2%	22.2%	31.0%
Aggressive	46.2%	62.6%	54.1%

The AAMA/AIAM portion of the program was conducted in late 1993 and early 1994. This 26-vehicle, eight-manufacturer program included hot stabilized testing with REP05, the 505, and the 866, but none with the Remnant or Start Cycles; thus, a complete assessment of in-use hot stabilized driving could not be conducted with the manufacturers' data. Nevertheless, comparisons were made between the EPA and manufacturer program results for REP05 as well as the difference between REP05 emissions and hot stabilized LA4 emissions. In looking at the emission difference between REP05 and hot LA4, the LDV and LLDT average for the EPA tested vehicles was 0.04 g/mi while it was 0.06 g/mi for the vehicles tested by the manufacturers. The CO emissions tracked better, with the REP05 and hot LA4 difference of 5.71 g/mi for EPA and 5.32 g/mi for the manufacturer tests. The manufacturer testing showed a much larger NOx differential. The NOx difference between REP05 and hot LA4 was 0.25 g/mi for the manufacturer's testing while only 0.09 g/mi for EPA testing. The non-methane hydrocarbons (NMHC) and CO differences are primarily among the LLDTs, while the NOx difference was found in LDVs and LLDTs. The Agency did not test any HLDTs, however, the manufacturers results showed these vehicles as having the largest gram-per-mile increases from hot LA4 to REP05. This comparison suggests that the EPA emission assessment should provide a reasonable, if not conservative, estimate of in-use emissions.

B. Emissions Following Intermediate Soaks

The Agency conducted the assessment of in-use emissions following intermediate soaks using data from EPA's Soak/Start Test Program, conducted in two phases between July 1993 and June 1994. The testing represented the soaks observed in the driving survey data, using nine intervals: no soak, the FTP soak intervals (10 minutes and overnight) and six intermediate-duration soaks (ranging from 20 to 120 minutes).[22] Six LDVs were tested, including three vehicles meeting the current 49-State ("Tier 1") emission standards and three vehicles certified to the previous ("Tier 0") standards but Tier 0 with catalyst technologies typical of Tier 1 vehicles. One Tier 1 LDT (a minivan) was also included. The primary cycles used to measure post-soak emission levels for the emissions assessment were variations of EPA's representative Start Cycle, ST01.

Post-soak emissions in the Soak/Start Test Program, measured over the ST01 cycle, increased steadily and sharply as soak duration incremented between ten minutes and one hour. The average ST01 emissions for all vehicles tested for NMHC, CO, and NOx were higher following the 60-minute soak than they were for the 10-minute soak by factors of seven, two, and four, respectively. The increases were significant in absolute terms as well; for example, the average NMHC emissions on three Tier 1 vehicles went from about 0.05 g/mi following the 10-minute soak to over 0.50 g/mi following the 60-minute soak. The rate of increase moderated with soaks longer than 60 minutes, such that emissions of all constituents following a two-hour soak were within 50 percent of cold soak levels. The subset of Tier 1 vehicles in the EPA program showed similar percentage increases as a function of soak duration relative to the Tier 0 vehicles, although the average emission levels of these vehicles were lower than the Tier 0 vehicles.

C. Emission Inventory Assessment of In-Use Air Conditioning Operation

The Agency conducted three test programs and participated cooperatively with AIAM and AAMA in an additional test program during late 1993 and early 1994 with the purpose of assessing in-

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In the current FTP, vehicles are soaked 12-36 hours prior to Bag 1 to represent an overnight ("cold") soak, and 10 minutes between Bags 2 and 3 to represent a "hot" soak use emissions due to A/C operation. Detailed descriptions of all of these programs and the results are contained in the Final Technical Report on A/C for the Federal Test Procedure Revisions Notice of Proposed Rulemaking (available in the public docket for review).

The first August 1993 program, by comparing emissions results with the ten percent dynamometer road-load horsepower adjustment to emissions obtained with the A/C actually operating, confirmed that the current A/C simulation method significantly underrepresents the actual load of the A/C on the engine.[23]

The second August 1993 program went beyond the current FTP by testing A/C impacts on three vehicles over the three representative cycles (REP05, ST01, Remnant) as well as over the LA4. As in the first program, results from this testing demonstrated an overall increase in actual emissions with the A/C operating. In particular, the magnitude of the NOx increase in both programs was much larger than expected and caused the Agency to focus further research and analysis on the effects of A/C operation on NOx emissions.

The third test program was very similar to the second but was designed to collect second-by-second emissions and vehicle operating data, again on three vehicles. Analysis of this data indicated that the most significant A/C related emission impacts were occurring during idles and accelerations; on the LA4, start, and Remnant cycles the combination of idles and accelerations accounted for more than 80 percent of the total observed NOx increase. As was the case in the previous program, the overall increases in NOx were heavily weighted towards the moderate and lower speed driving of the ST01, Remnant, and LA4 cycles, although some increases were seen on the REP05 cycle.

A detriment of these test programs is that they did not adequately or fully represent the actual conditions under which A/C systems are likely to be operated. To provide the most accurate real-world loads possible to the A/C system, an emissions testing program was developed and funded by vehicle manufacturers, the objective of which was to test vehicles under an accurate simulation of environmental conditions and vehicle speed in a sophisticated environmental test facility. The Agency and manufacturers agreed to cooperatively define a set of

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In fact, the Agency believes that the effect on emission values of the additional ten percent dynamometer road-load horsepower is negligible and unobservable within the range of current test-to-test variability.

environmental and meteorological parameters to represent a typical ozone non-attainment day. Based on EPA and manufacturer research and analysis of typical ozone exceedance days, the following meteorological conditions were reflected in the test program: an ambient temperature of 95°F, 40 percent relative humidity, and a solar load of 850 Watts/meter2. In addition, a pavement temperature of 135°F and an initial vehicle cabin temperature of 130°F were simulated.

Eight vehicles certified to the EPA's Tier 1 emission standards with HFC-134a A/C refrigerant systems were tested in the program.[24] Once again, the effects of A/C operation were most pronounced on the moderate-to-lower speed cycles. On a hot stabilized LA4 the average increases were 0.011 g/mi for NMHC, 0.3 g/mi for CO, and 0.205 g/mi for NOx. These figures best represent the in-use emissions increase due to A/C operation. Emissions were also gathered on the "cold start" bag of the FTP with the A/C operating, where a different picture was seen due to the fact that the catalyst is not operational for much of the exhaust test. The average increases from A/C operation on the cold start were 0.067, 1.459, and 0.256 for NMHC, CO, and NOx, respectively. Similar to the earlier discussion about the emission impact of in-use speeds and accelerations, these increases are simply an estimate of the additional amount modern technology vehicles actually emit in-use with the A/C engaged, compared to the FTP test results. The increases observed on the REP05 cycle were smaller than on the LA4, but still noteworthy due to the performance of several of the vehicles, causing the Agency some concern about the impact of A/C operation during aggressive driving behavior. Increases on REP05 were 0.017 g/mi for NMHC, 2.2 g/mi for CO, and 0.102 g/mi for NOx. Fuel economy decreased by about 13 percent on the REP05 with the A/C operating, substantially less than the 20 percent reduction on the LA4, further indicating that the A/C load as a proportion of total load tends to diminish as speeds and accelerations increase.

D. Emissions Assessment of Additional Elements Contributing to Engine Load

As part of the Non-LA4 Emissions Test Program, EPA conducted an evaluation of emissions 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

Data from one vehicle became suspect and was subsequently discarded.

increase of 0.04 g/mile, a highly variable CO increase averaging 3.2 g/mile, and a NOx increase (due largely to one vehicle) of 0.19 g/mile. 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. Controlling Emissions from Aggressive and Microtransient Driving Behavior

Aggressive driving behavior results in increased emissions. Several strategies may be used to control these emissions. The following discusses the causes, the options for control, and turning those options into emission control strategies and test procedures.

A. Identifying Causes of Aggressive-Driving Emissions

The Agency structured the Non-LA4 Test Program to serve several functions simultaneously: to perform the emissions assessment of non-LA4 driving behavior, to investigate possible causes of non-LA4 emissions, and to evaluate potential regulatory test cycles for emission control purposes. Thus, the testing with the EPA representative cycles described in the previous section was supplemented by testing with two additional cycles, each of which helped to identify causes of non-LA4 emissions and served as a candidate regulatory cycle. The first was the ARB02 cycle (1638 seconds in duration), developed by CARB from the Los Angeles chase car study to spotlight non-LA4 driving, including some extreme in-use events. The second was a high-load cycle named HL07 (420 seconds), developed jointly by EPA and AAMA, and consisting of a series of simple artificially generated acceleration events designed to force most vehicles into wide-open throttle.

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 A/C 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.

Commanded enrichment leads to increased emissions because it reduces the efficiency of the combustion process and decreases catalytic conversion. The AAMA/AIAM test program spotlighted commanded enrichment by retesting 15 of their 26 vehicles in a stoichiometric or "stoich" configuration (i.e., with the onboard computer reprogrammed to eliminate commanded enrichment), as well as in the "production" configuration.[25] AAMA/AIAM further supplemented the Agency's testing by providing second-by-second data acquisition capability for emissions and a variety of engine and emission control parameters, allowing fine scrutiny of individual driving events.

The Non-LA4 Test Program revealed several causes for the emission levels observed during aggressive driving behavior. As expected, the instantaneous and bag CO levels were both very sensitive to the presence of commanded enrichment. During one aggressive acceleration of the ARB02 cycle, the eight LDV's tested in production and "stoich" configuration averaged 8.3 seconds of commanded enrichment operation in the production configuration and a drop in air-fuel ratio from 14.6:1 (stoich) to 12.5:1 (production). The average tailpipe CO levels for the vehicles over that segment of driving dropped from 21.95 g/sec to 2.05 g/sec when the production configuration was replaced with the stoich configuration. The impact on the overall emissions for the ARB02 cycle was substantial. In the production configuration the average of the CO emissions was 15.1 gr/mi compared to 2.3 gr/mi for the "stoich" average. The data showed that the CO increases during enrichment reflected increases in engine-out CO as well as a drop in CO catalyst conversion efficiency, both the consequence of the oxygen-poor environment prevailing during commanded enrichment.

The Agency also isolated at least one driving event on a stoich vehicle where a drop in CO catalyst conversion efficiency may have resulted from catalyst breakthrough, that is, the inability of the catalyst to maintain highest conversion capacity in the face of high exhaust mass flow, despite the likely presence of sufficient oxygen to sustain catalysis. The magnitude of this phenomenon is unknown, although it should be restricted to infrequent high load events in a few vehicles.

The reprogrammed, stoichiometric configuration is not a true stoichiometric calibration. For the prototype test vehicles, only commanded enrichment was eliminated, and in some cases not all commanded enrichment seemed to be removed. Transient enrichment strategies would not have been effected by the calibration changes, and this is also the case for any lean-on-cruise strategies. Thus, while "stoich" is a useful and brief description of the recalibrations, it is a bit of a misnomer.

The average tailpipe (tailpipe refers to emission levels leaving the catalytic converter) HC levels over the same ARB02 acceleration event likewise showed an order-of-magnitude drop between the production and stoich configurations, from 0.343 g/sec to 0.037 g/sec. The overall NMHC emissions for the ARB02 cycle went from 0.22 gr/mi in production configuration to 0.05 gr/mi in the stoich configuration. However, the high tailpipe HC levels in the production configuration resulted primarily from a loss of HC catalyst conversion efficiency (although apparently not from catalyst breakthrough). The engine-out (levels emitted from the engine, but before it enters the catalytic converter) HC levels were relatively insensitive to the presence of commanded enrichment.

Increases in NOx emissions in aggressive driving were traced to both the engine-out and tailpipe exhaust. The likely explanation for higher engine-out NOx is that the higher loads seen in non-LA4 driving cause higher combustion temperatures to prevail, a condition that promotes greater NOx formation. High tailpipe NOx correlated with relatively poor NOx catalyst conversion efficiency, which in turn mirrored erratic air/fuel ratio control and either a lean-biased or unbiased control strategy. Low tailpipe NOx, on the other hand, correlated to tightly controlled air/fuel ratios and a slight rich bias. The importance of proper fuel control in response to throttle openings is also demonstrated by the Grand Prix, which did not have enough compensation for the lean spike following throttle opening and, hence, had greatly reduced NOx conversion efficiency following throttle openings. In addition, EPA did see isolated driving events indicating that NOx catalyst breakthrough might be occurring, though again with unknown frequency. Two vehicles in the Non-LA4 Test Program showed significant NOx increases during high-speed cruise, which was attributed to use of a lean-on-cruise strategy for increased fuel economy.

In summary, the Agency believes elevated HC and CO emissions during aggressive driving are due primarily to enrichment. High NOx emissions during aggressive driving, EPA believes, are due primarily to an increase in engine out NOx (from higher temperatures) and relative poor catalytic conversion, due to lean events resulting from erratic A/F fuel control, or an A/F control strategy which is not biased rich.

B. Identifying Causes of Microtransient-Driving Emissions

The Agency believes that enrichment during microtransient operation (transient enrichment) is a second cause of CO and HC emission increases. Microtransient driving behavior is characteristic of all in-use driving behavior (as discussed in Section VI) and EPA believes this behavior contributes to the elevated emissions found for of all of the in-use driving cycles, including the start and remnant cycles. The Agency tried to isolate this effect from commanded enrichment effects by focusing on the AAMA/AIAM stoich vehicles and the lone such vehicle in EPA's testing, a Mercedes 420 SEL. The measure of microtransient operation used in the analysis was delta throttle position (DTP), which is the sum of the one-second change in throttle position over any period of operation. The Agency found a statistically significant correlation between DTP and the emission differences between the stoich tests. As discussed in greater detail in the RIA, EPA believes the higher emissions during microtransients result from overcompensation by some vehicle designs for the lean spike that would typically accompany sudden throttle opening or momentary accelerations. (Lean spike refers to a short-duration change in the A/F to a lean operating condition--relative to stoich, more air for the same amount of fuel.) The overcompensation leads to an enrichment event and elevated HC and CO. As an additional concern, the Agency also considered the effects of hard decelerations, where an instantaneous rise in vacuum levels might flush fuel from the intake passages. Analysis indicated, however, that low mass flow levels during such events generated minimal overall emissions impacts.

The impact of microtransient operation on NOx emissions is not as well established as it is for HC and CO. EPA believes that the rapid throttle movement associated with microtransient driving behavior results in higher tailpipe NOx emissions as a result of erratic air/fuel control, as discussed in the previous section.

C. Candidate Strategies for Controlling Emissions from Aggressive and Microtransient Driving Behavior

The Agency considered five strategies that manufacturers might employ for addressing the causes of high emissions from aggressive and microtransient 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 NOx emission control systems. This section briefly discusses each of these strategies; subsequent sections will discuss the implications of each strategy on the design of the emission compliance program, the appropriate level of control, and issues of cost/benefit and feasibility.

The strategy of recalibration is actually composed of several options for bringing the air/fuel ratio into tighter control at, or very near, stoichiometry, and the option of recalibrating spark timing for better NOx control. Based on the

Non-LA4 Test Program results, the highest-impact options for CO and HC would be the reduction or elimination of commanded enrichment and transient enrichment during accelerations. Of lesser CO and HC impact would be control of hard deceleration emissions through decel fuel cutoff. The Agency projects that the highest-impact NOx control recalibration option would be tighter control of air-fuel ratios to minimize the size and duration of lean spikes. Optimization of the air/fuel ratio during non-LA4 operation just to the rich side (14.5:1 or 14.6:1) of stoichiometry may also be beneficial, although it would reduce CO conversion efficiency and may impact HC conversion efficiency as well. A second NOx control recalibration strategy would be elimination of the lean-on-cruise strategy. Finally, spark timing adjustments might be considered to reduce combustion temperatures, and thus reduce engine-out NOx levels.

Any feedback fuel metering system can be recalibrated with a design target of stoichiometric or no-commanded-enrichment operation. Nevertheless, the type of fuel metering technology itself limits how well recalibration can achieve this target. The precision of fuel control has generally increased as manufacturers have progressed from throttle-body injection (with one or sometimes two injectors mounted in the throttle body) to synchronous port fuel injection (with simultaneous-firing injectors mounted as close as possible to the intake valve ports) to sequential port fuel injection (which individually and optimally fires port injectors). Thus, one possible manufacturer strategy to address a need for tighter fuel control would be to upgrade the fuel metering system.

Similarly, the effectiveness of recalibration to control microtransient emission impacts faces a practical limit in the technology of the throttle mechanism. Systems with a conventional mechanical linkage from accelerator pedal through to the throttle plate, may employ electronic fuel control, but they are still reactionary -- the computer corrects fuel delivery based on an input signal from the throttle position sensor. In electronic (or "drive-by-wire") throttle control systems, the input signal comes from further "upstream," at the accelerator pedal, and the onboard computer proactively controls throttle position as well as fuel delivery. Manufacturers might therefore advance to drive-by-wire technology to achieve precision in air/fuel ratio control not attainable through simple recalibration of their mechanical throttle systems.

Catalytic conversion of HC and CO emissions resulting from commanded or microtransient enrichment is limited by the amount of available oxygen. Increasing catalyst size or noble metal loading would therefore not be an effective emission control strategy. As noted in Section VIII.A., however, some evidence of catalyst breakthrough was observed in the Non-LA4 testing program for both CO and NOx. Depending on the application and on the stringency of the emission standard, some manufacturers might therefore consider larger conversion capacity as a control strategy.

A final strategy manufacturers might employ is adding or increasing exhaust gas recirculation (EGR) to address engine out NOx increases during non-LA4 operation. Like spark timing, this strategy reduces combustion temperatures as a way to reduce engine-out NOx.

Of these strategies, the various recalibration options appeared to be the least costly, because each of the remaining strategies involved per-vehicle hardware modifications. In addition, data from the Non-LA4 test program also indicated that recalibrations would probably generate the greatest reductions in aggressive and microtransient-driving emissions.

D. Basic Approaches to Determining Standards and Test Procedures for Aggressive and Microtransient Driving Behavior Emission Control

The Agency evaluated three basic options for establishing standards and test procedures aimed at controlling emissions from aggressive and microtransient driving. Two options were based on emissions performance standards with emissions measured using a test cycle, and one option was based on a performance standard using the A/F ratio with a related test procedure. The Agency was guided by seven criteria in its the evaluation of the options. First, EPA sought an option that would lead to control of emissions over the broad range of aggressive driving behavior found in the in-use driving survey data. Second, due to the non-linear nature of HC and CO emission increase during enrichment, a high priority was to ensure sufficient content from the highest-emission operating modes to prompt manufacturers to employ appropriate control strategies, including curtailing commanded enrichment. Third, the Agency sought consensus with CARB, to avoid duplicate or incompatible test requirements. Fourth, EPA sought to take into account the technical input from the vehicle manufacturers, particularly manufacturer comment on the necessity of some commanded enrichment events to avoid elevated catalyst temperature levels from in-use operation leading to catalyst deterioration.[26] Fifth, EPA sought to pursue cost saving

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[26] The relationship between curtailing commanded enrichment and catalyst deterioration will be addressed in a discussion of feasibility, subsequently in this section.

elements like reduction in test time where practical. Sixth, the Agency sought practical control of microtransient enrichment, a candidate area of control that spans all driving. Finally, EPA favored strategies to control aggressive driving emissions that would also address the potentially significant (but unquantified) emissions from other engine load factors like road grade.

The first of the two emissions performance standard options evaluated by EPA used the representative aggressive driving cycle, REP05, for emission testing. Given the aggressiveness of the cycle, manufacturers would be motivated to appropriately calibrate vehicles for high load events, while still preserving catalyst integrity. Because the frequencies of speeds and accelerations in REP05 reflect the in-use frequencies of non-LA4 driving, employing this cycle for control purposes should translate directly into proportional control of in-use emissions from aggressive driving, i.e., reducing emissions ten percent on the cycle reduces in-use emissions by ten percent. However, because the cycle does not incorporate other load-increasing factors like road grade or increased vehicle loading, any combined effect with aggressive driving would not be addressed by REP05. In addition, the duration of the REP05 cycle exceeds 23 minutes, increasing testing costs and increasing driver fatigue. The cycle also misses some of the most aggressive events from the Los Angeles survey data, driving that was incorporated by CARB into the ARB02 driving cycle.

Working with substantial input from CARB and the vehicle manufacturers, EPA developed a second option by blending segments of driving from the REP05 and ARB02 cycles. This formed a new, shorter cycle, for use with an emissions performance standard (Figure 5). This 600-second cycle, called US06, preserves the range of non-LA4 operation, in-use microtransient behavior, and some of the most aggressive driving events of its predecessors. The speed and acceleration distribution is still representative of in-use, non-FTP distributions at most speeds and accelerations, however, the highest load conditions are over-represented. This should lead to control of in-use emissions from high-load events regardless of their cause (aggressive driving, road grade, vehicle loading, or combinations of these factors), while reducing the test time from over 23 minutes to 10 minutes. The shorter test time has the advantages of reducing the testing cost and driver fatigue.

INSERT FIGURE 5 - NOT AVAILABLE IN THIS ELECTRONIC VERSION

For the third option aimed at aggressive and microtransient and microtransient driving, EPA evaluated a proposal by one vehicle manufacturer for a system performance standard based on air/fuel (A/F) ratio using the HL07 cycle. This option would place standards on the duration or magnitude of deviations from stoichiometry, measured over the short HL07 cycle, instead of standards on emissions. The cycle was designed specifically to trigger enrichment events and the sole motivation of this option would be the control of commanded enrichment. This option has the advantage of being both short and inexpensive, since emissions would not be collected. However, drawbacks to this approach include: the lack of control for microtransient enrichment; lack of a suitable methodology for achieving NOx control; difficulties in devising an A/F standard for vehicles operating on diesel or alternative fuels, like compressed natural gas (CNG); and reduced manufacturer flexibility in designing a control strategy. This option effectively mandates a control strategy, while an emission performance standard provides manufacturers the flexibility to determine, case-by-case, the most cost effective way to achieve the desired emissions result.

Based on this evaluation, the option favored in today's proposal is an emissions performance standard based on the US06 cycle. However, EPA solicits comment on, and will consider adopting any of these options or any outgrowths of them.

E. Appropriate Levels of Emission Control During Aggressive and Microtransient Driving

Section VIII.B. identified recalibrations as the emission control strategy EPA believes will be the most cost effective. Thus, recalibration was the emission control strategy assumed in determining the appropriate levels of control and the most cost-effective control strategy for aggressive and microtransient driving. The discussion below assumes the US06 as the control cycle, thus, the discussion on appropriate emission levels are specific to the US06 cycle.

In determining appropriate levels of control, the Agency starts with the view that strategies that are appropriate for controlling emissions in the FTP regime have natural extensions that can be applied during aggressive and microtransient driving. The level of control that these strategies can achieve over aggressive and microtransient driving is pollutant specific, reflecting the different impact on the pollutant levels of factors like engine load and air/fuel calibration.

Engine-out hydrocarbon emissions, for example, vary directly with load on the engine. Thus, it should be possible to achieve comparable per-mile HC emissions over two cycles of comparable average load, as long as similar catalyst conversion efficiencies are maintained. The Agency tested this hypothesis on the 866 and US06 cycles using data from eight vehicles that were run in both the production and stoich configurations in the Non-LA4 Test Program. The 866 Cycle data, in hot stabilized condition, were drawn directly from Bag 2 of the FTP. The US06 data were simulated by splicing together the appropriate seconds of data from the US06 "parent" cycles, REP05 and ARB02, also in the hot stabilized condition. Comparisons of the fuel economy results from these tests confirmed that the US06 cycle, although clearly more aggressive in the speed and acceleration of its individual events, actually has a slightly lower average load (on a per mile basis) than the 866 Cycle.

For these same tests, EPA found that engine-out HC levels on the US06 cycle were less than engine-out HC emissions on the 866 Cycle, in both the production and stoich configurations, for every vehicle tested. At the tailpipe, US06 HC levels for the production tests were generally quite scattered and they exceeded the 866 HC levels. Coupled with the engine-out results, this indicates that catalyst conversion efficiencies in the production vehicles were lower during the aggressive driving of US06 than during the 866. In the stoich tests, however, only two vehicles had tailpipe HC levels that were higher on the US06 than on the 866, and one of these employed throttle-body injection vehicle, a declining technology with imprecise fuel control relative to fuel injection.

Based on these data, changes to the A/F calibration should allow HC catalyst conversion efficiencies to be achieved during aggressive and microtransient driving that are comparable to the levels currently achieved during hot stabilized driving on the FTP. Specifically, by eliminating commanded enrichment during most aggressive driving and otherwise maintaining tight A/F control, manufacturers can achieve a level of HC control that is comparable on a gram-per-mile basis to the level of control achieved during hot 866 testing.

Analysis of the same test data revealed a somewhat different situation for CO than for HC. First, engine-out CO levels are not consistent across cycles with similar average load, primarily because engine-out CO levels are extremely sensitive to even minor enrichment events. Thus, no production vehicle had engine out CO emissions on US06 that were anywhere near as low as the hot 866 CO levels. Even in the stoich configuration, five vehicles had higher engine-out CO emissions on US06 than on the hot 866 Cycle, indicating that microtransient enrichment or incomplete control of commanded enrichment were elevating CO levels in the US06 relative to the 866. In some cases, catalyst breakthrough may have occurred during particularly high mass flow events in the US06 cycle.

At the tailpipe, CO emissions of the production vehicle over the US06 cycle were still very high. The commanded enrichment not only increased engine-out emission levels, but also severely reduced CO conversion efficiency in the catalyst. Although the stoich vehicles fared much better, only one achieved tailpipe CO levels on US06 that were below the 866 emissions. These test results lead EPA to believe that even if manufacturers eliminated most enrichment events during aggressive driving, the high sensitivity of CO emissions to any enrichment would require additional control measures to achieve the CO levels of a hot 866 test. Depending in part on the cost-effectiveness of additional control measures, it might be appropriate to set the US06 control level at some margin above the 866 CO level.

Tailpipe CO levels are higher on the full FTP than they are on the 866 alone, in large part because CO catalyst conversion efficiencies are very low during the start driving portion of the cold start bag. Half of the stoich vehicles tested in the Non-LA4 Test Program would have complied, as tested, with current FTP composite standard. The Agency's analysis of the remaining vehicles indicated that in spite of the stoich calibration, their A/F control was poor. With tighter calibrations, these vehicles would also have control at levels comparable to the composite FTP. Thus, EPA believes that level of emission performance to be generally achievable by LDVs and LDTs.

Unlike HC, NOx emissions increase exponentially with load, and the aggressive accelerations of US06 produce higher instantaneous loads than those of moderate, FTP-like driving. Thus, EPA found that every one of the eight vehicles had higher engine-out NOx emissions on the US06 than on the 866 or even the composite FTP. In addition, almost all the vehicles showed engine-out NOx increases on the US06 of 10 to 20 percent in the stoich configuration relative to the production vehicles, suggesting that curtailing A/F enrichment would make NOx control more problematic.

On several vehicles in the stoich configuration, the tailpipe NOx emissions increased substantially more than the engine-out emission levels. In fact, a disproportionate increase came from mediocre catalyst conversion efficiency. Evaluation of the catalyst conversion efficiency impacts, for each vehicle tested, indicated that the vehicles with large drops in NOx conversion efficiency in stoich configuration also had fuel control which allowed significant lean A/F episodes. The two vehicles with relatively few lean events achieved stoich NOx conversion efficiency similar to, or better than, NOx conversion efficiency in production calibration. The Agency then determined the NOx conversion efficiencies that would have been required to control observed US06 engine-out NOx levels in the stoich vehicles to observed FTP NOx levels. The answer ranged between 86 percent and 95 percent. For half of the vehicles, the efficiency needed was at or below the NOx conversion efficiency actually observed over the 866 Cycle. On this basis, EPA believes that with adequate attention to A/F control, manufacturers can attain NOx conversion efficiencies during US06 operation that are on par with levels over the 866 Cycle, and in the process control NOx emissions to composite FTP levels on vehicles that are otherwise optimized for control of commanded enrichment.

One issue EPA has not fully evaluated is possible correlation between NOx and CO emissions. It is likely that the optimal control of NOx emissions would involve slight rich biasing of the A/F ratio to improve NOx conversion efficiency, and/or limited amounts of commanded enrichment to control engine-out NOx emission levels. Either strategy, if needed, could increase CO emissions. The Agency solicits comments on potential tradeoffs between NOx and CO control, and on the impact such tradeoffs could have on the appropriate level of CO control.

F. Feasibility

The first step in analyzing feasibility involves considering the availability of the core technologies used in the control strategy that will likely be used to produce complying vehicles. For emission control during aggressive and microtransient driving, the primary control strategy is expected to be recalibration of the existing fuel control strategies on fuel-injected vehicles. This core technology is already in place in the fleet. The ability of the various recalibration options to meet the proposed levels of control during aggressive and microtransient driving was addressed in the discussion of appropriate levels of control earlier in this section. The Agency identified HC, CO, and NOx levels that were achievable based on data from vehicles tested in the Non-LA4 Test Program. However, if manufacturers are to recalibrate their vehicles in order to comply with US06 standards at these levels, the effects on vehicle driveability, performance, and emissions durability must also be considered.

Optimization of fuel metering calibrations should, in general, improve driveability. The manufacturers reported no evidence of driveability problems during operation of the stoich vehicles in the Non-LA4 test program over the REP05 and ARB02 cycles. As noted in Section VIII.A., however, manufacturers frequently employ commanded enrichment as a power-enhancing strategy during operation under heavier loads. Thus, curtailing commanded enrichment has the potential for impacting performance on some vehicles. Manufacturer testing in the Non-LA4 Test Program did not include data that permits direct comparisons of engine horsepower in the production and stoich configurations, nor did the Agency possess any alternative source of data on stoich vehicles for performing such an analysis.

As a surrogate to comparing engine horsepower, EPA analyzed the duration of wide open throttle (WOT) operation between production and stoich US06 tests, seeking increases that might indicate significant power loss in the stoich vehicles. The changes in total WOT time across all events and in the duration of the longest continuous WOT event were determined for 11 Non-LA4 Test Program vehicles. The average production vehicle had a total of 14.6 seconds of WOT operation over US06, which increased by an average of 1.9 seconds (13 percent) in the stoich configuration. Some stoich vehicles showed substantially higher increases (e.g., the increase on one vehicle was 12.5 seconds, or 48 percent relative to the performance of the production configuration of that vehicle), while five vehicles actually had decreases (including one of 5.0 seconds, or 36 percent). The longest single WOT event for a production vehicle averaged 4.2 seconds, increasing by 0.4 seconds (ten percent) in the stoich configuration. The biggest such increase was 1.0 second, while one production vehicle saw its 3.0-second maximum WOT event drop to zero duration in stoich testing.

The broad range of WOT behavior observed, including vehicles with substantial decreases in WOT times in the stoich configuration, indicates there is no generic loss of power associated with removal of commanded enrichment. Based on further scrutiny of the data, EPA believes that two additional factors -- trace-to-trace driving variability and the fact that transmission shift schedules had not been re-optimized in the stoich vehicles -- overshadowed any power effects in the WOT data.

Manufacturers have voiced concern that removal of commanded enrichment could impose a two percent to ten percent power penalty. Beyond the foregoing discussion of WOT events, the Agency has no current basis, and manufacturers have not provided any additional information or data, to confirm or refute such claims quantitatively, or even to rationalize which part of a vehicle's performance range would incur such a penalty. In fact, more precise fuel metering systems should reduce the potential power penalty. In addition, the current FTP has not provided an incentive for manufacturers to probe the power potential of their systems in the absence of commanded enrichment. Further, power enrichment would not be precluded outright by this proposal, but rather curtailed only within the durations and speed-acceleration combinations found in the US06 cycle. Thus, the Agency believes on the basis of available data that compliance with the US06 standard should have a negligible effect on vehicle performance.

The second reason manufacturers employ commanded enrichment is to reduce engine and catalyst temperatures. A control strategy based on restricting commanded enrichment might raise exhaust temperatures, with durability implications for the engine and catalyst. Vehicle manufacturers have indicated to EPA that high exhaust temperatures may be problematic for materials sometimes employed in engine components like the exhaust manifold, exhaust valves, turbochargers and oxygen sensors. One stoich vehicle in the Non-FTP Test Program, a Ford Escort, showed maximum exhaust temperatures of 846°C, a level that might be of concern from a materials viewpoint. In the case of the Escort, EPA concluded that the temperatures of concern resulted from the compounding effects of a lean-on-cruise calibration with the elimination of commanded enrichment. The Agency expects that manufacturers will eliminate lean-on-cruise as they recalibrate to meet the proposed level of NOx control over the US06 cycle, so EPA believes that the actual temperatures encountered for a recalibrated Escort would not present an additional temperature-based design constraint on engine components.

At the catalyst, conversion efficiency tends to drop exponentially with continuous exposure to higher temperatures, as processes like sintering of the noble metals increase. Thus, the conversion capabilities of a catalyst reflect the accumulated time-at-temperature profile of the mileage accumulation to date, and relatively short periods of high temperature may have greater impact than much longer periods at lower temperature. Both the catalyst and vehicle manufacturers have indicated to EPA that a maximum catalyst temperature of 900°C is a design target for platinum (Pt) catalysts; for non-platinum catalysts (such as Palladium, or Pd) that threshold can be higher. Exposure above these temperatures (in the "steep" part of the exponential curve) risks unacceptable reductions in conversion efficiencies over the timescale of a vehicle's useful life. At significantly higher temperatures (around 1100°C) the risk changes to catastrophic failure, e.g., decomposition of the substrate material over short timescales (minutes, or even seconds).

Catalyst temperatures in the Non-LA4 Testing Program tended to confirm the temperature design limits just cited. Of the twelve production vehicles with Pt catalysts, none had a maximum temperature over the REP05 or ARB02 cycles greater than 843°C, and the single non-platinum catalyst (a Ford Escort) never exceeded 864°C on those cycles. The presence of catalyst temperatures in the 800°C to 900°C range in five of the 13 production vehicles indicates the manufacturers' comfort level with the durability implications of those test temperatures.

All 13 stoich vehicles examined by EPA showed increases in maximum catalyst temperature. The Pt-catalyst vehicle with the highest maximum temperature in the stoich configuration, at 851°C, also showed the smallest increase (just 8°C) from the production configuration. The only stoich vehicle to top 900°C was also the only vehicle with a non-Pt catalyst (the Escort). None of the stoich vehicles exceeded the design target temperature appropriate to its catalyst type.

While exposure to elevated temperatures is an important factor in catalyst degradation, the amount of exposure is of equal importance. A catalyst exposed to elevated temperatures for a significant period of time will incur far more degradation than a catalyst exposed to the same elevated temperature for a short period of time. As mentioned in Section VIII.C., an emissions performance standard based on US06 emissions will not delete commanded enrichment entirely, but rather eliminate enrichment events lasting in the range of 3 to 10 seconds, depending on the vehicle. Based on in-use survey data on enrichment activity, this type of operation accounts for less than two percent of in-use operation. The Agency is currently assessing the loss of catalyst conversion efficiency when this degree of exposure is extrapolated over a typical vehicle's life as a result of increased temperature exposure resulting from the reduction or elimination of commanded enrichment using a methodology similar to that reported in Section X of this preamble for evaluating the impacts of catalyst insulation. The Agency expects that losses in catalyst conversion efficiency over useful life resulting from the reduction or elimination of commanded enrichment should be very low. Thus, the Agency believes that additional system modifications solely to address catalyst deterioration will be unnecessary.

G. Test Procedures for Aggressive and Microtransient Driving Behavior

The following discussion describes the significant elements of the proposed test procedure designed to address emissions from aggressive and microtransient driving. The proposed test procedure is based on the US06 driving cycle. Subsequent sections will address overlapping requirements with other candidate areas of control and the integration of these elements into a broader Supplemental Federal Test Procedure.

The required elements of the proposed test procedure include the test cycle, equipment specifications, and vehicle preparation and preconditioning requirements. The test cycle is the US06 driving cycle, described previously in this section. It is designed to be run in hot stabilized condition on a single-roll, large diameter dynamometer, or an equivalent system capable of handling the significant power absorption requirements that accompany aggressive driving and also capable of reproducing representative road forces at the interface between the drive wheels and the dynamometer roll. High-volume exhaust flow for larger-displacement vehicles run on US06 dictates use of a larger-capacity constant volume sampler (CVS) than is needed for current FTP testing. Hot stabilized condition is achieved by including several preconditioning options as part of the formal procedure immediately prior to the test cycle. If the vehicle has undergone a soak of two hours or less, the preconditioning may be a 505 Cycle, the 866 Cycle, US06, or the Soak Control Cycle (SC01). Following longer soaks, the proposed preconditioning cycle is an LA4. For manufacturers who have concerns about fuel effects on adaptive memory systems, the proposal allows manufacturers and EPA, upon manufacturer request, to run the vehicle over the US06 cycle on the certification test fuel before entering the formal test procedure.

X. Controlling Emissions Following Intermediate Soaks Periods

A. Causes of Emissions Following 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 real-world 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.

Data from EPA's Soak/Start testing and the Albany Cooldown Study demonstrated that a vehicle's catalyst cools down much more rapidly than the engine following vehicle shutoff. If a vehicle is restarted quickly (e.g., following a 10-minute soak), the catalyst is generally still above the temperature needed to sustain significant catalytic activity, or "light-off" temperature. However, EPA data indicates that the catalyst generally cools to below light-off temperature within 20-30 minutes of vehicle shutoff. By the time a typical catalyst has soaked for two hours, the temperature is barely above ambient levels, while the engine is still near its normal operating temperature.

The Agency's data also showed that when catalyst temperature falls below light-off temperature following vehicle shutoff, there is a significant delay in the time required for the catalyst to achieve light-off temperature upon restart. This is because the rise in catalyst temperature after startup is apparently governed by the temperature of the engine-out exhaust rather then the start-up temperature of the catalyst. Following an intermediate soak, the engine exhaust is typically cooler than the catalyst. Thus, the catalyst temperature may stay stable or actually fall until it is surpassed by the engine-out exhaust temperature. The Agency found that this phenomenon results in significant delays in the time required for the catalyst to achieve light-off following an intermediate soak. In fact, the elapsed times required to lightoff following soaks as little as 60 minutes were often comparable to those following cold starts. 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. This strategy will not benefit the manufacturers in controlling FTP hot (10-minute) soak emissions, because the hot-soak catalyst never falls below lightoff temperature. For the cold soak, preventing catalyst cooldown overnight is not practical, and therefore not a productive strategy for improving FTP cold soak emissions. Although improved light-off performance would help to reduce emissions following intermediate soaks, these improvements are not occurring to the extent necessary since manufacturers are successfully controlling FTP emissions to Tier 1 levels without resorting to fast-lightoff catalyst technologies following the FTP cold soak.

While catalyst cooldown is the primary factor affecting emissions impacts from intermediate soaks, an additional potential factor found in the Soak/Start Test Program was differences in engine-out emissions. This is determined by the manufacturer's calibration strategy upon restart. For one EPA test vehicle, NOx emissions over the ST01 driving cycle following soaks less than 90 minutes increased ten-fold (to over 2.0 g/mi) from the levels following a 10-minute soak. The increase, coupled with significant drops in HC and CO emissions, was traced to a lean calibration strategy imposed on restarts following intermediate-duration soaks. Here, again, the test results indicate that significant emissions may be occurring in-use because of a lack of incentive for manufacturers to optimize start-up calibrations following intermediate soaks.

B. Candidate Strategies for Controlling Emissions following Intermediate Soak Periods

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. There are some current production applications of catalyst insulation for non-emission related purposes, although not to the extent likely necessary to adequately control intermediate soak emissions. There are two basic approaches regarding the enhancement of catalyst light-off. One group of strategies uses the thermal energy in the exhaust to hasten catalyst temperature rise. This can be accomplished by moving the catalyst closer to the engine, optimizing the start-up fuel calibration for catalyst light-off, insulating the exhaust pipe, or using a double-walled exhaust pipe. Manufacturers are already applying these strategies to some degree in complying with California Low-Emission Vehicle (LEV) standards. A second group, which would exploit newly emerging control technologies, uses heat that has either been stored or generated from sources other than the exhaust gas to speed catalyst lightoff. An example of this approach would be use of an electric catalyst heater immediately upon startup. Although the benefits derived from this approach would not be greater than for insulation, cost estimates of this approach were placed significantly higher than the other candidate control strategies. The Agency determined this approach to be the least cost effective, and it was therefore not considered further as a potential control strategy.

Of the potential catalyst-based approaches considered for control of intermediate soaks, EPA is focusing on catalyst insulation as the primary control strategy. The Agency believes that catalyst insulation will result in greater emission reductions over intermediate soaks than strategies which focus on improving catalyst light-off through conventional means and will provide 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. The Agency also anticipates that reductions over intermediate soaks will be incurred to some extent through improved calibration. The magnitude of reductions with this approach will likely be vehicle-dependent, since emissions following start-up are highly sensitive to the individual calibration strategy.

C. Basic Approaches for Controlling Emissions Following Intermediate Soak Periods

The approach evaluated was an emission performance standard applied to the results of testing over an emissions control cycle following a soak period of intermediate duration. As with control program approaches for aggressive and microtransient driving emissions, EPA believes that an emissions performance standard provides the most direct method of controlling the emissions arising during the particular type of vehicle operation. Given the particular causes of high emissions in this case, use of design standards or system performance standards would be particularly complex and restrictive of the manufacturers' options. To control catalyst cooldown with a design standard, for example, EPA would have to promulgate insulation specifications for the range of catalyst types, sizes, and applications in a diverse and evolving fleet.

The Agency developed a new Soak Control Cycle (SC01) to be used for controlling emissions following intermediate soaks. Initial idles and start driving are addressed in SC01 by incorporating the EPA Start Cycle (ST01) in its entirety. The balance of SC01 is composed of two microtrips of moderate driving, selected from the in-use survey database in order to bring the total distance of the new control cycle up to match the 3.6-mile distance of the 505 Cycle; the resulting cycle is 568 seconds long.[27] The purpose of matching the distance of the 505 was to allow evaluation of the emission performance over each cycle by providing a direct comparison of emissions between the SC01 and 505 cycles on a gram-per-mile basis. In order to make this comparison properly the implicit mix in each cycle of start emissions and hot stabilized emissions must be identical. This construction also adds control capability for warm-stabilized moderate driving, and (as will be seen subsequently) provides added flexibility in constructing the Supplemental Federal Test Procedure.

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(1) the severity of one SC01 acceleration was artificially modified to be less severe than in the original microtrip. This preserved the design objectives of matching the 505 trip distance and reflecting moderate, rather than aggressive driving. The representative level of microtransient behavior in the cycle was unaffected by this change. (2) Analysis of the two microtrips used to complete SC01 shows higher power levels than the comparable portion of the 505. Based on the concern of greater stringency brought on by these microtrips, the Agency plans to replace these microtrips with those which match power levels of the 505 more closely. The completed cycle, known as SC02, will replace SC01 and serve the same purpose.

The Agency considers the SC01 cycle preferable to the 505 following an intermediate soak because it has speeds and power levels that are more representative of in-use start driving behavior; in addition, because the cycle is comprised of in-use microtrips, microtransient operation (short timescale speed or throttle fluctuation) is more properly represented. Emissions following startup are very dependent on the warmup profile of the engine and catalyst, which in turn are very sensitive to how the vehicle is driven after startup. In-use data indicates that the 505, whose period of highest speed and acceleration takes place during the startup phase, is not as good a representation of real-world start driving behavior as SC01. The Agency is proposing the SC01 cycle due to the importance of representing how vehicles perform in-use following startup in a superior fashion than the 505.

D. Level of Emission Control Following Intermediate Soak Periods

In analyzing the appropriate level of emission control following intermediate soaks, EPA once again initially looked at extending the control currently achieved over the FTP into the new regime. As a starting point the Agency looked at whether it would be possible to employ the control strategy of insulating the catalyst to retard catalyst cooldown, and in the process, match the catalyst lightoff times following some intermediate soaks to the relatively short lightoff times found on the existing FTP hot start. Concept testing with both the Start Cycle (ST01) and Soak Control Cycle (SC01) in the Soak/Start Test Program confirmed this was practical. Applying external insulation to catalysts retarded catalyst cooldown to the point where NMHC, CO, and NOx emissions following soaks up to 60 minutes in length were comparable to emissions following a 10-minute soak on an uninsulated catalyst, for most vehicles tested. The Agency also found this to be true for the lone Tier 1 vehicle tested with catalyst insulation in the Soak/Start Test Program. Thus, extending the current FTP level of control following 10 minute soaks to soaks up to 60 minutes in length was determined to be a readily achievable level of control.

Testing in the Soak/Start Program showed that if the soak duration was held constant at 10 minutes, emissions of CO and NOx over the SC01 Cycle tended to be higher than the emissions over the 505 Cycle, while NMHC emissions were comparable. Thus, with soak effects removed, differences in driving cycle generated differences in emissions The CO results probably indicate that enrichment is occurring during the microtransients in SC01, while the NOx increases are probably either tied to lean spikes during the microtransients or to the somewhat higher loads of non-start component in SC01 relative to the loads during the 505. Unfortunately, the Agency did not have access to vehicles reprogrammed to eliminate microtransient enrichment, eliminate microtransient lean spikes, or optimized for NOx catalyst conversion efficiency. Testing with such vehicles could directly evaluate the emission levels that might be achievable by recalibration strategies targeting the FTP shortfall in start and moderate driving. Nonetheless, EPA sees no reason why such recalibrations could not address the 505 shortfall in representing real in-use start and moderate driving. Additionally, the replacement of SC01 with SC02, which will incur lower loading over the non-start portion of the cycle, will also result in emission levels on the cycle more comparable to the 505.

Combining the implications of the above for control of intermediate soaks, EPA believes that manufacturers should be able to control emissions on the SC01 cycle following a 60-minute soak to the same gram-per-mile emission levels currently achieved on the third bag of the FTP (a 10-minute soak followed by a 505 Cycle).

E. Feasibility

Although some vehicle manufacturers currently employ catalyst insulation on a limited basis for non-emission related purposes, the core technology for catalyst insulation as a control strategy for post-soak emissions is not currently in production. Consequently, the Agency performed its own evaluation of the feasibility of employing catalyst insulation for control of post-soak emissions. The evaluation considered impacts of external and internal insulation on the catalyst shell, mat, and the catalytic material itself.

The primary feasibility concern with catalyst insulation is the potential for degradation of catalyst performance due to increased catalyst temperature. The Agency compared catalyst substrate temperatures with and without external insulation on vehicles from the Soak/Start Program, covering a variety of catalyst types, across the range of in-use driving behavior. As expected, insulation generally raised the catalyst temperature. The average offset between the baseline catalyst temperature and the temperature of the catalyst when wrapped with insulation was less than 40°C. However, the data indicated that the catalyst temperature offset due to insulation decreases at higher temperatures, suggesting that the incremental temperature increase due to insulation is minimal during high catalyst temperature events which would cause the most concern for degradation. Conversely, the maximum temperature increase due to insulation tended to occur when the catalyst was relatively cool, when there is less concern for degradation[28]

The catalyst substrate temperature increases observed in the Soak/Start Test Program were not substantial enough to raise EPA concerns about catastrophic catalyst failure (e.g., substrate meltdown). However, the impacts of accumulated long-term exposure to higher temperatures on catalyst durability (and thus, catalyst conversion efficiency) were examined. The vehicle manufacturers and EPA consistently acknowledge that the loss in catalyst conversion efficiency per unit time increases exponentially with temperature. However, the exact coefficients of that relationship are specific to manufacturers. Based on concerns of confidentiality of data, EPA generalized the limited relevant data currently available to EPA and combined them with temperature distributions both from in-use and over cycles in the Soak/Start Test Program for vehicles equipped with underbody catalysts. From this, EPA projected losses in catalyst conversion efficiency which were on average less than 0.1 percent over the useful life of the vehicle.[29] On the other hand, the temperature increase resulting from insulation would increase catalyst efficiency over warmed-up operation (particularly low speed and extended idles, which experience low catalyst temperatures without insulation), not just post-soak driving. Thus, the Agency projects that these increases would overcompensate for deterioration-related losses of the projected magnitude. Even with the conservative assumption that these two effects are offsetting, EPA believes that internal catalyst insulation does not pose a temperature-based feasibility problem for underbody catalysts. The Agency had insufficient data to reach a firm view on this issue for the small number of Tier 1 vehicles which might need to insulate close-coupled catalysts. Thus, EPA solicits comment or data on the temperature-based feasibility of insulation for close-coupled catalysts.

At the proof-of-concept level, Agency work was performed primarily by wrapping the exterior of the catalyst with insulating material. For production purposes, however, external insulation may not be preferable due to the effects of this type of insulation on shell deformation and pressure changes or decomposition at the mat resulting from increased operating temperatures. Internal insulation would avoid these problems but still prompts evaluation of the temperature impacts at the substrate and the catalytic material. With assistance from

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See Section 4.1.1.2.3 of the Intermediate Soak Technical Report for discussion of the temperature impacts of insulation

See section 4.1.1.2.3 of the Intermediate Soak Technical Report several catalyst manufacturers, EPA worked to construct a prototype internally insulated catalyst, to compare the performance to the results to earlier concept testing on externally insulated catalysts and to evaluate potential problems and improvements in the prototype. The internal prototype was not as effective as the externally insulated concept catalyst at delaying catalyst cooldown. However, EPA and the catalyst manufacturers identified several improvements to the prototype, including insulating the catalyst cones, better attention to joints in the metal, and candidate changes to the insulating material. From this information, catalyst manufacturers have indicated that the development of a cost effective internal insulation system which meets the requirement for retarding catalyst cooldown is viable. Simulation by one catalyst manufacturer indicates that performance with these improvements would be slightly better than with EPA's original externally insulated concept catalyst[30].

On the basis of the above analysis, EPA believes that application of catalyst insulation as a strategy for control of emissions following intermediate soaks is feasible. Nevertheless, the Agency recognizes the importance of the catalyst durability issue, and EPA solicits data and comment from interested parties that is germane to these arguments. In addition, EPA solicits comments on strategies to mitigate temperature increases in the catalyst brought about by insulation (such as moving the catalyst further downstream and subsequently conserving exhaust heat ahead of the catalyst to not impair cold start performance, or switching to more temperature-resistant noble metals like palladium), as well as spinoff effects of such strategies.

Aside from catalyst-based approaches, manufacturers may gain some emission reductions through recalibration. The Agency does not anticipate feasibility problems associated with recalibration over intermediate soaks. In most cases, the Agency anticipates that recalibrating will involve making the calibration strategy on intermediate soaks proportional with strategies currently used on cold and hot starts, rather than requiring new strategies.

F. Test Procedure for Intermediate Soak Periods

The required elements for the proposed test procedure include the preconditioning, soak period and test cycle requirements. Prior to the soak period, the vehicle is to be preconditioned to allow engine and catalyst temperatures to

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See section 4.1.1.2.3 of the Intermediate Soak Technical Report stabilize at typical warmed-up operating temperatures. The Agency has determined that running the vehicle over EPA's Urban Dynamometer Driving Schedule (866) is adequate to achieve engine and catalyst stabilization regardless of the time period for which the vehicle was not operational prior to preconditioning. However, in the event the vehicle was shut off for less than 2 hours prior to preconditioning, the Agency has determined that a 505 cycle is adequate for preconditioning the vehicle, although the 866 is also acceptable. Other elements of the FTP test can be used for the purpose of preconditioning, to avoid having to run preconditioning cycles in addition to the test procedure. For example, preconditioning for the soak test procedure may be accomplished over Bag 3 of the FTP.

Immediately following the preconditioning cycle, the vehicle will enter the soak period. For purposes of certification or SEA testing, manufacturers will be required to soak the vehicle 60 minutes. The Agency will have the option of testing any soak duration between 10 and 60 minutes for certification, SEA, or in-use testing, and the proposed standards will be applicable across this range. This flexibility allows the Agency to reduce testing burden and assure compliance on soaks between 10 and 60 minutes. During this period, cooling fans directed at the vehicle are to be shut off. The vehicle may be removed from the dynamometer, provided the vehicle is not subjected to unrepresentative cooling of the engine or catalyst. Following the soak period, the vehicle will be run over the SC01 cycle for proper representation of engine and catalyst warm-up, start driving and moderate driving.

G. Impact of More Stringent Emission Standards On Intermediate Soak Requirement

Because Tier 1 standards are the current legal requirement for new motor vehicles and the status of future standard changes is uncertain at this time, this proposal presumes Tier 1 applicability. However, it is a likely possibility that many vehicles will certify to emission standards lower than Tier 1 by the time the proposal would take effect. The Agency recognizes that adoption of emission standards more stringent than current Federal Tier 1 standards will likely result in emission control strategies that reduce post-soak emissions, which may in turn reduce or eliminate the need for a separate intermediate soak requirement. As a result, the Agency is taking into consideration the impact of future lower emission standards on the need for an intermediate soak requirement before final adoption of the proposal.

Depending on the stringency of future lower emission standards, EPA is anticipating that many vehicles will adopt strategies to substantially improve cold start emissions by enhancing catalyst light-off, including some portion of vehicles which may use advanced technology such as electrically heated catalysts. If adopted, these strategies would inherently lead to reductions in intermediate soak emissions. Vehicles certified to lower emission standards will likely continue to have emission increases over intermediate soaks compared to hot soaks, because the reduced benefit from controlling only these emissions reduces the cost-effectiveness of the intermediate soak requirements proposed here. In addition, there may be feasibility issues connected with catalyst insulation for vehicles certified to lower standards due to the larger proportion of catalysts placed closer to the engine.

Three factors are primary in deciding whether the intermediate soak requirement will be put forth in the final rule: (1) The Agency's judgement as to the likelihood and level of emission standards more stringent than Tier 1 being put in place by or soon after the proposed implementation of the revised FTP rule, (2) the Agency's judgement on the most likely control strategies to meet such standards, and (3) the cost effectiveness and feasibility of requiring intermediate soak control on vehicles certified to the more stringent standards. The Agency believes it would be appropriate to finalize an intermediate soak standard if a significant proportion of vehicles are certified to Tier 1 standards for a significant time period following implementation, or if this is not the case, that it is cost effective and feasible to pursue control over intermediate soaks on vehicles certified to the lower standards. The Agency requests comment on the three factors noted above.

XI. Controlling Emissions from A/C Operation

A. Identifying Causes of Emission Increases from A/C Operation

The Agency approached the control of A/C-on emissions in the same manner as the other control areas, in that much of the testing, particularly the testing at AC Rochester (ACR), was designed to both assist the Agency in identifying causes of emission changes and to provide data for performing an emissions assessment. Going into this testing, the Agency believed that the current FTP probably does not adequately or appropriately represent the additional load imposed on an engine by an operating A/C system, and expected some level of emissions increase due to the load impact when the A/C system is actually turned on. The Agency's concerns were confirmed, as the magnitudes of the increases, at least with respect to NOx, were surprising.

While the Agency focused on NOx impacts because of the large and unexpected increases, the testing at ACR did confirm that HC and CO are also impacted by A/C operation. The bag emissions data from ACR showed average increases of 50 percent and 72 percent on a hot stabilized LA4 for tailpipe NMHC and CO, respectively. The tailpipe NMHC increase could not be traced to an increase in engine out THC levels. Analysis of the engine out data showed essentially no change in THC when the A/C is turned on, so the observed increase was judged to be related to the functioning of the catalyst. On the other hand, engine out CO increased by about 25 percent when the A/C is turned on. The Agency believes that these increases are related to the increased load on the engine triggering additional periods of commanded enrichment (when the vehicle's computer "commands" the air/fuel ratio to change to the rich side of stoichiometric, usually in response to increased load on the engine) when the A/C is on. A relatively greater increase in CO is expected because of its proportionately greater response to enrichment than NMHC.

The increases in tailpipe NOx with the A/C on at ACR could clearly be linked to large increases observed in engine out NOx, which are probably caused primarily by higher combustion temperatures due to the additional load of the A/C system. In proportion to road load, the load of the A/C system is greatest at idles and lower speeds, causing the bulk of the impacts to appear over this type of driving, a phenomenon noted earlier. In addition, the reduction of NOx in the catalyst is also dependent on air/fuel ratio. The Agency noted some large NOx increases on vehicles that employed a lean-biased air/fuel control strategy or an air/fuel ratio that tended to be poorly controlled in general, and hence, experienced relatively worse NOx conversion efficiencies.

B. Strategies for Controlling A/C-On Emissions

The Agency is principally concerned with controlling the NOx increases associated with the use of A/C. As noted in the previous section, the emission increases in HC and CO are largely attributable to enrichment events, the control of which is discussed throughout Section IX. The Agency believes that the control strategies for HC and CO discussed in that section will eliminate HC and CO emissions increases due to A/C operation as well as during aggressive driving.

With respect to NOx control, tailpipe NOx can be improved either by increasing NOx conversion efficiency in the catalyst or decreasing engine out NOx. Although Section IX addressed controlling emissions from aggressive and microtransient driving behavior, the strategies detailed in that section for control of NOx are equally applicable to mitigation of NOx increases associated with A/C operation, because emissions from aggressive driving and A/C operation are both caused by increased load on the engine. This is particularly so for optimization of the air/fuel ratio for NOx control at the catalyst. Other options also addressed in Section IX.B. include addition or enhancement of EGR systems and adjustments to spark timing to reduce combustion temperatures, elimination of the lean-on-cruise strategy, and catalyst improvements to improve NOx conversion efficiency, all of which will lead to reductions in NOx emissions associated with A/C operation.

Engine out NOx levels can also be mitigated by reducing the load imposed by the A/C on the engine or by strategically controlling the cycling of the A/C compressor. Controlling the cycling of the compressor could be accomplished through use of the onboard computer, which already typically senses throttle position, engine speed, and engine load (MAP). These inputs could be used to turn the compressor off for short durations during accelerations, thus eliminating the additional load during critical seconds when the compressor load has its greatest impact on generation of engine out NOx. Compressor cycling could be carefully managed by the computer to eliminate or reduce the load on the engine during accelerations and redistribute it to periods where NOx formation is less affected, such as cruises or decelerations. The impacts of this approach on the vehicle systems and occupants are discussed in the following section on feasibility.

Reducing the load on the engine could also come from improvements to the A/C system and the vehicle, such as the use of specialized glass that transmits less heat from the sun to the interior of the vehicle. The EPA also believes that innovations in A/C systems likely to lead to efficiency improvements are on the technological horizon that will enable further reductions in emissions associated with A/C operation. For example, the Agency is aware of a recently-developed A/C system that is electrically driven, uses a new low pressure refrigerant, weighs significantly less and is more compact than current systems, and has fewer moving parts than current systems. This system, due to be installed in a fleet of electric buses in 1995, offers potential future innovations such as the ability to run the system with solar power while the vehicle is soaking.

C. Basic Approaches to Control of A/C-On Emissions

The Agency analyzed several possible approaches to testing designed to control emissions due to A/C operation. These options hinged on determination of two important elements - the choice of a control cycle and the choice of a methodology for simulating A/C operation over that cycle. Based on the preferences for control options stated in Section IX.C., EPA pursued a control program for A/C-on emissions that utilized an emissions performance standard rather than other control options.

The Agency believes it's reasonable to assume that A/C use occurs over the full range of in-use driving and the data collected at ACR demonstrated a varying emissions impact over all types of driving. As in the case of the aggressive and microtransient driving control options (see Section IX), the Agency considered an emissions performance standard applied to fully representative driving cycles. However, the significant disadvantage stated in that section (impacts on testing time and costs) is even more relevant with respect to A/C control. Assuming A/C is used over all types of in-use driving, such an approach would have to use ST01, Remnant, and REP05 to represent all in-use driving, and drive time would approach 50 minutes.

As described in Section VIII.C., the most significant impacts from A/C operation were seen at lower speeds, accelerations, and idles. Increases of more than 90 percent in tailpipe NOx were seen at ACR on both the LA4 and ST01 cycles, while the average increase on the higher speeds and accelerations of the REP05 cycle was approximately 38 percent. Given this, the Agency believes that a cycle with slow to moderate speeds and a reasonable number of accelerations and idles could address the emissions increases associated with A/C operation. Since there are advantages to a control cycle with some historical familiarity and reasonable length, as well as one that meets the above criteria, the Agency first considered the full FTP in its current form. However, because the A/C impact is an issue of increased engine-out emissions, the primary way to address emissions increases on the cold start 505 (or "Bag 1", conducted following a 12-36 hour soak) would be to bring the catalyst to a hot functional condition faster than current technology vehicles are able to do so. This "quick lightoff" technology may become prevalent assuming future tightening of standards, but is not required in order to meet the current emission standards. Given that the Agency's general goal with these revisions to the FTP is to achieve the same level of control in the new control areas that is achieved on the FTP under the currently applicable standards, the Agency believes that the technology-forcing aspect of requiring control of A/C-caused emissions on a cold start test is inappropriate at this time because of the lead time requirements to implement the new catalyst technology. Consequently, a cold start test is not included in today's proposal for A/C-related controls. The Agency does believe that it may be appropriate to return to this issue with respect to future technologies and future test procedures and tighter emission standards. The Agency specifically solicits comment on this issue.

The Agency also investigated the possibility of requiring A/C control testing on the US06 cycle, proposed in Section IX to address emissions due to aggressive and microtransient driving. As noted above and in Section VIII.C., some vehicles exhibited significantly increased NOx emissions over driving with high speeds and accelerations with the A/C on. The Agency considered the possibility that some additional level of control might be gained by testing over that type of driving. However, the EPA determined that the average increase was being driven in large part by one vehicle in the ACR test program, and further analysis of the second-by-second data for that vehicle revealed behavior (particularly poor transient control of the air/fuel ratio, for example) that the Agency believes will have to be improved to achieve the levels of emission control necessary to conform to the requirements of the aggressive US06 cycle alone. Because of this applicability of the same technologies, the Agency believes that a test of A/C-on emissions using the US06 is not necessary, nor would it be likely to achieve emission benefits beyond those achieved by the US06 cycle and standards. In addition, an analysis presented to the Agency by the auto manufacturers indicated that the total US06 regime of loads on the engine when the A/C is on is effectively equivalent to the US06 load regime with the A/C off.[31] Preliminary information from the auto manufacturers also indicated some potentially significant problems providing adequate cooling to vehicles tested with the A/C on over the US06 cycle, and resolution of these issues could have significant test cell impacts. Consequently, the Agency is not proposing to use the US06 cycle for control of A/C-related emissions.

The Agency believes that an appropriate control cycle for A/C-related emissions is the LA4 (505 + 866). However, although the potential impacts of micro-transient driving (discussed in Section VI.A.) on A/C-related emissions is not clear, the Agency remains somewhat concerned with the unrepresentative "smoothness" of the LA4 cycle and requests comments on possible alternatives. Specifically, the Agency is proposing to substitute the cycle developed to represent start driving (SC01) for the 505 component of the LA4, as they are both of similar distance and time, and the SC01 clearly better represents in-use driving behavior than the 505. There may be some additional benefit beyond A/C control to including more representative micro-transient driving in the A/C test procedure, an issue that the Agency is currently

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investigating, and welcomes comment on. In addition, this option is discussed as part of the Agency's central proposal to combine several test elements and composite the emission results for comparison against one set of standards.

Independent from determining the appropriate control cycles for testing, the Agency evaluated three principle options for simulating A/C operation on a given test cycle. The least-developed is a method using laboratory bench equipment connected to or replacing parts of the existing A/C system to dynamically simulate the load of an A/C system directly on the vehicle's engine by applying a predetermined A/C load trace. A second procedure would make use of the advanced capabilities of a large-roll electric dynamometer to apply a simulated A/C load to the vehicle in addition to the standard road load. The third method would actually turn the A/C on for the duration of the emission test procedure. This third option has two sub-options: turn the A/C on with a full simulation of high-ozone environmental conditions (such as the test program at AC Rochester), or a "short-cut" procedure that can be carried out in a standard test cell. The Agency intends a procedure that best meets the following criteria: 1) leads to real and cost-effective in-use emission reductions, 2) provides the best incentives to manufacturers to design vehicles that accomplish actual in-use emission reductions, 3) accurately simulates the emissions response of current and future technology vehicles during typical high ozone conditions, and 4) is transportable across all Agency and manufacturer certification and in-use testing programs.

The first option, referred to as a "Direct Dynamic Load Simulation," has two conceptual elements. First, a test vehicle would be instrumented to collect time-based measurements of actual A/C compressor horsepower under the ambient conditions that most concern the Agency. This could be done in an environmental simulation chamber or, under the proper conditions, on the road, and would use the driving cycle selected for emissions testing. Once this baseline compressor horsepower record is determined, subsequent emission tests could be conducted in a standard test cell by using an auxiliary system to precisely apply the real-time compressor loading to the vehicle.

Unfortunately, the Agency does not have the resources necessary to develop such auxiliary systems in the time frame of this rulemaking, but at least three conceptual methods have been envisioned. The first possible method would apply load to the A/C compressor on the vehicle by operating it as if it were an air pump working against air pressures controlled in a way that duplicates the original baseline load record. The Agency believes that such a system could be developed and might be a highly practical solution, but questions remain about whether the properties of air make such an application impractical and whether it would have to be a closed or open system. A second and similar method would connect the vehicle's A/C compressor to a high-capacity off-board A/C system that lacks a compressor but is otherwise complete. Several issues complicate this approach, such as the requirement to provide cooling to the off-board condenser, but the Agency believes that this method represents a potentially viable approach. There is some indication that auto manufacturers may already utilize an auxiliary A/C system or other off-board test fixture for loading a vehicle's compressor during development testing. A third potential method differs from the first two in that it would not make use of the compressor on the vehicle, but instead would replace it with a hydraulic pump, belt-driven by the engine just like the compressor it replaced. The load applied by the hydraulic pump would be controlled externally, again to match the previously determined baseline load trace. While the hardware required for this approach may be currently available, installation in the vehicle may pose problems due to the variety of compressor locations and accessibility.

While these three methods remain essentially conceptual as of this proposal, the Agency believes that simulating predetermined A/C loads with some type of auxiliary system entails some significant advantages. First, it allows the bulk of the testing to occur in a standard test cell. Second, the loading applied to the engine for emission testing is a precise duplication of the compressor cycling behavior recorded under real-world or simulated real-world conditions, including incorporation of load impacts at idle. A disadvantage with this approach (and any approach that does not actually turn the A/C on) is that it does not account for the interaction between the vehicle's computer and compressor activity. The computer would not be able to anticipate the oncoming load from the external source and make adjustments to account for it. This may not be a significant issue if the compressor cycles infrequently under typical high-ozone environmental conditions, which seems to be the case for current technology vehicles, but is of more concern with respect to future unknown A/C system designs. There are several disadvantages regarding implementation and hardware, including the potential difficulty of implementing in the Agency's in-use vehicle testing programs. The Agency believes that these disadvantages could probably be adequately addressed, and specifically requests comment on the potential applicability of this type of A/C simulation procedure and whether this procedure should be retained as an option in the final rule to allow for its future development and use by petitioning for Agency approval.

The second A/C simulation method considered by the Agency would make use of the advanced capabilities of an electric dynamometer to apply an A/C load to the vehicle, in effect creating a more realistic version of the current dynamometer loading method. This approach, currently referred to as "Nissan-II" and under development by auto manufacturers, is similar to the first approach in that initial measurements are made of actual A/C loads on the Agency control cycle under a set of environmental conditions representing typical high ozone days, then those measurements are used to determine the load to apply in a standard emissions test cell. The difference is in how the appropriate load is determined and applied. With this approach a regression analysis would use the vehicle speed and A/C load data from testing under real-world or simulated real-world conditions to calculate an estimated speed versus A/C load curve which would then be added to the vehicle's base road load curve. This is therefore not a real-time simulation of compressor behavior, but instead a calculation that determines the load values to apply at given speeds (e.g., at every place in the control cycle where a given speed occurs, a load specific to that speed would be applied by the dynamometer).

An improved dynamometer simulation has several advantages, but most significant is the fact that it can be run in a standard test cell equipped with an electric dynamometer. Because the process of determining the A/C load is performed under real-world high ozone conditions, the proper incentives exist for vehicle and A/C system technologies that reduce the load impacts of the A/C under those conditions. The Agency does have several reservations with this approach, however. First, the dynamometer is incapable of applying a load to a vehicle at idle, and various analyses point to idles as significant contributors to NOx increases with the A/C on. Addition of a test element to address idle impacts (e.g., an emission test at idle with the A/C operating) would probably be necessary to address these concerns. An additional concern is due to the "smoothing" inherent in a regression analysis. The A/C load applied at a given speed is not the actual load experienced in real world conditions, but an average of all the A/C load points that occurred at that speed. By this measure, the first approach is more "pure" in that it represents actual loads where they actually occurred on the driving cycle. Because of this, the Agency is concerned that the transient impacts represented by compressor cycling activity would not be adequately accounted for in the dynamometer simulation. This concern is greater with respect to unknown future technologies that may cycle compressors more than do current technologies. As in the first approach, the Agency remains concerned about adequately accounting for possible calibration responses of the vehicle's computer to the operation of the A/C, which can only be observed with the A/C actually operating.

The "Nissan-II" approach is currently being evaluated by a consortium of auto manufacturers and the Agency expects to review and evaluate the data as soon as it becomes available to determine how accurately the emissions obtained with this dynamometer approach match the emission results obtained in the ACR test program (see Section VIII.C.). However, because the Agency currently lacks that analysis and has no information about the ability of a dynamometer simulation to reflect real world emissions responses due to A/C operation, a reasoned and supportable decision on such an approach can not be made at this time. The Agency specifically requests comments and data that would allow a better evaluation of this approach and its viability, as well as suggested improvements that would alleviate the Agency's concerns.

The third potential method of simulating A/C operation that the Agency considered is to actually operate the A/C system while the vehicle is driven over the proposed control cycles. Clearly the most accurate way to account for all the environmental and meteorological parameters that influence in-use A/C impacts is to fully simulate those parameters during an emissions test, as was done in the ACR test program. However, the Agency recognized the high cost of requiring a full environmental simulation as part of the certification and in-use testing regimes. Using the ACR test data as the benchmark of real world A/C impacts, EPA investigated several "short-cut" alternative procedures that still turn the A/C on but that could be carried out at significantly less cost in a standard test cell with few or no modifications.

To facilitate the Agency's investigation into "short-cut" procedures, the auto manufacturers supplied the Agency with seven of the vehicles that were part of the ACR test program. The Agency tested these vehicles on a hot stabilized LA4 cycle using several alternative procedures and compared the A/C-on emissions increases and compressor activity to the same parameters collected at ACR, with the objective of matching those parameters as closely as possible. With the exception of some additional tests conducted on one of the vehicles, all tests were run with the driver's side window down and with a 36 inch fan placed in front of the vehicle and operated at a single speed throughout the test. The Agency first investigated turning the A/C on in a standard test cell at standard test conditions (75°F, 40 percent relative humidity), and determined that on average such a procedure reflected only about 36 percent of the average NOx increase measured at ACR. Consequently, the Agency believes this alternative would be unacceptable. The Agency next investigated testing in a standard test cell with the ambient temperature raised to 95°F, and found a much closer comparison to the ACR data. The NOx increase due to A/C operation was on average eight percent higher than the increase measured at ACR, and the magnitude of increases in HC and CO also matched the ACR data within the range of test-to-test variability. The average pressure of the refrigerant as it leaves the compressor (or head pressure, a good indicator of the work done by the compressor) matched the ACR data to within about three percent, and the suction pressures were about twenty percent lower than those recorded at ACR. The average change in pressure from the high side to the low side of the A/C system (head pressure minus suction pressure) was nine percent higher than at ACR. The lower suction pressures may be an artifact of the inadequate cooling of the A/C condenser in the standard test cell compared to the wind tunnel simulation at ACR, although the overall impact of this difference on the load applied to the engine by the A/C system appeared to be small, as evidenced by very closely matching calculations of average A/C horsepower for several of the vehicles run under both conditions. Calculations of fuel economy also indicated that the overall load applied by the short-cut method is virtually identical to the full ACR simulation. Several additional tests were conducted on one vehicle to evaluate possible improvements to this test procedure, such as closing the driver's window, turning off the fan at idle to address possible overcooling, and applying an internal heat load via electric heaters, but the added complexity did not improve the correlation with the ACR data, so the Agency did not pursue these test elements.

Based on the results of this testing, the Agency believes that testing with the A/C on in a 95°F test cell represents an acceptable short-cut procedure for measuring emissions associated with A/C operation. The 95°F short-cut procedure appears to predict in-use emission impacts (represented by the ACR data) very accurately for current technology vehicles. However, the accuracy with which the procedure will work for future technologies, particularly those that might cycle the A/C compressor more frequently, is unclear, and is reason for some concern. The Agency noted that the close match with the ACR data is likely because of some of the tradeoffs inherent in this short-cut procedure, which sacrifices some of the test elements at ACR (adequate cooling of the condenser, sun load, high humidity) for other elements in the standard test cell that in balance generate a similar emissions effect (open driver's window, lower humidity, no sun load, inadequate cooling of the condenser) In other words, the short-cut procedure forgoes some of the real-world impacts and replaces them with artificial test cell impacts that lead to the same results.

The cost advantages of this short-cut approach are clear. A sophisticated simulation of many environmental parameters is not required, whereas the first stage of the other two approaches would require a facility capable of such simulations. However, this approach requires "standard" test cells capable of some degree of temperature control, a feature that will be more difficult for some manufacturers to install than others. Those with "open" cells, for example, will encounter greater expense.

With the exception of a costly full environmental simulation, this is the only procedure that allows and accounts fully for the interplay between the engine calibration logic of the vehicle's computer and the load imposed by the A/C system. In addition, the dynamic impacts of A/C compressor cycling would be fully represented with the A/C actually operating, an effect that is lost in the Nissan-II method but that may be included in future development of a dynamometer simulation. A potentially significant disadvantage with this approach is its inability to provide proper incentives for design improvements which are based on reducing the transmission of solar energy into interior heat. This arises because of this procedure's lack of real or simulated solar load on the vehicle. The Agency is also concerned about the possibility that this type of procedure will cause manufacturers to optimize emissions for the "short-cut" procedure, which may not translate into actual in-use emission reductions. However, given the tradeoffs and currently unknown capabilities of alternative methods to accomplish the desired results, this is the option favored by the Agency in today's proposal. The Agency specifically requests comments on the appropriateness of this type of procedure and alternative procedures, particularly regarding the ability to accomplish the Agency's objectives with respect to current and future technologies.

D. Appropriate Levels of Emission Control During A/C Operation

As in the Agency's approach to determining appropriate levels of emission control for aggressive and microtransient driving and soak/start driving, the Agency believes that many of the strategies used to control emissions during driving represented by the current FTP can be applied to control emissions from A/C operation. Additional strategies also exist that are specific to the A/C system and therefore have not yet been considered for implementation on the current FTP because the A/C is not run on the current FTP. The level of emission control is based both on the observed response of specific pollutants to A/C operation and on the potential strategies that might be employed for control.

Section VIII.C. explained that the HC and CO increases associated with A/C operation are largely attributable to commanded enrichment, which will be controlled due to required compliance with the US06 cycle and standards. The strategies expected to be implemented to address emissions over the US06 cycle are essentially the same as those that are required to address HC and CO emissions due to A/C operation, and the Agency believes that HC and CO increases due to A/C operation will be effectively eliminated by use of these strategies. Thus, the levels achievable on the LA4 with the A/C on should be comparable to levels achieved with the A/C off.

The level of control applicable to NOx is more difficult to determine. The Agency believes that the large tailpipe NOx increases due to A/C operation can be mitigated to some extent, but because these increases were typically tied to large engine out increases there is probably some increase in tailpipe NOx that is currently unavoidable with the A/C operating. The difficult issue to address is how much of that observed increase can be eliminated with the potential and feasible control strategies, and therefore, what the level of increase actually is.

As detailed earlier, there are two general strategies that can be taken to reduce the impact of A/C operation on tailpipe NOx. The first is to improve the NOx conversion efficiency of the catalyst, particularly via appropriate attention to the air/fuel ratio. An Agency analysis of NOx conversion efficiencies with the A/C operating demonstrated an average reduction across the seven vehicles tested at ACR of 0.10 grams/mile if the three vehicles that had below-average conversion efficiencies had been calibrated to perform at the average level.

The second strategy to reduce tailpipe NOx is to reduce NOx at the engine source, which can be done by lowering combustion temperatures or reducing the load imposed by the A/C system. Combustion temperatures can be reduced by enhancing and increasing EGR use and/or by modifying spark timing, both of which will result in decreased engine out levels of NOx. The Agency has not estimated the reductions that might be achieved by these methods independently, but the auto manufacturers have submitted a preliminary analysis to the Agency that suggests that when combined with improvements to NOx conversion efficiency these strategies might achieve reductions on the order of 0.20 grams/mile of NMHC + NOx. Based on the data collected at ACR, NOx accounts for 80 to 90 percent of the NMHC + NOx equation on average. Given this, a potential NOx reduction of up to 0.18 grams/mile can be extrapolated from the manufacturers analysis, although this figure should be regarded as a preliminary estimate that applies to a catalyst aged to 50,000 miles, and by comparison, the ACR data reflects catalysts aged to less than 5000 miles. The Agency has also evaluated the potential impacts of mitigating engine out NOx by shutting off the A/C compressor for several seconds on accelerations on the LA4 cycle. Lacking data from compressors that actually behave in this way, the Agency modeled this on the LA4 by substituting A/C-off emissions data for sequences of seconds in A/C-on tests. The result is a modeled decrease of approximately 0.024 grams/mile, or about 12 percent of the average A/C-on increase. While it is the Agency's expectation that actual implementation of this strategy could use inputs to the vehicle's computer to better target compressor-off periods and durations and possibly achieve a larger reduction, the potential benefit might still be small enough to make this a strategy of last-resort because of the manufacturer's concerns outlined in the following section on feasibility.

Overall, although comparison of these estimates for both new and aged catalysts compounds the difficulty of making an accurate estimate, the Agency believes that implementation of these strategies can reduce A/C-on emissions increases by 75 percent, which translates to an "uncontrolled" increase of 0.05 grams/mile with the A/C operating. The extent to which additional innovative control strategies (e.g., more efficient A/C systems, specialized glass, or interior cooling methods for vehicle soaks) can reduce engine out NOx is not easily estimated, but the Agency believes that the level of control defined above will encourage, but not require, the exploration of such technologies. Given the uncertainty of these analyses, the Agency requests comments on the feasibility of this level of control and the technology implications of controlling to this level.

E. Feasibility

The Agency believes that the technologies required to produce vehicles conforming to the levels of control discussed earlier in this section are already generally available and in place to varying extent in the current fleet. The feasibility of recalibration strategies (e.g., optimization and tight control of the air/fuel ratio) is addressed in Section IX.E. The Agency also believes that the onboard computers in current technology vehicles already typically sense the inputs necessary to implement the strategy of turning the compressor off at critical points. However, potential impacts of this option on vehicle driveability, driver comfort, performance, and emissions and component durability should also be addressed.

The Agency believes that vehicle performance will be unaffected or possibly improved by selectively shutting the compressor off during portions of some accelerations. Indeed, many current technology vehicles already employ this strategy but restrict it to wide open throttle accelerations, specifically to improve vehicle performance. Because the thermal inertia of the A/C system will cause cold air to continue to be discharged for several seconds following compressor shutoff, driver and passenger comfort should also be unaffected. The possibility that this type of cycling strategy will adversely affect the durability of the compressor does exist, but the Agency does not know how significant a problem this might be. Current technology compressors are designed to cycle on and off many times, perhaps hundreds or thousands of times in a typical day's driving. In fact, this strategy does not necessarily imply that the compressor must cycle more often; to make up for turning it off on an acceleration the system may compensate by not turning it off somewhere else. It should be noted that vehicle manufacturers have stated that this strategy is the least desirable among all the choices and is not likely to be implemented because of impacts on customer comfort and satisfaction and the belief that the resulting emissions benefit is likely to be very small. However, the Agency believes that this strategy can be a valid and useful element for addressing A/C-on emissions, and is interested in specific comments regarding customer and emission impacts.

F. Test Procedures for A/C Operation

The Agency believes that it is appropriate to include a test for A/C-related emissions as an element of an expanded Federal Test Procedure. The purpose of this new A/C test procedure is to represent an in-use driving condition that does not occur throughout the year but that has a significant emissions impact when it does occur. As was demonstrated by the survey in Phoenix, A/C use (and emissions impact) is high when conditions are most favorable for the generation of high ozone levels.

The following discussion identifies significant elements of a test procedure designed to address emissions due to A/C operation. Subsequent sections will address overlapping requirements with other candidate areas of control and the integration of these elements into a broader Supplemental Federal Test Procedure.

Based on the conclusions of the previous sections, the principle structure of a stand-alone test procedure for A/C operation is the LA4 driving cycle run with the A/C operating in a test cell with an ambient temperature of 95°F. However, this proposal also provides for the possibility that auto manufacturers may in some cases want a better simulation in a full environmental test facility, an option that is not excluded by the Agency if appropriate simulations are made of temperature, humidity, sun load, road surface temperature, and vehicle cooling. The Agency expects that A/C emission control at temperatures lower than 95°F should be equivalent or superior to control at 95°F, and as a consequence the Agency is proposing that official confirmatory tests may be conducted at any temperature between 68°F and 95°F, with the applicability of the proposed standards. Current regulatory language specifies that an A/C simulation be applied to test vehicles where "it is expected that more than 33 percent of a car line within an engine-system combination will be equipped with A/C" (40 CFR 86.129-94), criteria for applicability that the Agency proposes to carry across to the new A/C test requirements. All certification test vehicles meeting this criteria must therefore have a properly functioning A/C system installed. For SEA and in-use (recall) testing, EPA may elect to test non-A/C vehicles from an A/C family or subset thereof.

With the exception of the test environment, the specific test procedures for both the "short-cut" procedure and the full environmental simulation are essentially identical. A large-roll electric dynamometer or equivalent is required. The test should be conducted with the vehicle in a hot stabilized condition, therefore preconditioning over some type of driving will be required. Minimally, the vehicle should be driven over a 505 cycle if it has soaked for less than two hours, but an 866 or US06 are also acceptable. If the vehicle has soaked for more than two hours, an LA4 or US06 are acceptable preconditioning cycles. Following the preconditioning cycle the vehicle will immediately be driven over the control cycle and emission measurements will be made. If the vehicle is equipped with a manually operated A/C system, the settings will be as follows: the A/C mode switch will be set to the highest (coldest) position; the temperature control will be set to the lowest (coldest) position; the air flow will be set to discharge from the dash facing the front occupants; air source will be set to recirculation of interior air; and the fan set at position 3 of 4 speeds, position 2 of 3 speeds, or position 2 of 2 speeds. If the vehicle is equipped with an automatic climate control system, the A/C system will be set to control to a temperature of 72°F and the other parameters, if independently selectable, will be set to the specifications for manual systems. However, it has been brought to EPA's attention that there are some fan controls that have up to ten independently selectable positions, and that perhaps a better approach that would achieve more consistent settings across vehicles would be to base the fan setting on amperage. Another possibility would be to allow the manufacturer to select the appropriate setting with the understanding that the Agency could test with any desired settings. The Agency welcomes comments on the feasibility of these options and how an appropriate setting should be defined.

If the full environmental simulation option is selected, the test chamber should minimally simulate an ambient temperature of 95°F, a relative humidity of 40 percent, a sun load of 850

Watts/meter2, and wind speed equivalent to vehicle speed.[32] All vehicle windows will be closed. If the alternative procedure is used, the ambient temperature will be set to 95°F, the driver's window will be fully open, and cooling will be provided by a single large fan placed in front of the vehicle.

XII. Supplemental Federal Test Procedure (FTP)

The following describes the major requirements of the Supplemental FTP (SFTP) which combines the three new test cycles with the initial 505 seconds of the FTP.

A. Applicable Vehicle Classes

The primary purpose of this rule is to ensure that the level of emissions control required for driving conditions found in the FTP is maintained over the entire range of in-use driving conditions. The Agency's driving surveys indicate that all types of LDVs and LDTs are operated in roughly equivalent ways. In cases where differences exist between some types of vehicles in certain areas, EPA is proposing to make appropriate adjustments to the test procedures. (see Sections XII.M. and XII.N.) Thus, EPA is proposing that the requirements be applied to all light-duty classes, including LDTs.

B. Applicable Motor Fuels, Combustion Cycles, and Pollutants

The Agency is proposing that the new non-FTP requirements apply to all types of fuel. Very little emission data currently exists on non-FTP emission impacts using fuels other than gasoline. Because of this, EPA considered exempting alternative- and/or diesel-fueled vehicles from the non-FTP requirements. However, an exemption would not only give alternative-fueled vehicles an artificial competitive advantage over gasoline vehicles, but it could lead to degradation of in-use emissions should alternative-fueled vehicles gain appreciable market share. In addition, most, if not all, alternative fuel vehicles use the same basic emission control technology as gasoline vehicles (that is, three-way catalysts, oxygen sensors, and feedback fuel control). Thus, it is anticipated that the emission strategies discussed in this proposal for gasoline vehicles will also work for alternative fuel vehicles. If data are submitted to EPA in

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These parameters are designed to represent a typical ozone non-attainment day. A full discussion of the development of these parameters can be found in the Technical Report on A/C for the Notice of Proposed Rulemaking, which is available in the public docket for review.

response to this NPRM that indicates that some of the requirements may not be appropriate for one or more alternative fuels, EPA will consider modifying the non-FTP requirements for alternative-fueled vehicles in the final rule.

No work has been done to date on particulate emissions, for two reasons. First, particulate emissions are primarily a concern with diesel engines. As light-duty vehicles and trucks include very few diesel engines, particulate emissions were not a high priority for this project. Second, special equipment is needed to measure particulate emissions, especially from diesel engines. Such equipment has yet to be installed in conjunction with the new larger-roll electric dynamometers required for high speed and acceleration testing. Due to the lack of data and the relatively low concern with particulate emissions from gasoline vehicles, EPA is proposing to postpone the establishment of particulate standards for non-FTP requirements until a future rulemaking.

As of the 1996 model year, all existing Federal HC emission standards will be expressed in terms of both NMHC and total HC. In addition, future HC standards being considered by the Northeast states and by EPA as part of Tier 2 are also NMHC standards. As the non-FTP requirements are intended to complement the FTP standards, EPA is proposing to establish both NMHC and THC non-FTP requirements.

The test data on gasoline vehicles indicates that engine-out NOx increases dramatically with increased engine load, due to increased combustion temperatures. On diesel engines, this engine-out increase cannot be minimized with NOx reduction in the catalyst. This is because, with current catalyst technology, NOx reduction does not occur in an oxidizing environment and diesel engines always run lean.[33] Unfortunately, no data currently exist on diesel engines under the non-FTP conditions considered in this rulemaking to quantify the impact the lack of NOx catalyst reduction has on the ability of diesel engines to comply with the proposed procedure. In the absence of such data, EPA is proposing to apply the same standard setting criteria to diesel engines as all other fuels, as the less stringent FTP diesel NOx standards would be reflected in the non-FTP requirements proposed today. The Agency is attempting to arrange for testing of at least one diesel LDV and one LDT at it's test facility before the final rule. If these data, or data submitted in response to this

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Diesel engines do not have a throttle and always use the maximum amount of air the engine can deliver; only the fuel rate is varied to control power output.

NPRM, indicate that diesel engines cannot comply with the non-FTP NOx requirements, EPA will consider establishing alternative NOx requirements for diesel engines in the final rule.

C. Standard Setting Options Considered

Previous sections have discussed appropriate levels of control for each control area. This section evaluates four different options to translate these levels of control into compliance procedures and appropriate emission standards.

1. Stand-Alone Standards

This option would set stand-alone standards for each control area. Compliance procedures and standards would be established individually for aggressive and microtransient driving behavior, A/C, and intermediate soaks. This involves directly translating the appropriate levels of control and test procedures into emission standards and compliance procedures.

Preceding chapters have discussed the appropriate levels of control on a conceptual basis. Translating this level of control into appropriate emission standards is a two step process. The first step is to determine the emission levels that properly reflect the conceptual emission stringency. The second step is to determine the appropriate margin to add to these emission levels in order to set the final emission standard. Such compliance margin is typically appropriate to take into account the additional margin of control a manufacturer should build into their product to ensure compliance of all vehicles in-use. This additional margin takes into account normal variation in emissions from one vehicle to another, variation in the conditions encountered by vehicles in-use over their useful lives, and errors in predicting in-use emission levels during the development process. Without such additional margin, the stringency of the standard would be increased greatly, as manufacturers would have to target average emission levels below those determined in step one to avoid large numbers of in-use failures. The need to incorporate such a margin would typically not apply, for example, where the Agency was reducing a previously adopted standard, as a compliance margin would already have been built into manufacturers' strategy to comply with the prior standard.

Setting standards for stand-alone requirements has potentially serious problems with both of these steps which are not obvious. Determining proper numeric emission standards are a problem because emissions over the different non-FTP areas differed widely from vehicle to vehicle. Setting the level too high would allow many vehicles to comply without any reduction in non-FTP emissions. Setting the level too low would force many vehicles to adopt potentially expensive control measures.

The second step is to determine the appropriate margin to apply to the test vehicle emission levels determined in step one. However, such margins have been applied in the past only for the entire FTP, which includes a weighted average of cold start, stabilized, and hot start emissions. Margins for the individual components of the FTP have never been dealt with and could be quite different from the weighted total. While it would be theoretically possible for hot stabilized margins to be determined from in-use enforcement test data, it would be a difficult task. Further, because vehicles are generally selected for in-use enforcement testing on the basis of suspected high emissions, such a sample would be biased.

Primarily because of the lack of appropriate data to determine appropriate compliance margins for hot, stabilized driving, EPA has not translated the appropriate levels of control determined earlier into numeric emission standards for each control area. A theoretical discussion of average test results that might be used for step one of stand-alone standards is included in the Regulatory Impact Analysis (RIA), although it is not presented here because EPA has not thoroughly assessed the problem with loss of emission benefits or increased cost associated with stand-alone standards.[34]

2. Combine Stand-Alone Standards

This option would combine the three non-FTP areas of control into a single standard. There are a number of advantages to this approach include:

- Only one standard for EPA to promulgate and enforce.
- Allows manufacturers to choose most cost-effective solutions from along the non-FTP areas.
- Could combine the full A/C simulation over the 505 cycle with the intermediate soak test, shortening the test sequence. (A detailed explanation of the test sequence and a comparison to stand-alone standard test sequences can be found in the RIA.)

Two potential disadvantages to this approach, compared to stand-alone standards are: first, the incentive to control emissions due to throttle variation is reduced, as US06 would be

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Numeric stand-alone standards were included in the proposal submitted by the manufacturers and are available in the public docket for review.

only a portion of the overall standard instead of being 100 percent of a stand-alone standard. Inclusion of the new start cycle after the intermediate soak would help alleviate this potential concern, as the start cycle also has speed variations representative of in-use. Second, this approach would not guarantee emission reductions in each control area. This impact would be negligible if the weighting factors and the baseline emissions were chosen appropriately. While EPA is confident that appropriate weighting factors could be developed, there may be some concern about the baseline emissions used to develop the combined emission standard.

While this approach has some significant advantages over stand-alone standards, it does not improve upon the two primary concerns expressed for stand-alone standards. The selection of the appropriate hot, stabilized emission levels is simply the weighted average of the individual control area emission levels, leading to the same potential problem with loss of emission benefits or increased compliance cost. The lack of appropriate data to determine an appropriate compliance margin to add to the standard for hot, stabilized driving also remains a problem.

3. Composite Non-FTP Standard

This option would establish a composite standard based on results drawn from both the SFTP and the FTP. This approach is a variation of the single non-FTP standard discussed in the last section. While the basic concept is similar, the approach is specifically structured to mitigate the two primary concerns discussed for the first two standard setting options. This is done by artificially manipulating bags and bag weights, such that meeting the appropriate levels of control results in standards similar to the FTP emission standards. This allows two fundamental changes in the design of the standard. First, the appropriate level of control is implemented using bag weights. As discussed earlier, the appropriate level of control determined for each control area is tied to emission levels for portions or all of the FTP. As there appears to be less variability between each vehicle's non-FTP emissions and it's FTP emissions than there is from vehicle to vehicle, using bag weights to directly represent the appropriate level of control may reduce the risk of lost emission benefits and/or increased cost associated with directly setting numeric standards. Second, this option avoids having to create new in-use compliance margins by preserving the existing FTP compliance margins, as the composite non-FTP standard approach weights cold start, hot start, and stabilized driving similar to the approach used for the FTP.

How this approach would work can perhaps be best expressed by example. In the case of US06 NMHC standards, the appropriate level of control was determined to be Bag 2 FTP levels. Under a stand-alone US06 requirement or under the simple combination of non-FTP control areas in Section XII.C.2., the result would be an NMHC standard for US06 based upon average FTP Bag 2 emissions, with some (currently undefined) level of compliance margin added. However, if US06 NMHC emissions are to be the same or lower than Bag 2, then an equivalent emission stringency can be created by substituting US06 for Bag 2 weights in the composite calculation. So long as the vehicle complies with the design intent to have US06 NMHC emissions not exceed Bag 2, the composite emissions with US06 will be no higher than they were with Bag 2. The appropriate bag weights to be used for each pollutant under this approach, as well as areas where some adjustments to the FTP emission levels may be appropriate, are discussed in Section XII.D.

It should be emphasized that even though FTP emission levels are targeted under this option, the overall stringency is not any more or less stringent than the first two options. All three options use the appropriate level of controls determined in preceding sections as the basis for setting standards. This option simply accomplishes this by re-weighting bags and making adjustments to the FTP standards, rather than trying to set numeric standards directly.

Although the overall stringency is similar, this option offers three significant advantages over either the stand-alone standards or the combined standard in option 2. First, the calculation more accurately reflects the capabilities of different vehicle designs. The potential problems with not requiring any non-FTP control on some vehicles and/or very high levels of control on other vehicles are minimized. Second, as FTP cold start, hot start, and stabilized driving distributions are maintained, the overall FTP in-use compliance margins are preserved. Third, it allows additional flexibility for manufacturer compliance by including the cold start in the composite standard.

4. Create New FTP

The final option considered by EPA would replace the current FTP with an entirely new FTP that reflects, as accurately as possible, actual driving behavior. To do this, all in-use driving characteristics identified in the "Federal Test Procedure Review Project: Preliminary Technical Report" would be quantified and incorporated into a new test sequence. This would include a number of factors beyond the specific areas of non-FTP operation proposed today for additional control. These additional factors include start driving proportion; cold, warm, and hot start distributions; speed variation during all driving; and road grades (a more detailed description of these items can be found in the RIA). Incorporation of all factors would yield a test procedure that would look roughly as follows:

Bag 1--Cold start--new 1.4 mile start cycle with lower initial speeds and more speed variation (this cycle would also be used for warm and hot starts, although with different initial idle periods). Would be much shorter than the current 3.6 mile cycle to facilitate proper bag weighting. Would be run after an overnight soak and would incorporate full A/C simulation, although at a lower load to reflect the fact that most cold starts occur in the morning.

Bag 2--Hot, stabilized cycle--new cycle reflecting actual speed/acceleration distributions during typical driving. Would include the additional in-use speed variation and incorporate full A/C simulation. Possibly would include road grade effects.

Bag 3--Hot start--new 1.4 mile start cycle, run after a 10 minute soak with full A/C simulation.

Bag 4--High speed/acceleration cycle -- a cycle similar to US06, including full A/C simulation and possibly including road grades.

Bag 5--Warm start--new 1.4 mile start cycle, run after a 60 minute soak with full A/C simulation.

Bag weights would reflect the actual proportion of in-use vehicle operation represented by each bag, as determined from the in-use driving surveys.

An open issue would be the emission standards for the new procedure. If EPA were to adopt such a representative test procedure and apply it to the numeric emission levels established elsewhere in the CAAA, issues of lead time, benefits and cost of such new requirements would need to be addressed. It is unclear whether EPA would have authority to make an adjustment to the standards, if appropriate. Another issue would be how to handle CAFE for LDVs, as this test procedure would completely replace the existing FTP.

5. Comparison of the Four Options

Actually replacing the FTP has two significant advantages. It would better ensure vehicles actually achieve the desired levels of emission control in-use and it would provide a shorter test procedure than adding new non-FTP control on top of existing FTP.

Because replacing the FTP would offer better assurances of in-use emission control and would simplify the test procedure, EPA believes it makes sense in the long term to consolidate all the test requirements into a revised FTP. However, there are four short-term practical problems which make it difficult to replace the FTP at this time.

The major problem is consistency with test procedure changes and more stringent emission standards currently being considered for different parts of the country, such as the California LEV and ULEV standards, efforts by the Northeast states to adopt California requirements, and voluntary 49-state emissions standards ("FEDLEV"). Revising the existing FTP would potentially impact the stringency of these standards, especially for NOx. This is because (1) a complete revision of the FTP would include elements beyond the proposed non-FTP requirements whose impact on emissions have not been quantified and (2) EPA has concluded that some increase in NOx may not be feasible to control, assuming the current analyses of control techniques, when the A/C is turned on. Given the current lack of knowledge on how inclusion of the additional elements would impact standard stringency and the absence of non-FTP data on vehicles designed to more stringent standards, replacement of the FTP at this time would likely delay adoption of federal standards more stringent than Tier 1 while the appropriate numeric standard levels were being researched.

There are also three problems that would primarily impact cost or would require additional lead time to resolve:

- Determining the appropriate lead time for a new FTP would involve considerations of the costs and benefits of the change, assuming as discussed in Section IV that EPA did not have authority to revise the Tier 1 numeric emission standards.
- The manufacturers have a great deal of experience with the FTP. This experience has been used to develop "rules of thumb" which are used to design and calibrate emission controls while minimizing development work. Revision of the FTP would require them to develop all new rules of thumb, which would be time consuming and would significantly increase their development work until they were developed and verified.
- The original FTP would have to be maintained in any case simply for CAFE purposes or a great deal of data would have to be generated to determine test procedure adjustments.

To avoid jeopardizing work on more stringent emission standards and to avoid delaying implementation of today's proposal, EPA believes it is better to incorporate consolidation of the FTP with future consideration of tighter federal standards. Comments are solicited on when consolidation should occur.

Of the three options to establish separate non-FTP emission controls, EPA believes that there may be significant advantages to the non-FTP composite approach targeting FTP levels. This is based largely upon two perceived problems with the first two options; that is, the difficulty in determining a single emission level given the disparity in the emission levels from vehicle to vehicle and the lack of data to determine appropriate in-use compliance margins. Because of the lack of data on appropriate in-use compliance margins for hot, stabilized cycles, EPA is proposing the non-FTP composite approach as the primary option in this NPRM. However, EPA would view the first two options as being equal candidates for adoption in the Final Rule if data are provided in response to this NPRM that allow for the calculation of appropriate hot, stabilized compliance margins, and data indicate that establishing a single emission level for hot, stabilized emissions from all vehicles would not cause significant degradation of emission benefits or increased cost.

Comments are solicited on the relative benefits and disadvantages of each of the four options discussed. Based upon the comments and data submitted, EPA will re-evaluate each of the four options and determine which would yield the most cost-effective emission reductions for incorporation into the Final Rule.

D. Cycle Selection Considerations

As discussed, introduction of the combined approach reduces the weight given to US06, part of whose purpose is to provide emission control during higher levels of speed variation than is found on the FTP. Inclusion of the new start cycle would provide greatly increased representation of in-use speed variation over the composite test procedures. Thus, EPA is proposing to use the new start cycle in conjunction with the intermediate soak portion of the composite non-FTP requirements. The Agency would consider adopting the use of the 505 in the final rule if data is submitted indicating that the sensitivity of some vehicle emissions to throttle variation will be eliminated in the future even without adoption of the new start cycle and that start emissions using the 505 are proportional to start emissions using the new start cycle (that is, that the 505 is a good predictor of actual start emissions).

E. Selection of Bag Weights for the Non-FTP Composite Option

Under the non-FTP composite approach, the bag weights for each cycle are selected to mirror the appropriate level of control determined for each control area. The selection of appropriate bag weights to reflect the proposed level of control is discussed below by control area.

1. US06

As the US06 Cycle represents speed and acceleration driving conditions that were not previously included in the FTP, an appropriate weighting factor must be determined for the US06 Cycle. As discussed in the "Final Technical Report on Aggressive Driving Behavior for the Revised Federal Test Procedure and Notice of Proposed Rulemaking", driving at speeds and accelerations beyond the FTP distribution constitutes 28 percent of overall driving on the basis of miles driven. However, the US06 Cycle does not completely reflect the actual distribution of speeds and accelerations beyond the FTP. In order to maintain a representative sample of high load operation while reducing test time and driver fatigue, the cycle was shortened to 10 minutes while maintaining all high load operation. As a result, the US06 Cycle includes operation in all high speed and acceleration conditions that would be included in a longer, completely representative cycle, but with the highest load operation over-represented by a factor of about three on a time-weighted basis.

The Agency believes that the 28 percent weighting factor is still appropriate for US06. Except for the highest accelerations and the highest speeds, the speed and acceleration distribution is still representative of actual distributions. While the US06 generates higher gram/mile emissions than a representative high speed/acceleration cycle would due to the over-representation of the extreme events, the proper way to handle the difference in emissions is to adjust the standard stringency, not the bag weight. Any adjustment to the bag weight would proportionally impact all emissions from the cycle, not just the extreme events. Thus, any bag weighting adjustment to better represent extreme events would introduce a corresponding error to emissions from the great majority of representative high speeds and accelerations. Further, the increased emissions from the extreme events has already been accounted for in the determination of the appropriate level of emission control (a less severe cycle would have yielded high speed/acceleration emissions that were lower than those seen on the US06 or the portions of the FTP to which the US06 was compared). As the appropriate levels of control determined in the earlier sections were based upon the US06, a 28 percent bag weight for the US06 portion should yield the appropriate overall emission standards.

As described in Section IX, it was determined that an appropriate level of control for NMHC emissions over the US06 is FTP Bag 2 level. This level of control can be implicitly incorporated into a composite standard by substituting the 28 percent US06 Cycle bag weight for 28 percent of the Bag 2 weight. This substitution will yield identical overall weighted emissions as long as US06 NMHC emissions meet FTP Bag 2 levels, which is the desired level of control. Thus, EPA is proposing to reduce the Bag 2 NMHC weight by 28 percent when weighted together with Bag 1, the intermediate soak cycle, and the US06 Cycle to determine compliance with the non-FTP composite emission standards.

In the case of CO and NOx, it was determined that the appropriate levels of control over the US06 Cycle were equivalent to overall FTP levels. This level of control can be implicitly incorporated into a composite standard by substituting the 28 percent US06 bag weight for overall FTP emission levels. In practical terms, this means that the weights for Bag 1, Bag 2, and the intermediate soak will be reduced proportionally, such that they add up to 72 percent. The additional CO emission increment for US06 CO over FTP levels is appropriately handled by adjusting the emission standard.

2. Intermediate Soak

As described in Section X, the appropriate level of control for intermediate soak emissions should be based upon Bag 3 emission levels. The appropriate way to incorporate this into an non-FTP composite standard is to substitute the intermediate soak for the Bag 3 weight. If the vehicle achieves Bag 3 emission levels after the intermediate soak, then this substitution will not increase overall emissions for the composite standard calculation.

3. Air Conditioning (A/C)

Unlike high speeds, high accelerations, and intermediate soaks, A/C operation does not involve driving that is not represented on the FTP. Instead, it is an in-use driving condition that occurs during all driving modes during typical ozone nonattainment conditions. The Agency has simply determined that the previous method of simulating A/C load on the FTP is not adequate for emission control purposes. Thus, no bag weighting adjustments are needed for A/C operation.

4. Summary of Approximate Bag Weights for SFTP

Based on the discussions above, the appropriate bag weights for the entire SFTP were determined to be those shown in Table 10 below.

Table 10:

	THC/NMHC	CO/NOx
FTP Bag 1	21%	15%
Bag 4 - 866 (Bag 2 cycle)	24%	37%
Bag 5 - Intermediate soak	27%	20%
Bag 6 - US06	28%	28%

For comparison, the FTP bag weights are approximately 21 percent for Bag 1, 52 percent for Bag 2, and 27 percent for Bag 3.

F. Adjustments to Target FTP Levels

1. NMHC and CO Adjustments

The appropriate level of control for US06 NMHC emission was estimated to be the FTP Bag 2 emission levels. Since this was fully incorporated with bag weighting, no adjustments are needed to the FTP target levels. Similarly, the appropriate level of control for US06 CO emission was estimated to be overall FTP emission levels. Again, this was fully incorporated with bag weighting, so no adjustments are needed to the FTP target levels.

For A/C, it was estimated that vehicles could maintain existing NMHC and CO emission levels with the A/C turned on. Thus, no adjustments would be needed for this factor.

For intermediate soak, EPA is proposing that the appropriate level of emissions on the intermediate soak would be equal to Bag 3 emission levels. As this was fully incorporated with bag weighting, no adjustments are necessary.

Thus, the appropriate non-FTP HC and CO composite standards are identical to the FTP standards. For Tier 1 LDVs this would be 0.25 g/mi NMHC and 3.4 g/mi CO.

It should be noted that the determination of the appropriate level of control for CO was done independently of the NOx determination. There is concern that tradeoffs may exist between CO and NOx control that EPA's analysis did not consider. Comments are solicited on this issue. Significant NOx increases as a result of CO control are undesirable from the Agency's perspective. If additional test data are submitted demonstrating that controlling CO to the proposed emission stringency would significantly impact NOx emissions, EPA would intend to reduce the stringency of the SFTP CO standards in the Final Rule.

2. NOx Adjustments

The Agency believes that 0.042 g/mi of the NOx increase with A/C engaged is likely to be unavoidable without increasing the stringency of the FTP standards. Thus, an adjustment is needed to the FTP standards when setting composite non-FTP emission standards for NOx.

As for NMHC and CO, the appropriate intermediate soak and emission levels are fully incorporated with bag weighting. Thus, no NOx adjustments are necessary for intermediate soak.

Any adjustment to the NOx standard needs to incorporate both the average vehicle increase and the compliance margin associated with the average increase. This is done by applying the FTP margin observed on the test vehicles to the average emissions determined using the same test vehicles. The FTP margin is simply the FTP standard divided by the average FTP emission level for the applicable test vehicles. The average emissions are determined by weighting the proposed level of control for each bag of the non-FTP composite standard by the bag weights previously determined.

The following general equation is based upon this approach:

$$[(15\% * AE_1) + (37\% * (AE_2 + A)) + (20\% * (AE_3 + A)) + (28\% * US06)] * (FTP\ standard) / (FTP\ average\ emissions)$$

Where:
AE_1 = Average FTP Bag 1 emissions
AE_2 = Average FTP Bag 2 emissions
AE_3 = Average FTP Bag 3 emissions
A = proposed A/C increase in g/mi
US06 = proposed level of control for US06

In this case, the bag weights for Bags 1, 2, and 3 are proportional to the FTP calculation. Thus, ($15\%*AE_1 + 37\%*AE_2 + 20\%*AE_3$) is equal to FTP average emissions. The proposed level of NOx control for the US06 Cycle has also been set equal to FTP levels. After making these substitutions, the equation reduces to:

$$(1 + (57\% * A / FTP\ baseline\ emissions)) * (FTP\ standard)$$

Six of the seven vehicles for which appropriate data exists to calculate the increase with A/C simulation were certified to a 0.4 g/mi NOx standard for the FTP. For these six vehicles, the average NOx increase with full A/C simulation was 0.168 g/mi and the average FTP emissions were 0.167 g/mi. As discussed in the feasibility section (XI.E.), 25 percent of this increase, or 0.042 g/mi, is currently considered to be uncontrollable, based on the assumptions in that analysis. Thus, for vehicles certified to a 0.4 g/mi NOx standard, A = 0.042 and the adjusted SFTP NOx standard =

(1+(57%*0.042/.167))*0.4 = 0.457 g/mi, or 0.46 g/mi rounded to two significant figures (the procedure currently employed for motor vehicle standards).

As appropriate full A/C simulation data exists on only one vehicle certified to a NOx standard other than 0.4, EPA is proposing to apply the ratio of the SFTP NOx standard calculated for vehicles certified to a 0.4 g/mi FTP NOx standard, 0.46 / 0.4 = 1.15, to determine the appropriate SFTP NOx standard for vehicles certified to FTP NOx standards other than 0.4 g/mi. For example, the intermediate NOx standard for Heavy LDT would be 0.7*1.15= 0.805 g/mi. As the adjustment factor of 1.15 was rounded up from the formula, EPA is proposing to round down any calculated composite NOx standard that is exactly halfway between two significant figures. Thus, the 50k NOx standard for Heavy LDT would be 0.80 g/mi.

G. NMHC Plus NOx Standard

Vehicles differ widely both in their levels of engine-out NMHC and NOx emissions and in the relative effectiveness of HC and NOx catalyst conversion efficiency. This is especially true of high load events, as the engine experiences higher engine-out NOx levels than on the FTP. Thus, significant cost savings with the US06 Cycle requirements might be available by allowing manufacturers to comply with a single NMHC+NOx standard, instead of separate requirements for each pollutant. This would allow each manufacturer to pursue the control strategies on the US06 Cycle that are the most cost effective and which minimize total emissions. On the other hand, the impact of an NMHC+NOx standard on A/C and soak/start control is less clear. A/C control is largely for NOx emissions and, while soak/start impacts both NMHC and NOx, the impacts are largely proportional and do not involve substantial tradeoffs. Thus, EPA is asking for comments on whether or not it would be appropriate to establish a single NMHC+NOx standard for stand-alone A/C or soak/start requirements or for the proposed composite standards. Comments are also solicited on both the potential emission impacts and cost implications of this proposed alternative.

H. Applicability to FTP Standard Changes

The Agency believes the composite non-FTP emission levels should be proportional to FTP emission levels. As Bag 1 of the FTP is included in the composite non-FTP emission standards, improvements to cold start emissions in response to stricter FTP emission standards should yield proportional reductions in composite non-FTP emissions. In addition, technology improvements to reduce emissions during hot, stabilized operation, such as better fuel control and better catalyst conversion efficiency, should be just as effective in reducing emissions during non-FTP operation as on the FTP. Thus, reducing FTP emission levels without proportional changes in the composite non-FTP standards would likely reduce the stringency of the non-FTP emission requirements. To ensure the future effectiveness of non-FTP emission controls, the Agency is proposing to tie the non-FTP composite standards to FTP standards. Any phase-in of future FTP standard changes would equally apply to phase-in of adjusted standards for non-FTP controls.

As discussed in other sections, the Agency is proposing to make some adjustments from the Tier 1 FTP NOx standard for the non-FTP composite standard applicable to Tier 1 vehicles. One issue is how to handle these adjustments for standards other than Tier 1. The adjustments could be treated either as absolute offsets in grams/mile (that is, an additive increase), regardless of the FTP emission standards, or they could be treated as a proportional (or multiplicative) increase to the FTP emission levels. The Agency believes that the multiplicative case is more consistent with the position that composite non-FTP emission levels should be proportional to FTP emission levels. Thus, the Agency is proposing to use multiplicative adjustments to composite non-FTP emission standards to maintain equivalent non-FTP standard stringencies corresponding to any future changes to FTP emission standards. It should be noted that if EPA obtains evidence showing that the NOx increase with A/C use is in fact controllable, i.e., it is not unavoidable, then this NOx adjustment could be deleted.

One potential concern with tying the composite non-FTP standards to the FTP standards is a theoretical trade-off between NOx and NMHC conversion efficiencies. That is, biasing the air/fuel slightly rich to obtain maximum NOx conversion efficiencies may reduce the NMHC conversion efficiency, and visa versa. The Agency's analysis for Tier 1 vehicles, discussed in the RIA, concluded that the tradeoff between NOx and NMHC is minor compared to the tradeoff between NOx and CO and that at emission stringencies up to and including Tier 1 emission levels, the trade-off between NMHC and NOx is insignificant. However, it is possible that the tradeoff between NOx and NMHC becomes more significant at lower emission levels, when catalyst conversion efficiencies must be improved for NMHC and NOX simultaneously. Should EPA receive data, or other relevant evidence, substantiating that NMHC and NOx conversion efficiencies cannot both be maintained at high enough levels to proportionally reduce composite non-FTP emission levels relative to the FTP reduction, EPA may make some adjustment to the relationship between composite non-FTP emission standards and FTP standards in the Final Rule or defer the issue to subsequent rulemakings affecting future FTP emission standards.

Note that all the above discussion applies only to the non-FTP composite standard approach. The concept of proportional standards for the SFTP compared to the FTP standards does not work with stand-alone standards, or the simple average of stand-alone standards. Thus, should stand-alone standards be adopted in the Final Rule, SFTP standards would have to revisited as part of any future changes to the FTP standards.

I. Durability Implications

The proposed methodology for non-FTP composite standards is to set NMHC and CO standards equal to the FTP standard and to set a NOx standard equal to 1.15 times the NOx FTP standard. The Agency is proposing that this methodology be applied to both intermediate and full useful life emission standards for determining in-use compliance with the SFTP requirements. Should adjustments be made to the SFTP NMHC or CO levels in the Final Rule, it is proposed that any such adjustments also be applied proportionally to both intermediate and full useful life standards.

The proposed non-FTP composite standards use bag weights and standards very similar to the FTP. In addition, the new standards are expected to extend FTP calibration strategies to the proposed areas of control. Thus, FTP durability procedures and deterioration factors should also work well for the non-FTP composite standards. Consequently, EPA is not proposing new durability procedures for use in certifying vehicles to the non-FTP composite standards. Instead, deterioration factors determined for the FTP would also apply to the non-FTP composite standards. Comments are solicited as to the appropriateness of applying FTP deterioration factors to the non-FTP composite standards and what problems this approach might create with the implementation of Alternative Service Accumulation Durability Program.

Comments concerning stand-alone standards, or the simple average of the composite standards, should include consideration of how to set appropriate standards for both intermediate and full useful life. Durability procedures for the new stand-alone standards should also be addressed.

J. In-Use Enforcement

Consistent with EPA's other mobile source enforcement requirements, the proposed standards would apply for full useful life under Section 202 of the CAA. The warranty provisions under Section 207 of the CAA also apply to these standards. Any testing flexibilities discussed in other sections of this rulemaking for individual control areas or for reducing development and certification testing burdens are not intended to preempt the Agency's in-use enforcement ability. While some of the options included in this flexibility are not likely to be utilized (such as testing vehicles with catalyst preheaters over intermediate soaks), EPA wishes to preserve maximum flexibility to ensure compliance with all emission requirements.

K. Lead Time and Phase-In Options

Most vehicles should be able to comply with the high speed/acceleration and the A/C portions of the requirements simply with recalibration. Thus, a relatively rapid phase-in schedule should be possible for these two areas of control. The final rule is currently scheduled to be signed by October 31, 1995, based on a consent decree in Sierra Club v. Reilly, D.C. Cir. No. 92-1749. Manufacturers will have largely finished certifying 1996 vehicles by that time and will be well into the final calibrations for 1997 vehicles. Therefore, 1998 should be an achievable model year for vehicles that only need calibration changes to meet the requirements.

The intermediate soak requirements are anticipated to require catalyst insulation or moving catalysts forward on many vehicles. Because of the minor retooling required in either case, this control area would need the longest lead time of the three proposed control areas. Catalyst insulation may also increase the concern with high catalyst temperatures on some vehicles, which additional development time would help to alleviate. As EPA does not wish to delay potential benefits from the high speed/acceleration and A/C areas of control simply because intermediate soak requirements need more lead time, the Agency is proposing to decouple implementation of intermediate soak requirements from the other two control areas.

A great deal of variation exists from vehicle to vehicle in emissions over the proposed high speed/acceleration and A/C test cycles. There is also a large variation in the baseline catalyst temperatures. Some tested vehicles had relatively low temperatures and could easily handle some temperature increase, while others were already pushing the margin. Many vehicles at the lower end of the emission and temperature variation should be able to meet the non-FTP requirements with relatively straightforward calibration changes and minimal lead time. However, the vehicles with higher baseline emissions and temperatures may need to use more sophisticated emission control strategies to reduce emissions and avoid high catalyst temperatures, such as improved fuel control or control of engine-out NOx during A/C operation. Thus, an extra year or two may be appropriate for these vehicles.

Given these considerations, the Tier 1 phase-in schedule of 40 percent in the first year, 80 percent in the second year, and 100 percent in the third seems to be an appropriate schedule for high speed/acceleration and A/C compliance. Thus, EPA is proposing that 40 percent of a manufacturer's vehicles comply with the proposed standards in the 1998 model year, 80 percent in 1999, and 100 percent in 2000. The proposed high speed/acceleration and A/C requirements would all be included during this phase-in period, but the intermediate soak requirements would not be required. The Agency is proposing to add the intermediate soak requirements in the 2001 model year. As the manufacturers would have three extra years to prepare for the intermediate soak requirements, no additional phase-in should be needed.

Due to the time constraints in developing this proposal, EPA did not have time to do an in-depth analysis of the impact of this phase-in schedule on all competing programs. The Agency believes this schedule is feasible if this program is reviewed as a free-standing program. Comments are requested on the impact of this phase-in schedule when considered with other programs and suggestions for other schedules which will coordinate programs more effectively. Comments are also solicited on the benefits and feasibility of the proposed phase-in schedule. The Agency is particularly interested in data and comments on how potential concerns with higher catalyst temperatures should influence lead time, as well as how these concerns should be balanced with the objective to obtain the emission benefits under this rulemaking as quickly as possible. If it appears that control of commanded enrichment under this phase-in schedule could lead to unanticipated problems with catalyst deterioration, the Agency may elect to spread the implementation of the requirements over a longer period in the final rule. Another option might be to set an intermediate standard level for the initial phase-in. Comments are solicited on the relative benefits and costs of an intermediate standard compared to a phase-in directly to the final standards.

Small Volume Manufacturer Considerations

Because of the limited product offerings of most small volume manufacturers, it is generally not possible to split their fleet into multiple subsets. Thus, a percentage phase-in requirement often translates into having to do most or all of their product line immediately. In consideration of this fact and the limited resources of small volume manufacturers, EPA has generally exempted small volume manufacturers from phase-in periods, requiring them to simply have their entire fleet comply when the phase-in reaches 100 percent.

The Agency is proposing that this strategy be applied to the phase-in schedule being proposed in this NPRM. Thus, small volume manufacturers would be exempt from the proposed standards in 1998 or 1999, but would have to certify their entire fleet in model year 2000 to the high speed/acceleration and A/C requirements. Similarly, they would have to comply with the addition of the intermediate soak requirements in model year 2001.

L. Manufacturer Testing Flexibility

The new non-FTP requirements being proposed in this NPRM will substantially increase the length and cost of the test procedure, may require additional test facilities, and could increase the time it takes to calibrate engine parameters. While these costs are likely to be quite small when spread across 15 million vehicles per year, it is still desirable to minimize testing costs and calibration development time. This section discusses the testing flexibilities considered by EPA.

1. Substitution into FTP

The Agency at the option of the manufacturer is proposing to allow two blanket, automatic substitutions. The 866 Cycle may be run with full A/C simulation in place of Bag 2 of the FTP. Also, any combination of the intermediate soak bag may be used in place of Bag 3 of the FTP.

This blanket approval is based primarily upon the higher loads imposed by full A/C simulation, compared to similar FTP cycles without full A/C simulation. Because of these load increases, virtually no danger exists that such blanket approvals would have any negative air quality impact.

Manufacturers are highly unlikely to take advantage of this flexibility for official certification tests, due to the fuel economy implications. While the impact of full A/C simulation varies widely from vehicle to vehicle, the average decrease in fuel economy for the seven vehicles tested at AC Rochester was 13 percent. This decrease is likely to be far too large for manufacturers to accept unless one was unconcerned about both the CAFE impacts and the fuel economy label.

On the other hand, this flexibility could greatly reduce the testing burdens both for manufacturers' development work and manufacturer in-use testing. If FTP emissions met development target or in-use target levels using SFTP bags, it would be virtually certain that FTP emission levels would be acceptable without actually testing Bags 2 and 3 of the FTP. As the manufacturers typically conduct far more testing for both development purposes and for in-use testing than for actual certification, this flexibility should allow them to greatly reduce the additional testing burden imposed by the non-FTP requirements.

2. Substitution of FTP bags into Non-FTP Standards

Substitution of FTP Bags 2 and 3 for non-FTP test requirements is more problematic, due to the increased load imposed by full A/C simulation and to the impacts of longer soak periods. Because of these factors, substitutions of FTP bags in the non-FTP standards would require demonstrating that emissions will not increase with full A/C simulation and/or longer soak periods. On a per-vehicle basis, such a demonstration would require more work than just running the appropriate SFTP tests. The Agency considered the possibility of allowing blanket substitution approvals based upon single vehicle demonstrations. However, the impact of A/C load on emissions tends to be very sensitive to engine calibrations. Thus, EPA was not able to determine an acceptable means of allowing these substitutions which would not involve more work that running the tests. Suggestions for criteria that could be used for blanket substitution of FTP bags into non-FTP standards are solicited. In the absence of a workable scheme, EPA is not proposing to allow such substitutions.

3. Intermediate Soak Period Flexibility

The Agency is considering criteria for exempting vehicles from the intermediate soak requirements for stand-alone standards. Criteria are being considered to permit manufacturers to forego the data submittal requirement for testing following a 60-minute soak, allowing manufacturers to reduce the SFTP soak duration to 10 minutes. Under this option, manufacturers would be allowed to submit a technical justification demonstrating that a vehicle would clearly pass the intermediate soak requirement. For example, this might apply to a vehicle equipped with an electrically heated catalyst, which would meet the requirement provided the heater was activated. A technical justification might include a demonstration that the heater would be activated following all soaks. The Agency solicits comment on this option and potential criteria for granting such a waiver. It should be noted that, as long as testing is required for full A/C simulation, the start cycle should still be used after the 10-minute soak. Not only is this cycle more representative of how vehicles are actually driven after they are started, but the start cycle contains additional speed variation which is important to help ensure vehicles control emissions associated with throttle variation.

M. Manual Transmission Shift Points

As noted previously, the Agency is proposing two new cycles--the US06 aggressive driving cycle and the SC01 soak control cycle--for inclusion in the SFTP. The SC01 Cycle consists of moderate speeds and accelerations; consequently, EPA is proposing the shift point determination method employed for the LA4 Cycle as the method for the SC01 Cycle. Unlike the LA4 and SC01 Cycles, however, the US06 Cycle requires a fairly aggressive shift pattern (shifting at higher engine RPM) in order to properly follow the driving schedule. Based on experience in the Non-LA4 Test Program, EPA believes that the US06 Cycle shift points will be vehicle specific, and thus it would be inappropriate to promulgate a generic a US06 Cycle shift schedule for all vehicles. Thus, EPA proposes that manufacturers determine the appropriate shift points for their manual transmission applications and submit the shift schedules for EPA approval. In general, EPA will allow manufacturers to specify upshift points, but downshifting will not be permitted unless the vehicle is unable to stay within the driving tolerance on the speed trace in the existing gear.

N. Adjustments for Vehicle Type and Performance

The US06 Cycle was assembled from actual in-use driving segments and designed to control emissions from aggressive and microtransient driving. However, the analyses have shown a dependence of aggressive driving behavior on transmission type, Weight to peak horsepower (W/P), performance (measured as W/P) and vehicle type. This led the project team to conclude that it would be appropriate to adjust the aggressive driving test cycle for all HLDTs, and also for some low- and high-performance LDVs and LDTs. Based on the same analysis, EPA proposes to treat manual and automatic transmissions independently (see following section).

The proposal calls for US06 Cycle testing of Heavy Light-Duty Trucks (HLDTs) with the truck ballasted to curb weight plus 300 lbs and the dynamometer inertia weight determined from this same basis, while FTP testing remains at Adjusted Loaded Vehicle Weight. This reflects the project team's conclusion, based on the in-use driving survey analysis, that HLDTs in the more heavily loaded configuration would not exhibit the aggressive driving behavior incorporated in the US06 Cycle.

The proposed US06 Cycle adjustments based on performance level are summarized in Table 11. For low performance vehicles, the inertia weight is adjusted by multiplying the original inertia weight by the adjustment factor. This factor is the ratio of the applicable performance cutoff and the W/P of the test vehicle. Where an adjustment factor is called for, it is applied dynamically by the dynamometer only during those portions of the US06 Cycle that are the most aggressive.[35] No adjustment factors are proposed for mid-performance ("normal") vehicles.

Table 11: Performance-Based Adjustments

Transmission type:	**Performance (W/P range)**	**Adjustment:**
manual	low W/P>34	dynamic dynamometer inertia weight reduction
	normal 18 W/P 34	none
	high W/P<18	2 second stoich control
automatic	low W/P>31	dynamic dynamometer inertia weight reduction
	normal 18 W/P 31	none
	high (W/P<18)	2 second stoich control

For high performance vehicles (W/P less than 18), regardless of transmission type, the manufacturer must demonstrate stoichiometric control for wide-open throttle events of two seconds or less. The performance level of such vehicles is such that they are unlikely to experience wide-throttle operation over the US06 Cycle, and this requirement would ensure that these vehicles have aggressive driving emission control over similar vehicle operation as the rest of the fleet.

The numerical W/P cutoffs were determined from the analysis of the

Refer to the RSD for a detailed discussion of the points in the cycle where the proposed adjustments would be made.

fraction of time above certain specific power values in the combined Spokane and Baltimore databases (see Section VI). The different thresholds for manual and automatic vehicles and for low performance vehicles reflects the differences in their in-use driving behavior. For high performance vehicles, EPA believes the in-use differences are taken into account through the manual transmission shift requirement.

The determination of the high performance cutoff was complicated by the limited number of vehicles at the very high end of vehicle performance in the driving survey database. The Agency propose a high performance cutoff of 18; however, the Agency is concerned that this may provide a unfair advantage to vehicles in the 18-21 W/P range. The Agency test data indicate that some vehicles in this range may not experience a wide-open throttle event on the US06. Thus, without a two second stoich control requirement, vehicles in the 18-21 W/P range may be the only vehicles without some form of wide open throttle (WOT) emission control. The Agency solicits comment and data on the appropriate treatment of high performance vehicles.

The Agency has proposed a W/P-based measure for the performance cutoffs after also considering the alternative performance criteria based on a vehicle's acceleration time from zero to 60 mph. The W/P measure provides a good indicator of performance, but it does fail to account for differences in torque curves and aerodynamic design. The zero to 60 time provides a direct measure of performance; however, availability of this measure for vehicles in the in-use survey was problematic, making calculation of the appropriate cutoffs difficult. In addition, a standardized procedure for determining zero to 60 times of new vehicles would need to be determined and, perhaps, extended to address speeds up to 80 mph. The Agency rejected the zero to 60 time on the basis of these practical problems. The Agency solicits comments on the proposed method for making vehicle performance adjustments, as well as input on alternatives, including the one discussed above.

O. Drive Cycle Tolerances

Section VIII pointed out the sensitivity of emissions to microtransient operation over the driving cycle. The Non-LA4 Test Program found that some vehicles are particularly sensitive to throttle variation. Consequently, a principal objective of the SFTP driving cycles is to control emissions during microtransient operation that is more representative of in-use operation than found in the current FTP.

The current FTP regulations (40 CFR 86.115-78(b)) require that "the driver should attempt to follow the target schedule as closely as possible." To accomplish this, the regulation specifies a speed tolerance band and associated requirements for a valid test. The regulations also suggest that minimum throttle action should be used to maintain the proper speed-time relationship. Based on the driving cycle and emission analysis discussed in Section VIII, EPA believes that the speed tolerance band does not ensure that the microtransient components of the driving schedule are preserved, and the current minimum throttle action language in the regulations exacerbates the problem of microtransient representation.

The Agency proposes an additional trace tolerance criteria for all SFTP driving cycles using the speed-based measure, the sum of change in specific power (DPWRSUM). The Agency's analysis showed this measure to correlate with change in throttle as well as emissions. Unlike a throttle-based measure, DPWRSUM is independent of the physical characteristics of the vehicle and there exists a unique value corresponding to the nominal driving schedule. A test run which exactly matches the nominal driving schedule and, thus, matches the microtransient behavior of the driving schedule, would have a sum of change in power equal to the nominal DPWRSUM. Tests runs in which the DPWRSUM is less than the nominal value indicate that the exact trace was not maintained. Test run where the DPWRSUM is greater than the nominal value suggest excessive changes in power and, most likely, excessive throttle action

The Agency proposes that DPWRSUM be calculated for each emission test. A test with a DPWRSUM value greater than the nominal DPWRSUM value would be invalid. The Agency's preliminary analysis indicates that a lower threshold equal to 50 percent of the nominal value is reasonable. The Agency believes such a threshold would invalidate tests with "excessively smooth" driving traces. The Agency solicits comments on the appropriateness of the lower DPWRSUM threshold for a valid test. The Agency solicits comments on the proper method for setting the lower DPWRSUM threshold for a valid test.

XIII. Changes to the Conventional Federal Test Procedure

In addition to the SFTP, some revisions to the FTP are also proposed. As these complement provisions of the SFTP or ensure compatibility, many refer to discussions in previous sections.

A. Real Road-Load

The Agency is proposing to improve the accuracy of the dynamometer simulation of actual on-road operation during vehicle emission and fuel economy testing. Current EPA testing practice employs a small diameter twin roll chassis dynamometer equipped with a hydrokinetic power absorber. The vehicle drive axle tires are "cradled" between the twin rollers; the power absorber is adjusted to simulate vehicle road load at 50 mph.

This dynamometer configuration has several drawbacks. First, it can only be adjusted to simulate vehicle operation at one speed (currently 50 miles/hour). The road load imposed at other speeds typically differs from what the vehicle would see on an actual road. Second, the small diameter rollers (8.65 inches in diameter) present a significantly different surface to the vehicle tires than a flat road. Tire manufacturers are forced (by this unrepresentative interface) to make design compromises in their product that benefit only EPA testing. Finally, the two dynamometer rollers are not coupled and can turn at different speeds. Typically the forward roller runs slightly slower than the rear roller. Since the power absorber (and inertia flywheels) are connected to the front roller while the speed signal followed by the driver is taken from the rear roller, this tends to bias the system towards under-loading the vehicle.

During a recent test program run in cooperation with representatives from the motor vehicle industry, EPA evaluated differences between the small twin roll dynamometer and a 48" single roll dynamometer with an electric power absorber adjusted to reproduce vehicle road load over an extended speed range. A diverse group of nine vehicles was evaluated over EPA's standard emission and fuel economy tests; efforts were made to reduce sources of variability other than the two dynamometer configurations. While results varied widely from vehicle to vehicle, exhaust emissions were typically higher on the large roll dynamometer. The average increase was 0.027 g/mi HC, 0.98 g/mi CO, and 0.048 g/mi NOx. The test sample was heavily skewed towards trucks (five of the nine test vehicles) and rear-wheel drive vehicles (also five of the nine test vehicles). Only two front-wheel drive LDVs were tested, with much lower average emission increases: 0.012 g/mi HC, 0.27 g/mi CO, and 0.014 g/mi NOx. Complete results can be found in the docket.

The Agency is proposing to eliminate the understatement of emissions and other problems associated with the twin roll hydrokinetic dynamometer. Future emission (including non-FTP cycles) and fuel economy testing by EPA will employ a large diameter single roll dynamometer with an electric power absorber adjusted to simulate actual vehicle road load. This dynamometer design was previously specified for cold temperatures testing.[36] While manufacturers will be required to supply extended speed road load force characteristics for their vehicles to be certified, they will be free to use any dynamometer design that maintains acceptable correlation with EPA's test results.

The Agency is proposing this change because the larger roll electric dynamometers clearly do a better job of representing real-world conditions[37]. In addition, it is likely that much of the HC and CO increase seen on the nine test vehicles was due to triggering additional, brief periods of commanded enrichment. For NOx, all the test vehicles were Tier 0, which generally have poor catalyst conversion efficiency compared to vehicles calibrated to Tier 1 standards. Tier 1 vehicles are likely to convert a much higher proportion of any engine-out NOx increase, leading to lower increases in tailpipe emissions. Thus, for Tier 1 vehicles calibrated to control emissions during more realistic driving conditions, the emission increase due to the dynamometer change should be minimal. The key, from EPA's point of view, is simply to ensure proper calibration and therefore in-use emissions control by better representing actual, in-use driving conditions. Thus, EPA is not proposing to make any adjustments to the stringency of any emission standard due to this change in dynamometer specification. The Agency specifically solicits comments on the above conclusions.

The Agency is concerned about the negative impact maintaining two different types of dynamometers would have on laboratories and would like to implement the new road-load requirements as quickly as possible. In addition, minimal lead time should be necessary to comply with the new road-load requirements, as Tier 1 vehicles will be fully phased in by 1996 and any calibration changes required to eliminate commanded enrichment on the FTP

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"Electric Chassis Dynamometer Assessment Program", Government/Industry Dynamometer Task Group, June, 1992 Draft should be easy to implement and have virtually no impact on catalyst deterioration. Thus, the Agency is proposing that all testing be conducted with the new dynamometer and road-load requirements starting with the 1998 model year.

Comments are solicited on whether or not additional lead time is needed to implement the new road-load requirements. If data and additional information submitted supports longer lead times, the Agency may elect to phase in the FTP under the same phase-in schedule used for the new non-FTP requirements. Under this alternative, any engine family included in the SFTP phase-in would also use the improved road load simulations for FTP testing. To minimize the laboratory burden of maintaining two different sets of dynamometers, EPA would like to couple any phase-in of the new road-load requirements with procedures allowing an electric dynamometer to simulate the existing dynamometer load. Comments addressing new road-load should also comment on how such a simulation could be incorporated.

Under any scenario, manufacturers will be allowed to use the improved road load simulations in advance of the phase-in requirements, at their option.

B. Throttle Variation Criteria

Vehicles historically have had some emission sensitivity to frequency and magnitude of throttle variation. This was unavoidable with carbureted fuel systems used at the time the FTP was developed, due to the mechanical nature of the fuel control and problems with distribution of fuel to each cylinder shared by the intake manifold. Almost any vehicle could be made to fail the emission standards if the throttle was varied fast enough. As the goal was to have a repeatable emission test, language was added to the regulations to minimize throttle variation during the test. 40 CFR section 86.135-90(d) states, "Practice runs over the prescribed driving schedule may be performed at test point, provided an emission sample is not taken, for the purpose of finding the minimum throttle action to maintain the proper speed-time relationship..."

Fuel control technology has improved remarkably since the days of carburetors. Modern multi-point fuel injection systems and sophisticated computer software allow very precise fuel responses to throttle changes and virtually eliminate fuel distribution problems. Thus, with proper calibration, there is no reason why emissions should vary significantly over the range of normal in-use throttle variation. To ensure that proper calibration actually occurs, EPA is proposing to replace the current language in the regulations referring to "minimum throttle action" with "appropriate throttle action." Further, EPA is proposing a new speed tolerance criteria (see Section XI.O) which is intended to ensure representative throttle variation on the FTP driving cycles. However, EPA is also proposing to allow manufacturers to utilize controls that prevent rapid throttle changes, even if they fail the speed tolerance, so long as such controls function similarly in use.

C. Proportional Emission Requirements

The Agency currently prohibits the use of a defeat device; that is, any Auxiliary Emission Control Device (AECD) that "....reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal urban vehicle operation and use, unless (1) such conditions are substantially included in the Federal emission test procedure, or (2) the need for the AECD is justified in terms of protecting the vehicle against damage or accident, or (3) the AECD does not go beyond the requirements of engine starting."[38] Up until the mid-1970s, engine calibration was accomplished exclusively using a variety of mechanical devices, such as distributors, carburetors, and vacuum switches, and therefore EPA's defeat-device policy has historically focused on these mechanical hardware items for their defeat device potential.

The computer has changed the entire nature of engine calibration. Unlike mechanical devices, which are only capable of linear responses or on/off operation, computers can be programmed for any desired response curve or step-change. Modern vehicles control fuel delivery and spark advance almost exclusively using stored look-up tables and algorithms, plus AECDs such as the EGR valve and evaporative purge controls are increasingly controlled by the computer. Due to this increasing reliance on the computer, EPA's historical defeat device criteria has become increasingly difficult to apply.

A major step towards updating EPA's defeat device criteria occurred as part of the Cold Temperature CO Rulemaking[39], which added a new section to the CFR requiring linear control of CO emissions between 25°F and 68°F.[40] Some of the provisions of today's NPRM increase the importance of further improvements to EPA's defeat device policy. For example, OMSAPC Advisory Circular No. 24-2 uses the ratio of the highway cycle NOx to FTP NOx as an optional criteria for evaluation of a questionable AECD, a policy which becomes moot with the adoption of NOx standards for the US06 Cycle.

With the computer making virtually all calibration decisions, the important criteria is simply to ensure that the computer does not do anything inappropriate from an emission point of view. Thus, EPA is requesting comment on whether it would be appropriate to require proportional vehicle calibrations (that is, calibrations that generate emissions that vary proportionally to changes in computer inputs) and to prohibit "step-changes" in emission response under conditions not specifically included in the test procedures. The only exception would be for specific conditions that could damage the catalyst or engine, such as extended operation at WOT without enrichment. Such a "Proportional Calibration" policy would be patterned after the cold CO requirements for linear control of CO emissions with temperature. Some specific examples of areas where proportional emissions would be expected are:

- Any speed and load combination that falls between the US06 and LA4 Cycles

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40 CFR 86.094-2, 86.094-16(a)

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40 CFR 86.094-16

- Any soak period between those actually conducted as part of the FTP and the SFTP
- A/C operation during ambient temperatures other than 95°F
- Low RPM, near WOT conditions for manual transmissions
- Engine calibration changes based upon "user-selectable" switches.

D. Equivalent Test Weight (ETW) Cap

At the time the current FTP was developed, some modifications were required due to the limitations of the waterbrake dynamometers available at the time. One little-known limitation was a maximum of 5500 pounds ETW. With the incorporation of electric dynamometers and real road-load into the test procedure, a cap on the ETW is no longer necessary. Thus, EPA is proposing to remove the ETW cap and test vehicles at the ETW associated with their loaded vehicle weight (which would include 1/2 payload adjustments for HLDTs). This would apply to certification, SEA, and in-use (recall) testing.

XIV. Environmental and Economic Impacts

To estimate the emission reductions associated with the proposal, the expected lifetime emission reductions were determined per vehicle sold after implementation of the proposed regulations. Baseline emissions for this analysis are taken from the extensive test programs conducted by the Agency and the original equipment manufacturers in support of the FTP Review Project, as discussed earlier. The weighted averages of the emission results of these test vehicles over the various new test procedures constitute the baseline emissions used in this analysis.

A. Emission Reductions

The emission reductions used in this analysis were calculated by subtracting the proposed level of control for each control area from the baseline test vehicle emissions. These test vehicle reductions were then weight averaged in an attempt to simulate the reductions associated with the actual in-use vehicle fleet mix. It should be noted that these test results were derived for an average vehicle with a 50K mile catalyst and do not include any allowance for in-use compliance margins. Thus, the emission benefits calculated here are likely to be understated.

The average emission factor impacts per vehicle associated with the proposed regulations are shown in Table 12.

Table 12: Average Emission Factor Reduction Per Vehicle

Control Area	NMHC (g/mi)	CO (g/mi)	NOx(g/mi)
High speed/accel:	0.055	2.39	0.062
Soak/Start:	0.022	0.02	0.037
Air Conditioning:	0.000	0.00	0.150

These emission reduction numbers constitute the emission reductions associated with the proposed requirements in g/mi. These g/mi values were converted into the estimated lifetime emission reduction per vehicle using assumptions about average annual mileage accumulation rates, a discount rate of seven percent, and estimated survival rates. The results are listed in Table 13; a detailed discussion of the methodology can be found in the RIA (available in the public docket for review).

The calculated results for A/C control listed in Table 12 include a factor to account for driving with the A/C "on" versus driving with it "off". A recent survey of actual A/C operation in Phoenix, AZ found that the compressor was engaged about 61 percent of the time during typical ozone exceedance days. Thus, the g/mi reduction from Table 12 was multiplied by 0.61 before calculating the estimated lifetime emission reduction per vehicle in Table 13. It should also be noted that no attempt was made to account for the lower A/C usage during the rest of the year. The impact of A/C on emissions differs from most emission factors in that it has a disproportionate impact during typical ozone exceedances. To properly compare the cost effectiveness of controlling A/C emissions to other emission factors that are more consistent year around, it is necessary to use methodologies that target typical ozone exceedances.

Table 13: Discounted Lifetime Emission Reductions in Pounds Per Vehicle

Control Area	NMHC	CO	NOx
US06	10.1	441	11.4
Soak/Start	4.1	4	6.8
Air Conditioning	0.0	0	16.9
Total	14.2	445	35.1

Using the emission factor reductions shown in Table 12, including the 61 percent factor for A/C compressor operation discussed above, it is possible to estimate the tons per summer day emission reductions in various years as a result of the proposed test procedure modifications. This was done using estimates taken from the Agency's Fuel Consumption Model of vehicle miles traveled (VMT) for different model year vehicles during each year of interest. These annual VMT estimates were first divided by 365 to get the daily VMT, and were then multiplied by 1.05 to account for a slightly higher VMT during summer months. These results were then multiplied by the emission factor reductions shown in Table 12, including the 61 percent A/C factor, for all model years during which the proposed test procedure changes will result in emission reductions. During the 1998 through 2000 model year phase-in period, the results have been multiplied by factors of 0.32, 0.64, and 0.80, respectively, to reflect the 40-80-100 percent phase-in of US06 and A/C requirements, and the 80 percent contribution of US06 and A/C controls to the overall program. These calculations are shown in Appendix B of the RIA and are summarized in Table 14. The percent reduction columns in Table 13 compare these estimated ton per summer day emission reductions to the baseline emissions for the light duty fleet (cars and trucks). Calculations for these percentage reductions are shown in Appendix C of the Regulatory Impact Analysis.

Table 14: Fleet Emission Reductions in Tons/Summer Day and % Reduction in Light-Duty Fleet Emissions

	NMHC		CO		NOx	
Year	tpsd	%	tpsd	%	tpsd	%
2005	404	4	12655	11	1000	9
2010	577	6	18047	15	1427	12
2015	694	7	21717	17	1717	14
2020	765	8	23938	18	1892	14

B. Economic Impact

The proposed additions to emission test procedures will impose several costs on the original equipment manufacturers. These costs include added hardware for improved emission control and associated development and redesign costs, improved engine control calibrations, and increased costs associated with the certification process including durability data vehicle testing and reporting.

The cost estimates correspond to costs incurred by the manufacturer in complying with the proposed requirements. These costs can be divided into fixed and variable costs. Fixed costs are those costs made prior to vehicle production and are relatively independent of production volumes. The fixed costs considered in this analysis are those for engine control recalibration, vehicle redesign, mechanical integrity testing on redesigned engine families, certification durability demonstration, annual certification costs, and test facility upgrades and construction. Variable costs are costs for the necessary emission control hardware and are, by nature, directly dependent on production volume. The analysis assumes that each federally certified engine family has roughly a 5 year lifetime. The analysis also assumes an annual sales figure of 15 million vehicles outside the State of California. Table 15 presents a summary of the cost estimates calculated by the Agency. Discussion of the assumptions and data included in these estimates can be found in the Regulatory Impact Analysis.

Table 15: Regulatory Cost Estimates

	Annual Cost ($ million)	Cost/Vehicle ($)
Common Costs		
Recalibration	37.3	2.49
Test Facilities (Dyno Conversions and New Exhaust Emission Test Cells)	7.8	0.52
Certification	5.2	0.35
Common Cost Subtotal	50.4	3.36
US06 Costs		

Common Cost Subtotal/3	16.8	1.12
US06 Subtotal	16.8	1.12
Soak/Start Costs		
Redesign	8.7-9.3	0.58-0.62
Mechanical Integrity Testing	21.7-23.3	1.45-1.56
DDV Testing and Reporting	15.6-16.8	1.04-1.12
Hardware	76.7-120.8	5.11-8.05
Common Cost Subtotal/3	16.8	1.12
Soak/Start Subtotal	139.4-187.0	9.30-12.47
A/C Costs		
A/C Test Facilities	1.5	0.10
Common Cost Subtotal/3	16.8	1.12
A/C Subtotal	18.3	1.22
Totals	174.5-222.1	11.63-14.81

C. Cost Effectiveness

The cost effectiveness estimate represents the expected cost per ton of pollutant reduced. The costs presented in Table 15 are not necessarily equally spread among the three pollutant emissions (NMHC, CO, and NOx). Since the requirements associated with A/C are targeted for NOx control, all costs associated with A/C have been allocated to NOx. For US06, the costs associated with each area have been allocated equally across each pollutant. As the CO reduction from soak/start is minimal, the costs associated with soak/start have been split equally between NMHC and NOx. Table 16 contains the per vehicle cost allocation to each pollutant within each control area.

Table 16: Cost Allocation($/vehicle)

	NMHC	CO	NOx	Total
US06 Costs	0.37	0.37	0.37	1.12
Soak/Start Costs	4.65-6.23	0.00	4.65-6.23	9.30-12.47
A/C Costs	0.00	0.00	1.22	1.22
Total	5.02-6.61	0.37	6.24-7.83	11.6314.81

Dividing the costs shown in Table 16 by the discounted lifetime emission reductions shown in Table 13, gives the cost effectiveness estimates shown in Table 17.

Table 17: Cost Effectiveness Estimates($/ton)

Control Area	NMHC	CO	NOx
US06	74	2	50
Soak/Start	2325-3115	NA	1550-2077
A/C	NA	NA	1.53
Total	717-944	2	347-435

D. Consumer Impacts

Two impacts on value to the consumer not included in the above estimates are potential savings associated with reduced fuel consumption and impact on the horsepower output of some vehicle engines. As previously discussed, EPA expects manufacturers to eliminate or greatly reduce the amount of commanded enrichment currently used in order to meet the NMHC and CO standards for the

US06 control cycle. Due to the lower fuel consumption associated with stoichiometric air/fuel control as compared to commanded enrichment, this action will result both in a small improvement in fuel economy and a small loss in horsepower output. The Agency approximated the fuel economy benefit by determining how much extra fuel is used during commanded enrichment operating modes and the in-use incidence of these commanded enrichment operating modes. The result was an estimated 0.51 percent reduction in fuel consumption. Using this fuel consumption reduction and multiplying it by the miles driven in a given year, the appropriate survival rate and a seven percent discount factor, results in an estimated lifetime fuel economy savings of $16.56, based on a gasoline cost of $0.80 per gallon, excluding state and federal taxes.[41] A more detailed discussion of fuel economy cost savings can be found in the RIA for this rule.

Accompanying the lost horsepower output will be the potential for some consumers to consider such affected vehicles as having less value. The Agency does not believe that this lost value will be noticed by most consumers, as the horsepower loss is quite small, but acknowledges its potential effect nonetheless. Due to the difficult nature of trying to quantify a cost associated with reduced power output, or reduced 0 to 60 mph acceleration time, etc., the Agency has not been able to quantify the loss in consumer value. However, the Agency believes that this cost should be roughly negated by the associated savings in fuel expenses. Comments and data are solicited on ways to quantify the consumer value of the power loss.

The Agency does not anticipate that today's proposal will have any impact on Inspection/Maintenance programs.

From Cost Projections, FFA, 1992, updated from DOE/EIA Monthly Energy Review, May 1994 and DOT/FHA. According to FHA, average sales-weighted state taxes for gasoline were 18.54¢ in June 1994. Federal tax is 18.4¢.