

State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS FOR PROPOSED
RULEMAKING

Technical Status and Revisions to Malfunction and Diagnostic System Requirements for
2004 and Subsequent Model Year Passenger Cars, Light-Duty Trucks, and Medium-
Duty Vehicles and Engines (OBD II)

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I. EXECUTIVE SUMMARY

On-board diagnostics II (OBD II) systems are comprised mainly of software designed into the vehicle's on-board computer to detect emission-control system malfunctions as they occur by monitoring virtually every component and system that can cause increases in emissions. When an emission-related malfunction is detected, the OBD II system alerts the vehicle owner by illuminating the malfunction indicator light (MIL) on the instrument panel. By alerting the owner of malfunctions as they occur, repairs can be sought promptly, which results in fewer emissions from the vehicle. Additionally, the OBD II system stores important information, including identifying the faulty component or system and the nature of the fault, which would allow for quick diagnosis and proper repair of the problem by technicians. This helps owners achieve less expensive repairs and promotes repairs done correctly the first time.

The current OBD II regulation, section 1968.1 of title 13, California Code of Regulations (CCR), was originally adopted in 1989 and required all 1996 and newer model year passenger cars, light-duty trucks, and medium-duty vehicles and engines to be equipped with OBD II systems. The Air Resources Board (ARB) subsequently adopted modifications to this regulation in regular updates to the Board in 1991, 1993, 1994, and 1996 to address manufacturers' implementation concerns, strengthen specific monitoring requirements, add new monitoring requirements, and clarify regulatory language, among other reasons.

Since 1996, the ARB staff has identified several areas in the current regulation in which modifications would provide for improved emission-control system monitoring in future model year vehicles and facilitate incorporation of OBD II systems in the Smog Check program. Due to the number of changes being proposed, the ARB staff has developed a separate set of OBD II requirements, section 1968.2, to supercede section 1968.1 for all 2004 and subsequent model year vehicles. (Proposed section 1968.2, title 13, California Code of Regulations is included herewith as Attachment A.) Some of the changes being proposed are to account for California's increasingly stringent tailpipe and evaporative emission standards, particularly the Low Emission Vehicle II standards. As new vehicles are being designed to meet these stringent standards, the OBD II system must be more capable of detecting smaller increases in emissions associated with the new standards. Although much of the current OBD II requirements of section 1968.1 are being carried over into 1968.2, the staff is proposing some new requirements in the proposed section as well that can be grouped into four categories, which are discussed below.

First, the proposed regulation would address issues regarding the existing requirements, specifically by updating or expanding current monitoring requirements. For example, for 2005 and subsequent model year vehicles, the ARB staff is proposing to include catalyst system monitoring for oxides of nitrogen (NO_x) conversion efficiency in addition to the current requirement for monitoring hydrocarbon (HC) conversion efficiency. The ARB staff is also proposing revisions to require secondary air system monitoring for proper airflow during vehicle warm-up, when the system would normally

operate, rather than during some other portion of the drive cycle for 2006 and subsequent model year vehicles. The staff is also proposing more frequent monitoring of many components to ensure better detection of intermittent faults and improve overall monitoring reliability. The OBD II regulation currently requires illuminating the MIL for some components when emissions exceed 1.5 times the emission standards. The staff is proposing to increase this threshold for Super Ultra Low Emission Vehicles (SULEVs) to 2.5 times the emission standards to ensure reliable monitoring at extremely low emission levels.

Second, the proposed regulation would include new monitoring requirements to account for new emission-control technologies and would generally be phased in starting with the 2005 or 2006 model year. These include variable valve timing and/or control systems, cold start emission reduction strategies, and direct ozone reduction systems. New monitoring requirements are also being proposed for diesel vehicles to address emissions resulting from catalyst system and particulate matter trap malfunctions, beginning with the 2004 model year.

Third, the staff is proposing requirements to improve the availability of diagnostic information to assist repair technicians in effectively diagnosing and repairing vehicles as well as to assist Inspection and Maintenance (I/M), or Smog Check, technicians. These include provisions that would restrict the area in which diagnostic connectors (where technicians can "plug in" to the on-board computer) may be located to allow technicians to find these connectors more easily and provisions that would require the OBD II system to store more specific fault codes that all technicians can interpret. The staff is also proposing the Vehicle Identification Number (VIN) be stored and made accessible via a generic scan tool on all 2005 and subsequent model year vehicles. This would help deter fraud during I/M inspections by preventing inspectors from falsely passing a "dirty" vehicle by performing testing on a "clean" vehicle. Additionally, the existence of several protocols for communication between a generic scan tool and a vehicle's on-board computer has resulted in communication problems in the field, such as the inability to retrieve vehicle data with a scan tool. To address the problems associated with multiple protocols, the staff is proposing that all 2008 and subsequent model year vehicles use only one protocol, a Controller Area Network (CAN) protocol. To ensure that vehicles are complying with the proposed requirements of section 1968.2, the staff is proposing new requirements that would require manufacturers to conduct post-assembly line testing of production vehicles.

Fourth, the staff is proposing requirements that would address OBD II-related enforcement issues and problems the ARB staff had previously encountered. In past enforcement cases, there were problems applying the current general enforcement procedures to vehicles with OBD II-related problems, largely because the current general enforcement requirements were originally established for tailpipe and evaporative emission standard exceedance issues. This has necessitated a separate enforcement regulation that deals specifically with OBD II-related issues. Therefore, the staff is proposing adoption of section 1968.5, which would supercede the current general enforcement procedures for 2004 and subsequent model year vehicles.

(Proposed section 1968.5, title 13, CCR is included herewith as Attachment B.) Proposed section 1968.5 would apply specifically to OBD II systems that conform to the proposed OBD II regulation, section 1968.2, and would better address and identify the special circumstances involved in in-use testing and the issuing and implementing of remedial orders to correct any problems that are unique to OBD II systems. This includes specific procedures the ARB would have to conduct in order to find a problematic OBD II system and to implement remedial action, which may involve recall of the vehicles of concern.

Along with the difficulties encountered in applying the general enforcement requirements to OBD II systems, a specific issue was identified regarding enforcement of monitoring frequency. In the past, the ARB had found vehicles with OBD II monitors that did not run as frequently as required. However, it has been difficult to determine whether monitoring frequency is adequate based solely on the written material and data manufacturers provided during certification. As such, the ARB staff is proposing the adoption of a standardized methodology for determining the frequency of OBD II monitor operation for most monitors during in-use driving and a minimum operating frequency that manufacturers are required to meet. To ensure that vehicles are able to meet these new requirements (i.e., that the vehicles are calculating and reporting the monitor frequency value and meeting the minimum frequency requirement in accordance with the proposed regulation), the staff is proposing that manufacturers conduct production vehicle testing to verify these specific requirements.

II. INTRODUCTION AND BACKGROUND INFORMATION

Introduction

With on-board diagnostics II (OBD II) systems required on all 1996 and newer cars, more than 70 million vehicles nationwide are currently equipped with these systems. Input from manufacturers, service technicians, pilot Inspection and Maintenance (I/M) programs, and in-use evaluation programs indicate that the program is very effective in finding emission problems and facilitating repairs. The United States Environmental Protection Agency (U.S. EPA), in fact, recently issued a final rule that indicates its confidence in the performance of OBD II systems by requiring states to perform OBD II checks for these newer cars and allowing them to be used in lieu of current tailpipe tests in I/M programs. Overall, the Air Resources Board (ARB) staff is pleased with the significant and effective efforts of the automotive industry in implementing the program requirements. The staff appreciates the many challenges that have been overcome in getting to this point, and pledges to continue working closely with industry in meeting the remaining issues as OBD II is revisited to account for new technologies and/or other issues resulting from adoption of the Low Emission Vehicle II program in November, 1998. While some new requirements are outlined below, most of the proposed regulation is aimed at refining the program, better serving repair technicians, and improving incorporation of OBD II into I/M programs. Additionally, some of the proposed requirements are in response to improperly designed OBD II systems discovered in the field by the staff and the enforcement work associated with pursuing corrective action of those systems. These enforcement

actions have revealed a need for the ARB to strengthen and more clearly define appropriate certification and enforcement provisions.

The proposed requirements also reflect a substantial reorganization of the current requirements. As a result of having a regulation originally adopted in 1989 and subsequently modified in 1991, 1993, 1994, and 1996, the existing regulatory language and structure were due for updating. As such, the proposed requirements reflect a new structure that is more consistent with the structure used for other ARB regulations, and should be easier to read than previous versions. For example, in some instances, various but similar requirements that were previously scattered in different areas of the regulation have now been consolidated into a single section. In other instances, requirements covering vastly different subjects that were previously listed in a single section have been moved under more appropriate headings. While this reorganization is significant, the monitoring requirements have not changed very much. This staff report details the changes made to the existing requirements and the need for such changes.

What Problem is Addressed by OBD II Systems?

New vehicles are being designed to meet increasingly stringent exhaust and evaporative emission standards. When emission-related malfunctions occur, however, emissions can increase well beyond the standards the vehicle is intended to meet. One report estimates that approximately 40-50 percent of the total hydrocarbon and carbon monoxide emissions from fuel injected vehicles are a result of emission-related malfunctions.¹ Such malfunctions increasingly occur as vehicles age. Recent data show that the percentage of vehicles failing California's Inspection and Maintenance (I/M) program can range from about 0.6-0.9 percent for two to three-year-old vehicles, to about 10.6 percent for ten-year-old vehicles, to about 26.3 percent for 15-year-old vehicles.² The chances for emission-related malfunctions also increase as vehicles continue to show a trend of being driven longer and more often in California. For 2001, projections indicate that 60 percent of all light-duty passenger cars on the road in California will have accumulated more than 100,000 miles, 50 percent will have more than 125,000 miles, and 41 percent will have more than 150,000 miles.³ This reflects a significant increase even from 1995 when only 44 percent of all light-duty passenger cars had accumulated more than 100,000 miles, 27 percent had more than 125,000 miles, and 17 percent had more than 150,000 miles.⁴ Additionally, in 2001, 34 percent of all light-duty passenger car miles traveled will be by cars with more than 150,000

¹ Analysis of Causes of Failure in High Emitting Cars, American Petroleum Institute, Publication Number 4637, February 1996.

² Bureau of Automotive Repair: Smog Check, Executive Summary Report, January to December, 2000.

³ Emission Factors 2000 (EMFAC2000), Version 2.02

⁴ California's Motor Vehicle Emission Inventory (MVEI 7G), Version 1.0, September 27, 1996

miles on the odometer, an increase from only 10 percent in 1995. Taking into consideration that more cars are present in California in 2001 than in 1995, the increase in high-mileage vehicles and their miles traveled is substantial. Consequently, there is a significant need to ensure that emission control systems continue to operate effectively not only on relatively new vehicles, but especially on vehicles well beyond the first 100,000 miles.⁵

How Do OBD II Systems Help to Solve the Problem?

OBD II systems are designed into the vehicle's on-board computer to detect emission malfunctions as they occur by monitoring virtually every component and system that can cause emissions to increase significantly. With a couple of exceptions, no additional hardware is required to perform the monitoring; rather, the powertrain control computer is designed to better evaluate the electronic component signals that are already available, thereby minimizing any added complexity. By alerting the vehicle operator to the presence of a malfunction, the time between occurrence of the problem and necessary repairs is shortened. As a result, fewer emissions from vehicles occur over their lifetime. Besides alerting the vehicle operator of the problem by means of a malfunction indicator light (MIL) on the instrument panel, OBD II systems store important information that identify the malfunctioning component or system and describe the nature of the malfunction and the driving conditions under which it was detected. These features allow for quick diagnosis and proper repair of the problem by technicians.

How is OBD II Related to Other ARB Program Requirements?

To meet the very low and near-zero emission standards and the extended useful life requirements of the Low Emission Vehicle II program, manufacturers will need to improve the emission control performance and durability of their vehicles. To this end, ARB currently has in place many programs, including the OBD II requirements, to monitor the low-emission performance of vehicles and ensure that they are performing as required throughout their useful lives and beyond. While these programs are inter-related, the requirements are not redundant and each program serves an important role in achieving and maintaining low emissions at different points in a vehicle's life. It is important to understand that the OBD II program is unique in that it is the only one designed to ensure maximum emission control system performance for the entire life of the vehicles (regardless of mileage), well beyond the authority of the other programs.

To further understand what unique role OBD II serves, a brief overview of the specifics of the other related ARB programs might be helpful:

- (a) Certification (Durability Vehicle Testing): The certification process requires manufacturers to demonstrate that vehicle designs are capable of meeting the applicable emission standards throughout their useful life (which, for Low Emission

⁵ Current tailpipe emission standards generally only apply to vehicles with less than 100,000 to 120,000 miles.

Vehicle II applications, is defined as 120,000-150,000 miles, depending on their emission category). This has usually done through the use of high mileage durability vehicle testing, typically involving only one or two vehicles. Such testing is performed under tightly controlled conditions by the manufacturers before certification is granted. More recently, most manufacturers have gained ARB approval to conduct “accelerated” durability testing using bench-aged components to simulate high mileage operation, thereby avoiding actual operation of a vehicle up to high mileage.

- (b) Warranty Requirements and Warranty Reporting: California emission warranty requirements cover a 3 year/50,000 mile period for most components and a 7 year/70,000 mile period for high cost components (typically only the catalyst and on-board computer). For Partial Zero Emission Vehicles (PZEVs), warranty requirements extend for 15 years/150,000 miles for all emission-related components. Such warranty requirements promote improved durability since manufacturers do not want to be liable for the cost of replacing components within the warranty period. Warranty reporting provisions also exist that require manufacturers to keep track of how often emission related components are replaced during warranty and notify the ARB if any one component exceeds defined failure levels. Vehicles experiencing a high percentage of emission control component replacements may be subject to recall in order to remedy the problem.
- (c) In-use Compliance Testing: The in-use compliance testing program has been established to ensure that vehicles continue to meet the adopted tailpipe and evaporative emission certification standards in-use. The ARB may conduct in-use compliance testing of vehicles up through a vehicle reaching 75 percent of its useful life. Thus, for 120,000-mile Low Emission Vehicle II applications, in-use compliance testing can be conducted on vehicles that have up to 90,000 miles, and for vehicles certified according to the 150,000-mile requirements, the testing interval is up to 112,500 miles. The in-use compliance program is a powerful incentive for manufacturers to design durable vehicles that will perform well in-use.

Although all three of these programs are effective in encouraging manufacturers to design durable vehicles that perform well in-use, the effectiveness as they apply to older, high mileage vehicles is limited by the nature and/or the expressed limitations of the different programs. For example, the effectiveness of the certification program is limited by the fact that testing is performed on only a few durability vehicles under very controlled conditions. Similarly, the effectiveness of the warranty and in-use compliance programs is limited by the expressed time and mileage constraints of the respective programs.

The OBD II program is not similarly restricted in that the intent of the program is that OBD II systems be designed to perform for the entire life of the vehicle and be capable of detecting defects beyond a vehicle’s applicable useful life. Consequently, the OBD II program is the only program that assures that the ever increasing fleet of high mileage vehicles (e.g., vehicles with more than 100,000 miles) will be properly

performing at or near the established emission standards. Given that most emission problems occur as vehicles age and accumulate high mileage, the importance of the OBD II system is underscored.

Further, warranty reporting and in-use compliance testing are most effective in finding systematic failures of the same component that are occurring at a high rate in-use. Today's vehicles, however, are complex systems comprised of many individual components. Only the OBD II system, which individually monitors each of these components, provides an effective method of identifying the specific vehicles in need of repair, regardless of the failure rate of that individual component for the entire fleet. Thus, even if no one component fails at a high enough rate to be discovered during warranty reporting nor in-use compliance testing, the vehicles that do have a failed component are identified, repaired, and returned to tailpipe levels at or near the emission standards.

For these reasons, the OBD II program effectively complements the other certification and in-use programs, ensuring that vehicles, especially those with high mileage, that have emission-related problems are expeditiously repaired so that they perform at or near emission certification levels. Moreover, the OBD II program, in conjunction with the other programs, encourages manufacturers to design and build increasingly durable emission control systems.

What Does the OBD II Regulation Require?

For most emission control systems and components, the OBD II regulation requires malfunctions to be identified before any problem becomes serious enough to cause vehicle emissions to exceed the standards by more than 50 percent (i.e., when emissions exceed 1.5 times the tailpipe emission standards). This requires manufacturers to correlate component and system performance with emission levels to determine when deterioration of the system or component will cause emissions to exceed 1.5 times the tailpipe standard. When this occurs, the regulation requires the diagnostic system to alert the operator to the problem by illuminating the MIL.

For the components and systems in which the 1.5 times the standard criterion is not sufficient or cannot easily be applied, the regulation establishes different malfunction criteria to identify emission problems. For example, in addition to having to detect engine misfire before emissions exceed 1.5 times the standards, the regulation requires that misfire levels be detected that will cause catalyst damage due to overheating.

Further, the 1.5 times the tailpipe emission standard criterion is currently not applicable to evaporative system malfunctions. The regulation requires the OBD II system to detect leaks equivalent or greater in magnitude to a 0.040 inch diameter hole and, by the 2003 model year, a 0.020 inch diameter hole. While data from evaporative system designs show that leaks approaching a 0.020 inch hole begin to rapidly generate excess evaporative emissions (up to 15 times the standard), current

monitoring technology and serviceability issues do not permit detecting and repairing smaller leaks.

The 1.5 times the tailpipe emission standard criterion is also not applicable to the monitoring of electronic powertrain components that can cause emissions to increase when malfunctioning, but generally to less than 1.5 times the standard. The regulation requires such components to be monitored for proper function. For example, for components that provide input to the on-board computer, the OBD II system is required to monitor for out-of-range values (generally open or short circuit malfunctions) and input values that are not reasonable based on other information available to the computer (e.g., sensor readings that are stuck at a particular value, or biased significantly from the correct value). For output components that receive commands from the on-board computer, the OBD II system is required to monitor for proper function in response to these commands (e.g., the system verifies that a valve actually opens and closes when commanded to do so). Monitoring of all such components is important because, while a single malfunction of one of these components may not cause an exceedance of the emission standards, multiple failures could synergistically cause high in-use emissions.⁶ Further, the OBD II system relies on many of these components to perform monitoring of the more critical emission control devices. Therefore, a malfunction of one of these input or output components, if undetected, could lead to incorrect diagnosis of emission malfunctions, or even prevent the OBD II system from checking for malfunctions.

In addition to malfunction detection requirements, the OBD II regulation requires that diagnostic repair information be provided to aid service technicians in isolating and fixing detected malfunctions. For each malfunction detected, a specific fault code is stored identifying the area and nature of the malfunction (e.g., a mass air flow sensor with an inappropriately high reading). The OBD II system also provides technicians with access to current engine operating conditions such as engine speed, engine load, coolant temperature, fuel system status, etc. The OBD II system even stores the operating conditions that exist at the time a malfunction is detected. All of this information can be accessed with the use of a generic scan tool (i.e., one tool that can access all makes and models of vehicles), and helps assist the technician in accurately diagnosing and repairing problems.

OBD II and Inspection and Maintenance

Current Inspection and Maintenance (I/M) programs (e.g., the “Smog Check” program) rely primarily on tailpipe testing to find vehicles with emission malfunctions. When a high-emitting vehicle is identified, a repair technician must diagnose the cause of the emission failure and then perform necessary repairs. The effectiveness of the

⁶ The regulation only requires detection of any single component failure that can affect emissions rather than detection of every combination of multiple component degradations that can cause emissions to exceed the standards, due to the overwhelming time and cost resources that would be required to evaluate the latter.

repairs in bringing the vehicle back into compliance can be known with certainty only when the vehicle again undergoes a tailpipe test.

OBD II systems offer the potential to greatly simplify and improve this process. Instead of measuring tailpipe emissions directly once every two years, the OBD II system monitors virtually every emission control component for malfunctions during normal driving by the vehicle owner. When a malfunction is detected, the MIL will illuminate and the proper fault codes will be stored. If the MIL were not illuminated, nor any fault codes stored, there would be considerable assurance that the vehicle is not emitting excessive emissions (i.e., virtually all the potential sources for an emission problem are operating without defect). In addition, OBD II monitoring includes emission-related components and systems that cannot be otherwise checked during a tailpipe-only I/M test, such as cold start emission reduction devices (e.g., cold start ignition retard strategies, oxygen sensor heaters, or air injection systems)⁷, or misfire and fuel system malfunctions that occur exclusively outside of the I/M driving conditions. With an OBD II system, the technician would only have to connect a scan tool to the vehicle to access the data. Thus, an OBD-I/M inspection is faster and more comprehensive than a tailpipe-only I/M inspection, which would require technicians to run an emission-test cycle in order to retrieve emissions data. Further, OBD II malfunction criteria are tailored to the emission control equipment and calibration parameters for each individual vehicle and the emission standards that the vehicle is certified to meet. In contrast, to ensure minimal false errors of commission for all vehicles in a particular model year group, tailpipe emission tests use “cut points” (the test limits above which vehicles are failed) that must take into account the various vehicle types and emission standards pertaining to each group. These cut points do not effectively identify out-of-compliance vehicles until emissions are potentially many times the allowable standard. This shortcoming is especially true in California, where in a single model year, vehicles may be certified to tailpipe standards varying from Federal Tier 1 standards down to the extremely low Super Ultra Low Emission Vehicle (SULEV) standards.

The staff has been working with EPA and other states for the last several years to develop national guidelines for the incorporation of OBD II checks into the I/M program. During this process, pilot test programs, including state-run programs in Wisconsin and Colorado, have been carried out, as well as a 200-vehicle test program conducted by a Federal Advisory Committee Act (FACA) workgroup. Results from these programs confirm the effectiveness of OBD II systems in correctly identifying vehicles with malfunctions and show higher cumulative emission gains for OBD II-based repairs than for IM240/tailpipe-based repairs. As such, EPA recently published its final rule requiring the use of OBD II checks in the I/M program by January 1, 2002. According to this rule, EPA recommends that states may perform an OBD II inspection

⁷ State of California-Smog Check-Inspection Manual instructs technicians to make sure the vehicle engine is at normal operating temperature (i.e., warmed-up) before beginning the inspection. Thus, malfunctions that occur only on cold starts or only affect cold start emission controls are not likely to be detected during an I/M test. Unfortunately, the highest emissions also occur during cold starting and warm up.

in lieu of (as opposed to in addition to) any tailpipe testing for all 1996 and newer model year vehicles. 1995 and older model year vehicles (e.g., pre-OBD II) would still be required to undergo tailpipe testing under the current I/M program.⁸

Although California has already been doing partial “OBD” checks (e.g., failing vehicles with the MIL on) as part of its I/M (Smog Check) program for several years, the OBD II check required by EPA is a more comprehensive check than currently implemented. The ARB is currently working with the Bureau of Automotive Repair (BAR) to determine the most effective method for implementing EPA’s required revisions to the current California Smog Check program, which is administered by BAR. The intent of this joint effort is to develop a program that meets EPA’s requirements as well as to minimize any inconvenience to consumers. California has already begun pilot testing of OBD II software at a few I/M stations.

III. TECHNICAL STATUS AND PROPOSED MONITORING SYSTEM REQUIREMENTS

As emission standards become increasingly stringent, new technologies and enhancements to existing technologies are being developed to help new vehicles meet these standards. Accordingly, as part of the ARB’s biennial reviews of the OBD II regulation, the staff has been meeting with industry to determine changes and additions to the OBD II regulation that are considered necessary for vehicles in meeting the stricter emission standards and ensuring the robustness and effectiveness of the OBD II monitoring systems. In addition to these discussions and reviews, increased experience with OBD II systems in the field as well as ongoing enforcement issues have required rewriting and restructuring of the current regulation, which resulted in the following proposed monitoring requirements.⁹

A. CATALYST MONITORING

NOx Catalyst Monitoring

Virtually all OBD II-equipped vehicles use three-way catalysts (i.e., catalyst systems that simultaneously convert hydrocarbons (HC), carbon monoxide, and oxides of nitrogen (NOx)). The current OBD II regulation (title 13, CCR section 1968.1) requires catalyst monitoring only of HC conversion efficiency. Recently, the staff analyzed emission data from OBD II demonstration vehicles with deteriorated

⁸ 40 CFR Parts 51 and 85: “Amendments to Vehicle Inspection Maintenance Program Requirements Incorporating the Onboard Diagnostic Check;” Final Rule.

⁹ Many of the requirements set forth in proposed section 1968.2, title 13, CCR for 2003 and subsequent model year vehicles have been carried over from existing section 1968.1, title 13, CCR. The carryover provisions were previously addressed at earlier Board hearings (see 1989, 1991, 1993, 1994, and 1996 Staff Reports – complete titles listed in References section). This staff report will address only those proposed requirements that are new and that substantially change existing requirements in section 1968.1.

catalysts (i.e., catalysts that are detected by the OBD II system as malfunctioning). The data showed that for Low Emission Vehicle I applications, even though only HC conversion efficiency was monitored, HC and NOx emissions both degraded to about equal multiples of their respective standards (e.g., on average, HC and NOx emissions were about 1.5 times the applicable HC¹⁰ and NOx standards, respectively). Thus, despite not having a direct monitoring requirement for NOx conversion efficiency, catalyst malfunctions were generally detected before NOx emissions were unacceptably high.

However, this is not anticipated to occur for Low Emission Vehicle II applications. For these vehicles, the staff does not believe that the HC-only monitoring requirement would provide sufficient protection from high NOx emission levels. While the HC emission standards for Low Emission Vehicle I and II applications are the same, the NOx emission standards for Low Emission Vehicle II applications are approximately one-fourth the levels for Low Emission Vehicle I applications. Therefore, the same NOx emission level that was equivalent to about 1.5 times the Low Emission Vehicle I NOx standard would correspond to an even higher multiple of (i.e., about 6.0 times) the Low Emission Vehicle II NOx standard.

To protect against such high in-use NOx emissions and to maintain the emission benefits of the Low Emission Vehicle II program, the staff is proposing that manufacturers monitor for NOx conversion efficiency of the catalyst. This requirement would apply only to 2005 and subsequent model year vehicles certified to Low Emission Vehicle II standards. For the 2005 and 2006 model years, the staff is proposing an interim malfunction threshold for illuminating the MIL of 3.5 times the Federal Test Procedure (FTP) full useful life standard. For 2007 and subsequent model years, the staff is proposing a final malfunction threshold for LEV II, ULEV II, and medium-duty SULEV II vehicles of 1.75 times the FTP full useful life standard, while the final malfunction threshold for passenger car and light-duty truck SULEV vehicles would be 2.5 times the FTP full useful life standard.

Manufacturers currently use the catalyst's oxygen storage capacity to estimate HC conversion efficiency. With this strategy, a catalyst malfunction is detected when the catalyst's oxygen storage capacity has deteriorated to a predetermined level. To measure oxygen storage, manufacturers typically use a second oxygen sensor located downstream of the monitored portion of the catalyst system (this second sensor is also used to control the precision of the fuel metering system). By comparing the level of oxygen measured by the second sensor with that measured by the primary sensor located upstream of the catalyst, manufacturers can determine the oxygen storage capacity of the catalyst and thus, estimate the HC conversion efficiency.

¹⁰ Regarding HC emission standards, Low Emission Vehicle I and II applications refer to non-methane organic gas (NMOG) emission standards rather than "HC" emission standards. However, only the term "HC" is used in this staff report to avoid confusion.

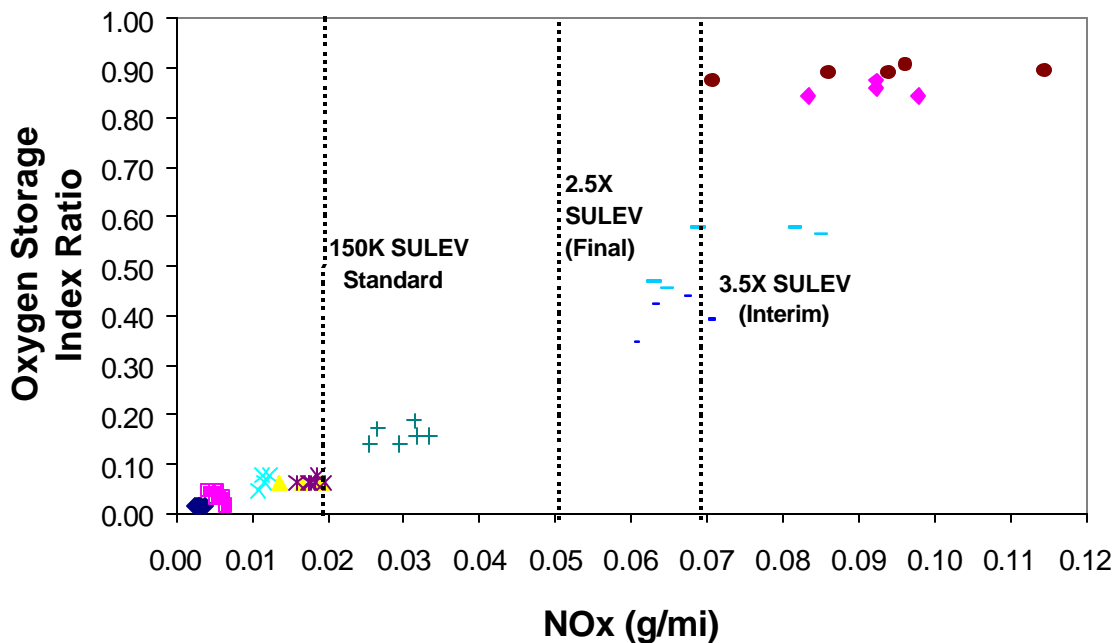


Figure 1

A similar relationship also exists between catalyst oxygen storage capacity and NOx conversion efficiency. Thus, the staff believes that manufacturers will likely use this relationship in conjunction with current monitoring methods to satisfy the proposed NOx requirement. The correlation between oxygen storage and NOx conversion efficiency is generally recognized in the industry as a slightly more linear correlation than the relationship that exists for HC conversion efficiency. Manufacturers presented data identifying this correlation at the July 2001 workshop (see Figure 1 below¹¹). In Figure 1, the individual data points represent catalysts that have been subjected to various levels of aging and/or poisoning. The data show that, in general, as the catalyst's NOx conversion capability decreases (i.e., tailpipe NOx emission levels increase along the x-axis), the oxygen storage capacity of the catalyst also decreases. The data points in the lower left corner represent catalysts aged up to 150,000 miles and show that oxygen storage remains very high, while the other data points representing further aging and/or poisoning show decreases in the oxygen storage capacity.

While the data in Figure 1 show that catalysts aged to the proposed OBD II thresholds (e.g., the final or interim thresholds of 2.5 or 3.5 times the NOx standard shown on the graph) appear to have some separation (i.e., difference in oxygen storage index ratio values) from catalysts below the emission standards, manufacturers generally indicate that further separation is needed to accurately detect malfunctions. Ideally, manufacturers like to design the system such that

¹¹ In Figure 1, tailpipe NOx emission levels ("NOx (g/mi)"), which is inversely proportional to catalyst NOx conversion efficiency, is correlated with the "oxygen storage index ratio". The "oxygen storage index ratio" is the oxygen storage measurement that has been "normalized" to a value between 0.00 and 1.00, with 0.00 representing very high oxygen storage and 1.00 representing no oxygen storage. From a presentation by Paul Baltusis, Ford, at the OBD II Public Workshop, July 18, 2001.

threshold catalysts (i.e., catalysts aged to the OBD II malfunction thresholds) will have very low oxygen storage (e.g., a value on the y-axis of the graph of 0.80 or higher). This determination, however, may depend on the amount of the catalyst system that is monitored. Modification of the monitored volume would alter the relationship between oxygen storage and NOx conversion efficiency. Thus, if a smaller portion of the total catalyst system was monitored, a manufacturer can wait for oxygen storage in the monitored portion of the system to deteriorate further while overall catalyst system NOx conversion efficiency remains high (due to the larger portion of catalyst system that is still functioning properly downstream of the monitored portion of the catalyst system). In addition to modifications to the size or volume of the monitored portion, manufacturers should also be able to alter precious metal loading and washcoat formulations to achieve similar results that would likely allow the system to meet the required emission thresholds.

Accordingly, the proposed regulation would provide additional flexibility to manufacturers in catalyst monitoring by modifying a previous requirement that restricted the minimum volume of the catalyst system to be monitored. By significantly relaxing this minimum volume requirement, the manufacturers should be able to more substantially resize catalyst volume and/or modify catalyst composition materials to meet the final malfunction thresholds.

Other monitoring technologies, such as the use of a NOx sensor, might also be used to meet the proposed requirement.¹² These technologies continue to evolve and may be viable candidates for NOx catalyst monitoring by allowing manufacturers to directly measure NOx concentration levels after the catalyst to determine NOx conversion efficiency. A third possibility for monitoring NOx conversion efficiency would be to evaluate the light off characteristics of the catalyst using a catalyst temperature sensor, as documented in a published Society of Automotive Engineers (SAE) paper.¹³ While the paper primarily focused on correlating the temperature sensor readings to HC conversion efficiency for HC-based catalyst monitoring, this method offers similar potential for NOx conversion efficiency monitoring. Additional data and analysis supplied by a manufacturer to ARB showed trends that are similar for NOx emissions and catalyst light-off characteristics. Moreover, the addition of a catalyst temperature sensor or a NOx sensor for monitoring would also provide manufacturers with secondary benefits such as enhanced fuel control.

Catalyst Aging

As discussed above, manufacturers use oxygen storage capacity as a measure of catalyst performance/conversion efficiency. In order to determine the proper OBD II malfunction threshold for catalysts (i.e., the acceptable level of oxygen

¹² NOx sensor technologies have been presented in a number of SAE papers (SAE Reference Numbers 1999-01-1280, 980266, 980170, and 970858).

¹³ This method was discussed in SAE paper 1999-01-0311, "Closed Loop Temperature Feedback for Controlled Catalyst Lightoff and Diagnostics for ULEV."

storage capacity at which a malfunction should be indicated), manufacturers progressively deteriorate or “age” catalysts to the point where emissions exceed 1.75 times the standard. The two most common methods of catalyst aging are oven aging and misfire aging,¹⁴ both of which try to replicate excessive temperature conditions.

The OBD II regulation currently allows a manufacturer to infer catalyst system performance from monitoring only a portion of the catalyst volume (e.g., just the front catalyst of a two-catalyst system). When manufacturers age a catalyst system with a partial volume monitor, the monitored portion of the catalyst is aged to the OBD II threshold level and the unmonitored portion is aged to the equivalent of the end of the vehicle’s useful life. In the past, the ARB has approved this aging methodology based on the assumption that the monitored portion of the catalyst, which is typically upstream of the unmonitored portion, buffers or protects the unmonitored portion from advanced deterioration by the commonly recognized failure modes (e.g., thermal damage due to misfire or poisoning). However, some manufacturers contend that this assumption is not entirely valid because real world deterioration of the unmonitored catalyst largely depends on total catalyst system design, operating conditions when the monitored catalyst is damaged, failure mode, and fuel control during misfire. So if the unmonitored catalyst is not protected by the monitored catalyst and is deteriorated beyond its normal limits, emission levels will likely exceed the malfunction threshold specified in the OBD II regulation (i.e., generally 1.75 times the standard) when a catalyst malfunction is detected in the real world.

To address this problem, the staff is proposing more specific requirements for aging catalysts and determining the malfunction thresholds (i.e., the oxygen storage capacity level at which a malfunction is indicated) for the catalyst monitor. Under the proposal, manufacturers would be required to use deterioration methods that more closely represent real world deterioration, thereby ensuring that the MIL would illuminate at the appropriate emission level during real world operation. The proposal would further require that the catalyst system be aged as a whole (i.e., manufacturers would simultaneously age the entire system, not just the front catalyst) for most 2005 and subsequent model year vehicles certified to the Low Emission Vehicle II standards. The monitored catalysts would be aged to the malfunction criteria, and the level of deterioration of the unmonitored catalysts would simply be a result of the aging of the monitored catalyst, as is the case during real world operation. However, manufacturers that use fuel shutoff to misfiring cylinders in order to minimize catalyst temperatures may continue to use the current process of aging the monitored catalyst to the malfunction criteria and the unmonitored catalysts to the end of the useful life. Such systems are not subjected to extreme temperatures, so they would likely age with the closest monitored catalyst experiencing most of the deterioration.

¹⁴ Excessive temperature resulting from engine misfire is recognized by industry as a dominant failure mode of catalysts.

B. MISFIRE MONITORING

Under the existing regulation, manufacturers have been allowed to request that the misfire monitor be disabled if necessary to assure that the systems reliably identified misfire. With increasing experience in software development, improvements to sensors and their location, and use of better engine control processors, manufacturers have significantly improved their ability to monitor misfire in recent years. Additionally, since initial promulgation of the misfire requirements, the ARB has provided manufacturers with additional time to evaluate whether misfire is present and sufficiently repeatable. Given these improvements, it is no longer necessary to permit many of the disablements that have been previously allowed.

The proposed misfire monitoring requirements would restrict the number of possible disablements by, in general, limiting disablements to specific conditions. This should help limit the variability that has existed in the ability of certified misfire monitors to reliably detect misfire and should improve the overall quality of the monitors. The proposal would also minimize the time the staff must spend to determine when misfire systems are really active. This has been a concern in the past, when numerous overlapping disablements have made it very difficult to determine whether misfire monitoring was active during most driving conditions. By minimizing the number of allowed disablements, the task of evaluating manufacturers' certification documentation should be less difficult, allowing for a more expeditious certification process. A more comprehensive list would also provide clear direction to engineers developing misfire monitoring systems as to what types of disablements would be allowed.

In general, the proposed requirements would no longer permit misfire monitoring disablement during throttle movements less rapid than occur over the US06 (or "off cycle") driving cycle, automatic transmission shift changes except under wide open throttle conditions, air conditioning compressor on and off cycling, or other conditions that have been shown to be unnecessary. Additionally, because of the availability of better computers, manufacturers should no longer need to disable misfire detection during engine speed changes that, in the past, had taxed their engine computer's ability to keep up with the calculation requirements. Accordingly, such disablements would no longer be allowed on 2005 and subsequent model year vehicles.

For remaining disablements, manufacturers would still be required to list all disablements in their certification applications for review by the ARB staff. Manufacturers would also be required to submit driving traces of the FTP and US06 cycles for selected representative engine groups, showing where disablements occur and indicating the reason for each disablement. Similarly, manufacturers may be required to demonstrate that misfire can be reliably detected during portions of the FTP and US06 driving cycles, prior to the staff granting certification.

Additionally, the staff has added several clarifications to the proposed misfire monitoring requirements. To address industry inconsistency regarding fault code setting and catalyst-damaging temperature, the staff is proposing a better definition of when a single cylinder or multiple cylinder misfire code is set, and establishing a more

specific means of determining the temperature at which catalyst damage occurs. The staff is also setting floors of one percent (for a 1000-revolution monitoring interval) and five percent (for a 200-revolution monitoring interval) for detecting emission-related and catalyst damage misfires, acknowledging that successful diagnosis and repair of smaller percentages of misfire is difficult. The staff also recognizes that distinguishing misfire from normal firing is difficult during periods of reduced torque. Therefore, the staff is permitting a reduced threshold for probability of misfire detection when a cold start emission reduction strategy that causes engine torque to be significantly reduced is operative.

C. EVAPORATIVE SYSTEM MONITORING

New Evaporative System Monitoring Strategies

The ARB originally adopted a leak detection requirement for 1996 and subsequent model year vehicles certified to the enhanced evaporative emission standards. The requirement was limited to 0.040 inch leak detection capability because detection of smaller leaks was not feasible at that time. Emissions from leaks smaller than 0.040 inches, however, can be many times the evaporative emission standards. It isn't until the leak size falls below 0.020 inch that evaporative emissions begin to diminish substantially. With improvements in technology, manufacturers were later able to detect leaks as small as 0.020 inch. Accordingly, in 1996, the Board adopted the 0.020 inch leak detection requirement for all 2003 and subsequent model year vehicles. To assure that larger leaks (e.g., loose or missing gas cap or disconnected evaporative system hoses) continued to be quickly detected, the OBD II regulation continued to require a separate 0.040 inch monitoring requirement.

Initially, the ARB recognized that the 0.020 inch monitor may require more restrictive monitoring conditions to assure robust monitoring, so that the monitoring frequency of such systems tended to be less than desired. However, recently, manufacturers' abilities to detect 0.020 inch leaks have improved considerably so that monitoring, in general, occurs more frequently. In addition, some manufacturers have developed innovative approaches that are less costly than previous systems, yet provide for more robust detection of the smaller 0.020 inch leaks while maintaining adequate monitoring frequency.

Given these improvements in small leak detection, it may be less important to detect 0.040 inch leaks than in the past. In fact, some manufacturers have suggested that it may now be more beneficial to detect leaks in the 0.090 inch range. They have indicated that such detection would occur more rapidly than detection of 0.040 inch leaks, and that this would be especially true for detection of large leaks in the evaporative control system caused by conditions such as a loose or missing gas cap and split or disconnected vacuum lines. More rapid detection and correction of large leaks would help reduce emissions compared to leak detection systems geared toward detecting 0.040 inch leaks. Accordingly, the staff

is proposing greater flexibility for manufacturers in detecting evaporative system leaks for larger hole sizes, as long as their evaporative system leak detection accurately detects 0.020 inch leaks and the overall evaporative system monitor meets minimum monitoring frequency requirements discussed later in section IX.

Standardized Orifices

The current regulation requires the OBD II system to detect leaks greater than or equal to those caused by 0.020 or 0.040 inch diameter orifices in the evaporative system. In recent in-use and enforcement testing, the ARB staff used orifices that consisted of 0.040 inch diameter holes drilled in thin wall stainless steel tubing. Some manufacturers have contended that the use of such orifices does not constitute a rigorous industry standard and that such a standard is necessary. They additionally contended that the orifice shape and length, as well as production tolerances, can significantly affect flow rates and consequently the evaporative system monitor's ability to detect a leak. Various manufacturers have proposed that "standardized" orifices be adopted to address these concerns.

To address this concern, the staff proposes the use of a specific orifice supplied by O'Keefe Controls Corporation, a manufacturer and supplier of precision orifices used by many in the industry. Orifices with equivalent specifications from other suppliers would also be acceptable.

Statistical MIL Illumination

Generally the OBD regulation requires a fault code to be stored and the MIL to be illuminated if a malfunction is detected on two consecutive driving cycles. The current regulation allows the use of other statistical protocols to evaluate monitoring data and illuminate the MIL if the manufacturer can demonstrate that they are equally effective and timely in illuminating the MIL. Strategies that, on average, require more than six driving cycles to illuminate the MIL are not acceptable. As discussed above, when the 0.020 inch requirement was adopted, the ARB recognized the difficulty in monitoring for 0.020 inch leaks and adopted regulatory language that permitted more restrictive monitoring conditions that would run less frequently. Even with this additional latitude, some manufacturers may still not be able to develop a sufficiently robust monitor that can detect a 0.020 inch leak in two consecutive driving cycles or in six driving cycles as currently permitted for statistical protocols.

The staff is proposing to allow a manufacturer even more flexibility to use additional cycles to illuminate the MIL, provided the manufacturer can demonstrate that the overall ability of the monitor to illuminate the MIL when a malfunction is present is approximately two weeks time for 50 percent of the drivers (as defined by meeting the minimum monitoring frequency requirements discussed later in section IX). Thus, alternate strategies that require data from more driving cycles to make a decision but still provide for timely and reliable monitoring would be allowed.

D. SECONDARY AIR SYSTEM MONITORING

Secondary air systems are used on vehicles to reduce cold start exhaust emissions of hydrocarbons and carbon monoxide. Although many of today's vehicles operate near stoichiometric (where the amount of air is just sufficient to completely combust all of the fuel) after a cold engine start, more stringent emission standards may require secondary air systems, generally in combination with a richer than stoichiometric cold start mixture, to quickly warm up the catalyst for improved cold start emission performance. Secondary air systems typically consist of an electric air pump, various hoses, and check valves to deliver outside air to the exhaust system upstream of the catalytic converters. This system usually operates only after a cold engine start for a brief period of time. When the electric air pump is operating, fresh air is delivered to the exhaust system and mixes with the unburned fuel at the catalyst, so that the fuel can burn and rapidly heat up the catalyst.

The OBD II requirements presently allow manufacturers to perform a functional check in lieu of correlating secondary air system airflow to emissions (i.e., 1.5 times the applicable FTP standards) if the design of the system is unlikely to deteriorate. The regulation also allows manufacturers to define the appropriate conditions for operating the monitor with the limitation that the defined conditions are encountered during the first engine start portion of the FTP.

On current vehicles, the majority of vehicle manufacturers with secondary air systems have been able to opt out of correlating airflow to emissions, either by providing data indicating that a total failure of the system would not cause emissions to exceed the malfunction threshold or by submitting data or designs to the ARB demonstrating that system deterioration is unlikely. The ARB had originally incorporated the durability demonstration clause to provide some monitoring relief to manufacturers if they designed a system that was unlikely to fail in use. However, the process of projecting the durability of secondary air designs is a difficult and imprecise task. Furthermore, secondary air system designs are fairly complex and diverse, involving designs that utilize various materials, valves, and other components. To compound the problem, these systems are subjected to rigorous environments. These factors make it difficult to determine the durability of these systems, which may result in the staff approving systems that fail in-use and are not detected by the diagnostic system until they are no longer functional.

Another issue concerns malfunctions that only occur during cold engine starts when the secondary air system is normally active. The current regulation does not restrict diagnostics to the period when the secondary air system is active, so many manufacturers execute their diagnostics after the vehicle is warmed up by intrusively commanding the air pump on when it normally would be off. With this monitoring technique, there is no assurance that the system operates correctly after a cold engine start when the secondary air system is normally on. Certain malfunctions such as

sticking check valves or worn pump shaft bearings, for example, may yield decreased pump flow when the system is cold but not when the vehicle is warm.

In order to avoid the uncertainty connected with projecting secondary air system durability and to increase the robustness of the diagnostic system, the staff proposes to require all vehicles to indicate a secondary air system malfunction that causes airflow to diminish such that the vehicle would exceed 1.5 times any of the applicable FTP emission standards. Additionally, this diagnostic would be required to monitor the secondary air system while the system is normally active (e.g., during vehicle warm-up following engine start) and not when the system is intrusively turned on solely for monitoring purposes.

In order for the OBD II system to effectively monitor the secondary air system when it is normally active, linear oxygen sensors (often referred to as wide-range oxygen sensors or air-fuel ratio sensors) would most likely be required. These sensors are currently installed on many new cars and their implementation is projected to increase in the future as more stringent emission standards are phased in. Linear oxygen sensors are useful in determining air-fuel ratio over a broader range than conventional oxygen sensors and are especially valuable for controlling fueling in lean-burn engines and other engine designs that require very precise fuel control. Since linear oxygen sensors are able to determine air-fuel ratio accurately, the amount of secondary airflow needed to keep emissions below 1.5 times the tailpipe emission standard can be correlated to the air-fuel ratio, making linear oxygen sensors useful for secondary air system monitoring.

One concern that some manufacturers have expressed regarding secondary air system monitoring directly after a cold engine start is that the oxygen sensor needs time to warm-up before it becomes active. The staff believes that more powerful heaters available on new oxygen sensor designs should alleviate these concerns since these “quick light-off” sensors are active within about 10 seconds. Since secondary air injection duration typically ranges from about 20 seconds to as high as 40 seconds, the “quick light-off” linear oxygen sensors should become active within a sufficient time to monitor the secondary air system when it is normally active.

These new requirements would apply only to 2006 and subsequent model year vehicles certified to Low Emission Vehicle II standards. For the 2006 and 2007 model years only, a manufacturer may request Executive Officer approval to perform an interim, simpler functional check during the cold start in lieu of the emissions performance diagnostic. This interim check would require a manufacturer to incorporate an additional airflow diagnostic that is correlated to emissions during an intrusive operation later in the same drive cycle. By 2008 model year, only a performance check during cold start conditions would be accepted.

E. OXYGEN SENSOR MONITORING

Maintaining the air-fuel ratio at stoichiometric is an important factor in achieving the lowest engine emissions. In order for the emission control system to operate most efficiently, the air-fuel ratio must remain within a very narrow range (less than 1 percent deviation) around the stoichiometric ratio. Modern vehicles have traditionally performed fuel control with an oxygen sensor feedback system. Oxygen sensors are typically located in the exhaust system upstream and downstream of the catalytic converter. The front or upstream oxygen sensor is generally used for fuel control and is often called the “primary” oxygen sensor. The rear or downstream oxygen sensor is generally used for adjusting the front oxygen sensor as it ages and for monitoring the catalyst system and is often called the “secondary” oxygen sensor.

The OBD II regulation currently requires the diagnostic system to monitor the output voltage, response rate, and any other parameter that can affect emissions and/or other diagnostics of the primary and secondary oxygen sensors. For heated oxygen sensors, the heater circuit must be monitored to detect when the current or voltage drop within the circuit deteriorates below the manufacturer’s specified limits for proper operation.

Like many of the other major system monitors, the current OBD II regulation requires the oxygen sensor diagnostics to only operate once per driving cycle. The comprehensive component monitors, on the other hand, generally require continuous monitoring for many common electrical failure modes (e.g., shorted or open circuits). As a result of the current structure of the regulation, manufacturers have been able to execute all of the oxygen sensor diagnostics, including basic electrical diagnostics for open and shorted circuits, once per trip rather than continuously. However, recently the ARB has found that some manufacturers were having difficulties detecting some oxygen sensor malfunctions such as intermittent oxygen sensor circuit malfunctions, which have less chance of being detected when the diagnostic is run only once per trip.

Since the oxygen sensor is a critical component of a vehicle’s fuel and emission controls, the proper performance of this component needs to be assured in order to maintain low emissions. Thus, it is important that any malfunction that adversely affects the performance of the oxygen sensor is detected by the OBD II system. Hence, the staff is proposing to require virtually continuous monitoring of the primary oxygen sensor’s circuit continuity and out-of-range values and the secondary oxygen sensor’s out-of-range values for malfunctions. A manufacturer may request Executive Officer approval to disable the continuous oxygen sensor monitoring when an oxygen sensor malfunction cannot be distinguished from other effects (e.g., disable out-of-range low monitoring during fuel cut conditions). For heated oxygen sensors, continuous monitoring will also be required for all circuit continuity faults of the heater circuit that conflict with the commanded state of the heater. For example, in a situation where a heater is turned on by supplying 12 Volts, the manufacturer would be required to monitor for open circuits or shorts to ground (0 Volts) while the heater is commanded on and monitor for open circuits or shorts to battery (12 Volts) when the heater is commanded off. In addition, continuous monitoring for any malfunction of the primary oxygen sensor that causes the fuel system to stop using the oxygen sensor as a

feedback input (e.g., causes default or open loop operation) would be required. It should be noted that many of the manufacturers' current fuel system monitors may already identify some of these oxygen sensor malfunctions. However, fuel system faults are generally one of the most difficult faults to diagnose and repair because of the substantial number of possible causes. As such, these changes would help to pinpoint the oxygen sensor as the malfunctioning component if a circuit problem is occurring. This requirement would apply only to 2006 and subsequent model year vehicles certified to Low Emission Vehicle II standards.

F. ENGINE COOLING SYSTEM MONITORING

Manufacturers generally utilize engine coolant temperature as an input for many of the emission-related engine control systems as well as the diagnostics for these systems and components. The engine coolant temperature is often one of the most important factors in determining if closed-loop fuel control will be allowed by the engine's powertrain computer. If the engine coolant does not warm up sufficiently, closed-loop fuel control is usually not allowed and the vehicle remains in open-loop fuel control. Since open-loop fuel control does not provide precise fuel control, this results in increased emission levels. Engine coolant temperature is also used to enable many of the diagnostics that are required by the OBD II regulation. If the engine coolant does not warm-up sufficiently due to a malfunctioning thermostat or if the engine coolant temperature sensor malfunctions and remains at a low or high reading, many diagnostics would not be enabled.

The current OBD II regulation requires monitoring of the thermostat and engine coolant temperature sensor. Starting in the 1994 model year, manufacturers have been required to monitor the engine coolant temperature sensor to ensure that the vehicle achieved the closed-loop enable temperature (or for diesel vehicles, the minimum temperature needed for warmed-up fuel control to begin) within a manufacturer-specified time after start up. The current regulation also requires that the coolant temperature sensor be monitored for rationality, electrical, and out-of-range failures. In the 2000 model year, additional diagnostics to monitor the thermostat for proper operation were phased-in. Although manufacturers, in general, determine when the coolant temperature is taking too long to reach the closed-loop enable temperature, the current regulation places a maximum warm-up time of two minutes for engine starts at or above 50 degrees Fahrenheit and five minutes for engine starts between 20 degrees and 50 degrees Fahrenheit. For the thermostat monitor, the current regulation requires the diagnostic to detect malfunctions when the engine coolant temperature does not achieve the highest temperature required to enable other diagnostics or warm up to within 20 degrees Fahrenheit of the manufacturer's thermostat regulating temperature.

Currently, the engine coolant temperature sensor and thermostat monitoring requirements are identified in different sections of the OBD II regulation or in separate advisory mail-outs.¹⁵ In order to clarify the various engine cooling system requirements,

¹⁵ Mail-Out s #95-20, "Guidelines for Compliance with On-Board Diagnostics II (OBD II) Requirements," (May 22, 1995), and #98-01, "On-Board Diagnostic II Compliance Guidelines," (January

the staff is consolidating them into one section of the OBD II regulation under the “engine cooling system” diagnostic heading. Most of the requirements themselves are not new.

Due to increasingly stringent emission standards, manufacturers have been lowering the engine coolant temperature required to enable closed-loop fuel control. By enabling closed-loop fuel control more quickly, manufacturers have been able to reduce their cold-start emission levels and comply with the new stringent emission standards. As a result, the times to achieve the manufacturer-specified closed-loop enable temperature after engine start are now considerably shorter than the times projected when the engine coolant temperature monitoring requirement was first adopted. Therefore, the current maximum allowable warm-up time thresholds may be too lenient.

The staff is proposing to modify the time-to-closed-loop monitor’s malfunction criteria to better reflect the lower enable requirements used on current vehicles. For engine starts that are up to 15 degrees Fahrenheit below the closed-loop enable temperature, the diagnostic would be required to indicate a malfunction if the enable temperature is not achieved within two minutes of engine start (rather than allowing two minutes above 50 degrees Fahrenheit, regardless of the manufacturer-specific closed-loop enable temperature). For engine starts that are between 15 and 35 degrees Fahrenheit below the closed-loop enable temperature, a malfunction would be required to be indicated when the enable temperature is not achieved within five minutes of engine start (rather than five minutes above 20 degrees Fahrenheit). Vehicles that do not utilize engine coolant temperature to enable closed-loop fuel control would continue to be exempted from time-to-closed-loop monitoring. These new limitations would apply to 2006 and subsequent model year vehicles certified to Low Emission Vehicle II standards.

Concerning the thermostat monitor, some of the manufacturers’ largest vehicles require a high capacity passenger compartment heating system. In cold weather, use of the heaters may not allow sufficient coolant temperature to be achieved in order to avoid illumination of the malfunction light, even when the thermostat is functioning normally. As a result, manufacturers have been forced to select very restrictive monitoring conditions that may not be frequently encountered in-use to ensure an accurate decision.

Therefore, the staff is proposing that vehicles that do not reach the temperatures specified by the malfunction criteria would be allowed to use alternate malfunction criteria and/or temperatures that are a function of coolant temperature at engine start. This provision would apply only for engine starts below 50 degrees Fahrenheit and would require the manufacturer to demonstrate why the standard malfunction criteria are not sufficient. Above 50 degrees Fahrenheit, the monitor would need to meet the standard malfunction criteria.

For the coolant temperature sensor, manufacturers have been monitoring the sensor for various rationality faults including readings that are inappropriately low or inappropriately high. However, some confusion has arisen among manufacturers as to what temperature ranges the rationality faults should cover. Typically, for non-temperature sensors, a rationality monitor is sufficient if it can verify the sensor is not reading inappropriately high at a single point where it should be reading low and not reading inappropriately low at a single point where it should be reading high.

However, the engine coolant temperature sensor is an essential sensor used extensively for both fuel and spark timing control as well as for several other OBD II monitors. And for some manufacturers, proper sensor performance is crucial in enabling nearly all of the other major OBD II monitors. If a malfunction occurs that causes the engine coolant temperature sensor to read a lower than actual temperature, monitors that only run when the sensor indicates the car is warmed-up can be delayed or even disabled. If a sensor malfunction occurs that causes the sensor to read higher than normal (e.g., due to corrosion on the sensor terminals, etc.), monitors that only run on cold starts may run less frequently or be disabled altogether. Accordingly, staff has continually worked with manufacturers to determine the level of rationality monitoring necessary based upon the extent the manufacturer relies on the engine coolant temperature sensor for other monitors. Further complicating the issue are the exemptions identified in OBD II Mail-outs¹⁵ which exempt the manufacturer from portions of the rationality monitoring dependant on the actual hardware used by the manufacturer (e.g., dashboard gauge or warning light, single or dual element sensors, etc.).

With the years of experience now gathered by industry and the staff, it is appropriate for the proposed language to more specifically elaborate on the necessary level of monitoring and clarify when the exemptions do or do not apply. As such, the proposed language includes clarifications that rationality monitoring for engine coolant temperature sensors must identify sensors that read inappropriately low (and thus, disable or delay operation of other monitors) or sensors that read inappropriately high (again, disabling or delaying operation of other monitors). Additionally, the language clarifies which monitoring requirements a manufacturer will be exempted from when utilizing specific hardware configurations.

G. COLD START EMISSION REDUCTION STRATEGY MONITORING

The largest portion of exhaust emissions are generated during the brief period following a cold start before the engine and catalyst have warmed up. In order to meet increasingly stringent emission standards, manufacturers are developing hardware and associated control strategies to reduce these emissions. Most efforts are centering around reducing catalyst warm-up time. A cold catalyst is heated mainly by two mechanisms, heat transferred from the exhaust gases and heat that is generated in the catalyst as a result of the catalytic reactions.

Manufacturers are implementing various hardware and control strategies to quickly light off the catalyst (i.e., reach the catalyst temperature at which 50 percent conversion efficiency is achieved). Most manufacturers use substantial spark retard and/or increased idle speed following a cold start to quickly light off the catalyst. However, customer satisfaction and safety (i.e., vehicle driveability and engine idle quality) limit the amount of spark retard or increased idle speed that a manufacturer will use to accelerate catalyst light off. On a normally functioning vehicle, engine speed drops when the ignition timing is retarded, therefore causing the idle speed control system to compensate and allow more airflow (with a corresponding increase in fuel) to the engine in order to maintain idle speed stability during spark retard. Since idle quality is given a high priority, spark retard is typically limited to the extent that the idle control system can quickly respond and maintain idle quality. A poorly responding idle control system may cause the computer to command less spark retard than would normally be achieved for a properly functioning system, thereby causing delayed catalyst light off and higher emissions. The OBD II regulation currently requires monitoring of the idle control system and monitoring of the ignition system by the misfire monitor. However, the idle control system is normally monitored after the engine has warmed up, and malfunctions that occur during cold start may not be detected by the OBD II system, yet have significant emission consequences.

Given the escalating cost of precious metals, there is an industry trend to minimize their use in catalysts. To compensate for the reduction in catalyst performance, manufacturers will likely employ increasingly more aggressive cold start emission reduction strategies. It is crucial that these strategies be successful and properly monitored in order to meet the new, more stringent emission standards in-use.

Considering the issues outlined above, the staff is proposing a requirement to monitor the key parameters used to implement cold start emission reduction strategies. This would ensure that the target conditions necessary to reduce emissions or catalyst light-off time are indeed achieved and emissions do not exceed 1.5 times the tailpipe standard. These parameters would be monitored while the strategy is active. For example, if the target idle speed for catalyst light-off could not be achieved or maintained adequately to maintain emissions below 1.5 times the standard, a malfunction would need to be indicated. Similarly, if the target spark retard necessary for catalyst light-off could not be achieved due to an idle control system malfunction, a fuel system malfunction, or any other malfunction, a fault would need to be indicated.

Monitoring techniques that are projected to be used for cold start monitoring strategies mainly involve software modifications. For example, if ignition retard is used during cold starts, the commanded amount of ignition retard would have to be monitored if the timing can be limited by external factors such as idle quality or driveability. This can be done with software algorithms that compare the actual commanded timing with the threshold timing that would result in emissions that exceed 1.5 times the standard. Cold start strategies that always command a predetermined amount of ignition retard independent of other factors do not require monitoring of the commanded timing. However, other factors that ensure the actual timing has been reached, such as

increased mass air flow and/or increased idle speed, require monitoring when the strategy is active. Since mass air flow and idle speed are both currently monitored by the OBD II system, monitoring these components when the cold start strategy is invoked should require only minor software modifications.

As required for other OBD II monitors, the stored fault code would, to the fullest extent possible, be required to pinpoint the likely cause of the malfunction to assist technicians in diagnosing and repairing these malfunctions. The industry has expressed concern that this monitoring requirement, while feasible, would require significant time-intensive calibration work. In response to these concerns, the proposal would allow a manufacturer to develop calibrations on representative vehicles and apply the calibrations to the remainder of the product line. To provide manufacturers with sufficient leadtime to comply with the new requirements, a phase-in is proposed beginning with the 2006 model year for Low Emission Vehicle II applications.

H. AIR CONDITIONING SYSTEM COMPONENT MONITORING

The use of air conditioning systems can significantly affect tailpipe emissions. Accordingly, in July 1997, the Board adopted a new test cycle (A/C Test) and accompanying emission standards for measuring emissions with air conditioning systems in operation.¹⁶ Vehicle manufacturers are required to begin meeting the new A/C Test standards in 2001 with complete phase-in of their product line by the 2004 model year. Generally, the new standards ensure that emissions occurring during air conditioning operation remain well-controlled (the staff plans, however, to revise the current standards for vehicles certified to the Low Emission Vehicle II emission standards). To ensure good emission control during air conditioning operation, manufacturers have employed revised fuel control, spark control, and other strategies. Some manufacturers, however, maintain that no revisions are needed to their engine control strategies to meet A/C Test emission standards.

In determining appropriate OBD II monitoring requirements for air conditioning systems, it seems unnecessary to monitor most aspects of the proper operation of the driver-operated controls or the various sensors for sunlight load, passenger compartment temperature, passenger skin temperature and others. This is because the A/C Test procedure ensures that the A/C compressor is operating virtually full time during the test, and therefore represents a worst case condition. At worst, failure of the above components could result in more A/C operation than otherwise selected by the driver, but the vehicle should still be capable of meeting the A/C Test standards. The exception would be for manufacturers that utilize an alternate engine control strategy for reducing emissions during air conditioning operation. Should the air conditioning system be commanded on but fail to become operational, the alternate engine control strategy would be invoked without increasing the engine load. Under these conditions, the level of emissions would be uncertain since the engine control strategy is not properly matched to the engine load. The other possibility is that failure of some components could result in the operation of the air conditioning system but not the

¹⁶ Refer to title 13, CCR sections 1960.1(q) and 1961(r).

alternate engine control strategy, which would also result in the mismatching of the engine load and control strategy. For example, should a manufacturer employ a richer fueling strategy to reduce NOx emissions, and this strategy was not invoked when the air conditioning was operating, higher NOx emissions might result.

The staff is proposing that manufacturers using alternate engine control strategies be required to monitor for the two types of malfunctions mentioned above. Manufacturers would need to monitor for failures of electronic components that yield emissions exceeding 1.5 times the applicable FTP or A/C Test standard. Generally, the FTP test would be applicable for malfunctions occurring when a special engine control strategy has been invoked, but the compressor has not been engaged. The A/C Test would be appropriate for malfunctions that result in compressor engagement but with an accompanying A/C engine control strategy that is not active.

Manufacturers using the alternate engine control strategies would be required to perform electrical circuit and rationality diagnostics on input components that could cause emissions to exceed 1.5 times the applicable standard. For output components, manufacturers would be required to perform electrical circuit and functional checks for malfunctions that could cause emissions to exceed 1.5 times the applicable standards (e.g., verify the component accomplished the command given by the control unit). Also, malfunctions that would disable other monitors would require monitoring. By conducting electrical circuit checks in combination with monitoring of compressor cycling performance during appropriate periods or in response to commands issued as part of an intrusive monitoring strategy, manufacturers should be able to discern failed electrical components, including relays, pressure switches, compressor clutches, or others that cause emissions to exceed the emission threshold. To provide manufacturers with sufficient leadtime to comply with the new requirements, a phase-in is proposed beginning with the 2006 model year for Low Emission Vehicle II applications

The staff expects very few A/C components to require monitoring under this proposal, but wants to ensure that adequate safeguards exist in case they are needed.

I. VARIABLE VALVE TIMING AND/OR CONTROL SYSTEM

Many of today's vehicles utilize variable valve timing primarily to optimize engine performance. Variable valve timing and/or control has many advantages over conventional valve control. Instead of opening and closing the valves by fixed amounts, variable valve timing controls can vary the valve opening and closing timing (as well as lift amount in some systems) depending on the driving conditions (e.g., high engine speed and load). This feature permits a better compromise between performance, driveability, and emissions than conventional systems. With more stringent NOx emission standards being phased in under the Low Emission Vehicle II program, even more vehicles are anticipated to utilize variable valve timing. By utilizing variable valve timing to retain some exhaust gas in the combustion chamber to reduce peak combustion temperatures, NOx emissions are reduced. Manufacturers utilizing variable

valve timing are often able to remove external exhaust gas recirculation (EGR) valves and controls from their vehicles, offsetting the cost increase for the system. While the OBD II regulation does require monitoring of the individual electronic components used in the variable valve timing system, it currently does not contain specific monitoring requirements for the detection of variable valve timing system malfunctions.

Since valve timing can directly affect exhaust emissions, the staff is proposing specific requirements for monitoring variable valve timing and/or control systems. Beginning in the 2005 model year on all Low Emission Vehicle II applications, manufacturers would be responsible for detecting target errors and slow response malfunctions of these systems. For target error and slow response malfunctions, the diagnostic system would be required to detect malfunctions when the actual valve timing and/or lift deviates from the commanded valve timing and/or lift such that 1.5 times the applicable FTP emission standard would be exceeded. For variable valve timing and/or control systems that cannot cause emissions to exceed 1.5 times the FTP standard or are used on vehicles prior to the 2005 model year phase-in, manufacturers would still be required to monitor the system for proper functional response under the comprehensive component requirements. This is the same requirement that is currently applicable to variable valve timing and/or control systems. Manufacturers are currently monitoring for these types of malfunctions, and the staff's proposal would correlate detection of these malfunctions to exceedance of emission standards.

J. DIRECT OZONE REDUCTION MONITORING

Direct ozone reduction systems consist of a special catalytic coating placed on a vehicle's radiator (or other surfaces such as the air conditioning condenser) that promotes ozone-reduction reactions in the ambient air. As the air passes across the warmed coated surfaces during normal driving, ambient ozone is converted into oxygen. While vehicles do not directly emit ozone from the tailpipe, they do emit hydrocarbon (HC) and nitrogen oxide (NOx) emissions, which are precursors to the formation of ozone. As such, ARB adopted a policy, detailed in Manufacturers Advisory Correspondence (MAC) No. 99-06, which allows manufacturers to offset higher tailpipe emissions by equipping vehicles with direct ozone reduction systems. Under this policy, manufacturers may receive NMOG credit, calculated in accordance with specific procedures described in ARB MAC No. 99-06, for its direct ozone reduction system.

The ozone conversion performance of the direct ozone reduction system will likely deteriorate over time, due to constant deposition of airborne particulate matter onto the coating, or by the gradual flaking of the coating due to age. Additionally, the loss of the entire coating, either gradually or suddenly, results in no ozone conversion at all. Currently, the OBD II regulation does not contain specific monitoring requirements for the detection of direct ozone reduction system failures, since it is a relatively new emission control technology. While manufacturers are not required to utilize direct ozone reduction systems in their vehicles, as they are not needed to meet the applicable emission standards, several manufacturers are pursuing the technology for use on future model year vehicles since they can receive emission credit for doing so. If

a manufacturer chooses to implement a direct ozone reduction system in its vehicles, it will be required to implement OBD II monitoring of such devices. Therefore, the addition of specific direct ozone reduction system monitoring requirements to the OBD II regulation is being proposed.

OBD II requirements for direct ozone reduction systems were developed in ARB MAC No. 99-06 and were structured analogous to conventional tailpipe emission reduction device monitoring requirements. The proposed requirements follow those established for direct ozone reduction system monitoring as set forth in ARB MAC No. 99-06, and formally incorporate them into the OBD II regulation.

Accordingly, if the direct ozone reduction system qualifies for a relatively small emission reduction credit (i.e., the NMOG credit assigned to the direct ozone reduction system is less than or equal to half the applicable FTP NMOG emission standard to which the vehicle is certified), manufacturers would only be required to perform a functional check of the direct ozone reduction system to verify that the coating is still present on the radiator. In other words, the OBD II system would indicate a malfunction when it is unable to detect some degree of ozone conversion.

Alternatively, if the direct ozone reduction system qualifies for a relatively large emission reduction credit (i.e., the NMOG credit assigned to the direct ozone reduction system is greater than half the applicable FTP NMOG emission standard to which the vehicle is certified), manufacturers would be required to monitor the ozone conversion efficiency of the system. The OBD II system would indicate a malfunction when the ozone reduction performance deteriorates to a point where the difference between the NMOG credit assigned to the properly operating direct ozone reduction system and the NMOG credit calculated for a direct ozone reduction system performing at the level of the malfunctioning system exceeds 50 percent of the applicable FTP NMOG standard. This is analogous to OBD II monitoring of other components, where the OBD II system indicates a malfunction prior to tailpipe emissions exceeding 1.5 times the applicable standards.

In developing monitoring strategies for the direct ozone reduction system, manufacturers have identified physical and electrical properties of the coating that correlate to its ozone conversion performance. To date, three different potential monitoring strategies have been presented to the ARB. The electrical (resistive) approach monitors the resistance change of the coating. This method involves an electrical probe that is used to indicate changes in the resistive properties of the coating that correlate to changes in the thickness of the coating. The second, an optical (reflective) approach, uses reflective light to monitor the capability of the coating. This method uses certain spectrums of light (e.g., red, white, near infrared) to obtain voltage readings from the radiator surface in order to distinguish between properly coated and deteriorated or uncoated surfaces. Both methods are essentially indirect approaches for detecting the presence or loss of the catalytic coating. The third approach involves the use of an ozone sensor that directly measures ozone conversion efficiency.

While some manufacturers are highly confident that the identified strategies will meet the monitoring requirements by the 2005 model year, none of the monitoring technologies is currently sufficiently developed for immediate implementation. To allow for proper development, the proposed requirements would allow manufacturers to use the direct ozone reduction system to offset tailpipe HC emissions for three years without meeting the monitoring requirements. Since the direct ozone reduction system does not directly affect any other tailpipe or evaporative emission control system or diagnostic, malfunctions or improper operation of the direct ozone reduction system that go undetected, due to the lack of an OBD II monitor, will not cause higher tailpipe or evaporative emissions nor will it affect the proper operation of any other OBD II monitor. However, to account for the lack of monitoring, the proposed requirements would only allow manufacturers to use 50 percent of the NMOG/HC emission credits assigned for the direct ozone reduction system as calculated in accordance with the guidelines set in ARB MAC No. 99-06. It is a reasonable expectation that if the direct ozone reduction device meets the durability guidelines outlined in ARB MAC No. 99-06, the radiator and direct ozone reduction system (i.e., coating) will likely be effective for at least half of the life of the vehicle.

According to the current guidelines, manufacturers are allowed to use the NMOG credit assigned to the direct ozone reduction system to offset NMOG tailpipe emissions. Consistent with this offset, manufacturers have requested ARB approval to also offset the OBD thresholds, where appropriate. The ARB staff agrees and is proposing requirements that would allow a manufacturer to adjust the malfunction threshold for other monitors (e.g., catalyst, oxygen sensor, etc.) to account for the direct ozone reduction NMOG credit. In other words, if a manufacturer implements a direct ozone reduction system in its vehicles, it may set the OBD II malfunction threshold at 1.5 times the applicable HC standard plus the direct ozone reduction credit (i.e., $(1.5 \times \text{HC std.}) + \text{direct ozone reduction credit}$).

K. PASSENGER CAR AND LIGHT-DUTY TRUCK SULEV THRESHOLDS

The most stringent Low Emission Vehicle I standard is the ULEV standard for the passenger car and light-duty truck category, with emission levels of 0.055 grams/mile non-methane organic gas (NMOG), 2.1 grams/mile CO, and 0.3 grams/mile NO_x at the useful life regulatory interval. The Low Emission Vehicle II standards, however, include a SULEV standard for passenger cars and light-duty trucks that is even more stringent. The SULEV standard has significantly lower emission levels of 0.01 grams/mile NMOG, 1.0 grams/mile CO, and 0.02 grams/mile NO_x. The current OBD regulation does not specify malfunction thresholds for vehicles certified to the SULEV standard. However, the ARB recently certified a vehicle meeting the SULEV emission standard, with OBD II malfunction thresholds of 1.5 times the SULEV standard for most monitors and 1.75 times the SULEV standard for the catalyst monitor.

While it is feasible for SULEV vehicles to use the current malfunction thresholds, industry and others have expressed concern that these thresholds are too low. After considering these comments, the staff is proposing thresholds of 2.5 times the

applicable standards (referred to in this section as “2.5 threshold”) for passenger car and light-duty truck SULEVs¹⁷, which are appropriate for a number of reasons:

- Measuring emissions at SULEV levels using current emission measurement technologies is a recognized challenge by government and industry. This is due to the fact that test-to-test variability (due to production vehicle variability and test equipment variability) constitutes a larger percentage of the standard for SULEV vehicles than for ULEV and less stringent vehicles. In order to ensure compliance on production vehicles, manufacturers certify to both the applicable tailpipe and evaporative emission standards and the OBD II standards with some amount of compliance margin. Given this increased relative variability, a manufacturer is forced to certify to a lower absolute level of emissions than for other vehicles. A 2.5 threshold would reduce a manufacturer’s in-use SULEV’s liability while providing the time necessary for industry to reduce vehicle variability and to improve the capability of emission-measuring equipment.
- The stringency of the SULEV standards will require manufacturers to develop and produce some emission control components with tighter tolerances. However, industry to date has had minimal production experience with SULEV emission levels and tolerances. Accordingly, if industry used an OBD II malfunction threshold of 1.5 times the tailpipe standards on SULEV vehicles with current production tolerances, the OBD II system could falsely illuminate the MIL for components that are in fact good (i.e., still within production tolerances). A higher threshold would provide manufacturers with sufficient separation between “good” components that are at the limits of production tolerances and “bad” components that are malfunctioning.
- The 2.5 threshold would allow manufacturers to use similar levels of component deterioration on SULEV vehicles as those used on vehicles certified to less stringent standards (e.g., ULEV vehicles). Manufacturers have production and in-use experience with malfunction thresholds, production tolerances, and deterioration on ULEV vehicles. Using a similar level of component deterioration on SULEV vehicles would provide greater assurance that a component is truly malfunctioning and not just at the limits of production tolerances.

Because the SULEV standards are so low, thresholds at 2.5 times the standards would still provide some reasonable level of protection against high emissions while recognizing the challenges associated with vehicles certified to the SULEV standards. The staff will monitor the industry’s progress in meeting these challenges and propose revising the thresholds as necessary.

¹⁷ For these SULEV applications, the proposed NOx catalyst monitoring requirement would be phased in with an interim threshold of 3.5 times the applicable NOx standard, beginning with the 2005 model year, and with a final threshold of 2.5 times the applicable NOx standard required for 2007 and subsequent model year applications.

L. CATALYST AND PARTICULATE MATTER TRAP MONITORING FOR DIESELS

The current OBD II regulation specifically excludes catalyst monitoring for diesels. Unlike gasoline vehicles, current diesels do not have sensors in the exhaust stream that are sufficient for monitoring the catalyst system. Additionally, current diesel vehicles do not require extensive aftertreatment to meet the applicable standards. However, as manufacturers design systems to meet increasingly stringent NO_x and particulate matter (PM) emission standards applicable to future diesel light-duty and medium-duty vehicles, many will likely use NO_x adsorbers, selective catalytic reduction devices, oxidation catalysts, and PM traps to achieve the necessary emission levels. In order to protect against unacceptably high emissions on vehicles using these technologies, the U.S. EPA adopted requirements for diesel catalyst and PM trap monitoring on 2004 and subsequent model year vehicles with a gross vehicle weight rating (GVWR) of less than 6,000 pounds and 2005 and subsequent model year vehicles with a GVWR between 6,000 and 14,000 pounds.

However, since the U.S. EPA originally adopted its requirements, substantial progress has been made in the development of diesel aftertreatment devices. While it originally appeared unlikely that diesel vehicles would use these devices to any significant extent before the 2007 model year (when more stringent tailpipe standards take effect), there has been some recent indication that manufacturers will use these types of devices to allow light-duty vehicles to meet LEV II program emission standards in the near future. As such, the staff is proposing diesel catalyst and PM trap monitoring requirements that reflect the capability of these new systems and are consistent with gasoline vehicle monitoring requirements.

For 2005 and 2006 model year medium-duty vehicles and engines, the proposed requirements are identical to the U.S. EPA's requirements and are adequate for the level of technology expected to be used on those vehicles. For the 2004 and subsequent model year light-duty vehicles and 2007 and subsequent model year medium-duty vehicles and engines, however, the proposed requirements reflect more stringent monitoring requirements, consistent with both the expected technology to be used and with the current requirements for gasoline vehicles.

For 2005 and 2006 model year medium-duty vehicles, the proposed catalyst requirements would require monitoring of reduction catalysts (i.e., catalysts primarily involved in reducing NO_x emissions via reduction processes) for proper conversion capability. Monitoring of oxidation catalysts (i.e., catalysts primarily involved in reducing HC emissions via oxidation processes), which generally have a relatively small emission impact on diesel vehicles, would not be required. Manufacturers would be required to indicate a reduction catalyst malfunction when the conversion capability of the catalyst system decreases to the point that emissions exceed 1.5 times the applicable NO_x or PM standard. If a malfunctioning reduction catalyst cannot cause emissions to exceed the emission threshold of 1.5 times the applicable standards, a manufacturer may request an exemption from the requirements for diesel reduction catalyst monitoring.

For 2004 and subsequent model year light-duty vehicles and 2007 and subsequent model year medium-duty vehicles, the proposed catalyst monitoring requirements would require monitoring for both HC and NO_x conversion capability. Manufacturers would be required to indicate a catalyst malfunction when the conversion capability of the catalyst system decreases to the point that emissions exceed 1.5 times the applicable HC, NO_x, or PM standard. Consistent with all other OBD II monitoring requirements, if a malfunctioning catalyst cannot cause emissions to exceed the emission threshold of 1.5 times the applicable standards, a manufacturer would only be required to functionally monitor the system and indicate a malfunction when no HC or NO_x conversion efficiency could be detected. Additionally, through the 2009 model year, no monitoring would be required if the conversion efficiency of the catalyst system was less than 30 percent.

For 2005 and 2006 model year medium-duty vehicles, the proposed requirements for PM traps would require monitoring for proper performance. The malfunction threshold for a PM trap, however, would not be based on a specific emission level. Rather, manufacturers would be required to indicate a PM trap malfunction when catastrophic failure occurs (e.g., a cracked trap substrate). Similar to catalyst monitoring, a manufacturer could be exempted from PM trap monitoring if catastrophic failure would not cause emissions to exceed 1.5 times the applicable standards.

For 2004 and subsequent model year light-duty vehicles and 2007 and subsequent model year medium-duty vehicles, the proposed requirements for PM traps would require monitoring for proper performance. Manufacturers would be required to indicate a PM trap malfunction when the capability decreases to the point that emissions exceed 1.5 times any of the applicable standards. If a malfunctioning PM trap cannot cause emissions to exceed the emission threshold of 1.5 times the applicable standards, a manufacturer would only be required to perform functional monitoring of the system and indicate a malfunction when no PM trap capability could be detected.

Technological Feasibility

In order to comply with future emission standards, diesel engine manufacturers are expected to utilize NO_x adsorbers, lean NO_x catalysts, oxidation catalysts, and PM traps. Manufacturers may use various groupings of these devices in a system, including some devices that are combined (e.g., a combined trap/NO_x adsorber). Diesels will require precise fuel control to optimize aftertreatment device efficiencies and to limit losses in fuel economy due to fueling strategies associated with the devices. With NO_x adsorbers, the frequency of fuel addition to the exhaust, intended to reduce NO_x emissions, should be minimized to optimize fuel economy. This would suggest the use of a NO_x sensor to determine when fueling should occur (manufacturers could rely on engine mapping to achieve the same result, but this might result in excess fueling strategies to provide a safety factor for meeting emission standards). This sensor could also be used to monitor the NO_x conversion efficiency of the adsorber. Similarly,

selective catalytic reduction systems that rely on the urea additive to accomplish NO_x reduction could also rely on a NO_x sensor to meter the additive as well as for monitoring purposes. For clean-up oxidation catalysts, the possible use of linear oxygen sensors could be employed for monitoring purposes. Non-passively regenerated traps will likely rely on pressure sensors to determine optimum regeneration frequency to prevent trap damage due to delayed regeneration that could lead to excess temperatures. The same pressure sensor could also be utilized to evaluate the suitability of the trap for controlling particulate emissions.

At this time, diesel control systems are evolving and production intent systems are continuing to be developed. Nonetheless, it appears that the same sensors necessary for aftertreatment device operation can also be utilized for diagnostic purposes. The staff has examined one prototype light-duty diesel vehicle expected to meet the Low Emission Vehicle II standards and believes that monitoring of the aftertreatment systems consistent with the requirements being proposed can be done with the aftertreatment control sensors. The staff will be developing monitoring requirements for heavy duty engines next year and will further evaluate monitoring strategies and requirements for diesel vehicles at that time.

M. COMPREHENSIVE COMPONENT MONITORING

The current OBD II regulation, title 13, CCR section 1968.1, requires the monitoring of comprehensive components, which covers all other electronic powertrain components or systems not mentioned above that either can affect vehicle emissions or are used as part of the OBD II diagnostic strategy for another monitored component or system. They are generally identified as input components, which provide input directly or indirectly to the on-board computer, or as output components or systems, which receive commands from the on-board computer. Typical examples of input components include the mass air flow sensor, manifold absolute pressure sensor, intake air temperature sensor, vehicle speed sensor, and throttle position sensor. Typical examples of output components/systems include idle speed control valves and automatic transmission solenoids.

The OBD II regulation currently requires input components to be monitored continuously for out-of-range and circuit continuity faults (e.g., shorts, opens, etc.) and “once-per-driving cycle” for rationality faults (e.g., where a sensor reads inappropriately high or low but still within the valid operating range of the sensor). The regulation currently requires output components and systems to be monitored once per driving cycle for proper functional response (e.g., when the component is commanded to do something by the on-board computer, the OBD II system verifies that the action has occurred). If functional monitoring is not feasible, circuit continuity monitoring is required.

Monitoring of comprehensive components is essential since the proper performance of these components can be critical to the monitoring strategies of other components or systems. Generally, these components are also essential for proper fuel

control or driveability, and malfunctions of them often cause an increase in emissions or impact fuel economy and/or vehicle performance. Because of the vital role that some of these components play and because they continuously provide input to and are used by the on-board computer, the proposal would require more frequent monitoring for some specific components. Specifically, for 2005 and subsequent model year vehicles, rationality monitoring of input components would be required each time all manufacturer-defined enable conditions are met instead of once per driving cycle as previously required in section 1968.1. This would provide earlier detection of components that are beginning to fail, especially those exhibiting intermittent failure.

For output components and systems, the proposal would specifically require functional monitoring of the idle speed control system to be done each time the vehicle is operated at idle and meets the manufacturer-defined monitoring conditions. This change would help ensure that idle speed control system malfunctions are detected as quickly as possible and minimize the chance for problems to go undetected because the system was operating properly the one time during the driving cycle that monitoring occurred. Further, because idle speed control system problems often can prevent other monitors from running and are frequently noticeable to the driver (e.g., stalling or erratic idle), proper detection is essential.

For input components, the proposed regulation would also require manufacturers to store different fault codes that distinguish rationality faults from faults due to lack of circuit continuity and out-of-range values. This would help technicians repair vehicles expeditiously and efficiently by enabling them to perform repair procedures specific to the malfunction present rather than using a lengthy general troubleshooting procedure that covers all possible failure modes. Additionally, for input component lack of circuit continuity and out-of-range circuit faults, manufacturers would be required to store different fault codes for each distinct malfunction (e.g., out-of-range low, out-of-range high, open circuit). Again, this would enable technicians to find and repair malfunctions more efficiently. However, in cases where lack of circuit continuity faults cannot be distinguished from out-of-range circuit faults, manufacturers would not be required to store separate fault codes for each distinct malfunction.

N. OTHER EMISSION CONTROL OR SOURCE DEVICE MONITORING

While the OBD II regulation lists very specific requirements for most emission controls commonly used today, the automotive industry is continually innovating new emission control technologies in addition to refining existing ones. In cases where the technology simply reflects refinements over current technology, the OBD II monitoring requirements are generally sufficient to ensure the improved devices are properly monitored. However, in cases where the new technology represents a completely different type of emission control device, the monitoring requirements for existing emission controls are not easily applied. Typical devices that fall under this category include hydrocarbon traps, NO_x storage devices, and thermal storage devices. The purpose of OBD II, however, is clearly to monitor all emission-related and emission control devices. Accordingly, with the regulatory changes that occurred in 1996, a

provision was included that required manufacturers to submit a monitoring plan for ARB's review and approval for any new emission control technology prior to introduction on any future model year vehicles. To date, this policy has worked effectively by allowing manufacturers and ARB staff to evaluate the new technology and determine an appropriate level of monitoring that was both feasible and consistent with the monitoring requirements for the conventional emission control devices. As such, the proposed regulation would continue this provision.

However, modifications would be made to provide further guidance as to what type of components would fall under the requirements of this section instead of under the comprehensive component section. Specifically, the staff is concerned that without these changes, confusion may arise for emission control components or systems that can also be defined as electronic powertrain components because they fit the definitions of both sections. As such, the proposal would delineate the two by requiring components/systems that fit both definitions but are not corrected or compensated for by the adaptive fuel control system to be monitored under the provisions of the "other emission control devices" requirements rather than under the comprehensive component requirements. A typical device that would fall under this category instead of the comprehensive components category because of this delineation is a swirl control valve system. Such delineation is necessary because emission control components generally require more thorough monitoring than comprehensive components to ensure low emission levels throughout a vehicle's life. Further, emission control components that are not compensated for by the fuel control system as they age or deteriorate can have a larger impact on tailpipe emissions relative to comprehensive components that are corrected for by the fuel control system as they deteriorate.

Also, to ensure that all devices that can generate emissions on hybrids and other advanced vehicle propulsion technology vehicles are properly monitored, the proposal would expand the requirement to require monitoring of "emission source devices" in addition to emission control devices. For purposes of the proposed regulation, "emission source devices" would be defined as components or systems that emit pollutants that are subject to vehicle evaporative and exhaust emission standards (e.g., NMOG, NOx, PM, etc.). These may include non-electronic components and non-powertrain components such as fuel-fired passenger compartment heaters and on-board reformers. For these devices, manufacturers would be required to submit a plan for Executive Officer approval of the OBD II monitoring strategy, malfunction criteria, and monitoring conditions in the same manner used for emission control devices.

IV. REVISIONS TO STANDARDIZATION REQUIREMENTS

One of the most important aspects of OBD II is the requirement for manufacturers to standardize certain features in the OBD II system. Effective standardization assists all repair technicians by providing equal access to essential repair information, and requires structuring the information in a consistent format from manufacturer to manufacturer. To facilitate the requirements, the ARB has worked

closely with the Society of Automotive Engineers (SAE) over the last 15 years to jointly develop standards for OBD II systems.

These standards include specifications for items including the tools used by service technicians, the methods for accessing information in the on-board computer, the numeric fault codes stored when a malfunction is detected, and the terminology used by the manufacturer in service manuals. With continual evolution of technology and the extensive feedback received from technicians in the field and pilot Inspection and Maintenance (I/M) programs around the nation, the ARB is proposing to clarify and update existing requirements and modify others as necessary to assist technicians and ease implementation of OBD II into the I/M program.

A. Phase-in of Controller Area Network (CAN) communication protocol

The current OBD II regulation allows manufacturers to use one of four protocols for communication between a generic scan tool and the vehicle's on-board computer. Currently, a generic scan tool must automatically cycle through each of the allowable protocols to establish communication with the on-board computer. While this has generally worked successfully in the field, some communication problems have arisen due, in part, to the use of multiple protocols. Additionally, the current protocols do not take advantage of many of the technological advances that have occurred over the last several years.

In keeping up with advances in communication technology, the proposed requirements would allow the use of a fifth protocol known as International Standards Organization (ISO) 15765 on 2003 and subsequent model year vehicles. This protocol, a Controller Area Network (CAN) protocol, incorporates significant improvements over those protocols that are currently being used including faster update rates to the scan tool and standardization of more data. Further, to reduce the chance for problems in the field due to the use of multiple protocols and to make sure all vehicles are equipped with the added features available through the CAN protocol, the staff is proposing phasing out the other four currently allowed protocols by the 2007 model year. Thus, all 2008 and subsequent model year vehicles would be required to use CAN as the communication protocol.

The proposal would also modify a provision that currently exists for manufacturers to use an alternate protocol known as SAE J1939 to eliminate the specific reference to SAE J1939 as the allowable alternate protocol. The current provision allows manufacturers of medium-duty vehicles to request Executive Officer approval to use J1939 in lieu of virtually all of the other standardized requirements including communication protocol, diagnostic connector, and access to diagnostic data. This provision was originally intended to allow manufacturers that produce engines for use in both heavy-duty vehicles (not currently required to have OBD II systems) and medium-duty vehicles to use a protocol that was being designed for heavy-duty vehicles. To date, all of the medium-duty vehicles certified to OBD II requirements have used one of the other four allowable protocols and no manufacturer has submitted a

request to use the SAE J1939 protocol¹⁸. Additionally, the California Bureau of Automotive Repair (BAR) has indicated a desire to include all light-duty and medium-duty vehicles in the current I/M (Smog Check) program. To this end, BAR has indicated that the elimination of this provision would ensure that I/M stations in California would be able to inspect all medium-duty vehicles certified for sale in California without having to purchase additional equipment for vehicles using the SAE J1939 protocol.

Recently, the U. S. Environmental Protection Agency (EPA) has begun work on developing OBD regulations for heavy-duty vehicles. ARB has also indicated its intentions to do the same. However, at this time, neither agency has conclusively determined which protocol (or protocols) are appropriate for the standardized requirements that will be used by all manufacturers. ISO, a body similar to SAE but with a larger European influence, has also developed a protocol for heavy-duty vehicles similar to, but not identical to, SAE J1939. Rather than prematurely determining the appropriate protocol for heavy-duty vehicles in the OBD II requirements for light- and medium-duty vehicles, staff has modified the existing provision to allow manufacturers to use whatever protocol ends up being designated as acceptable for heavy-duty OBD rather than specifically designating SAE J1939 as the only allowable exception. With this change, the original intent of the provision is maintained (i.e., engines used in both medium-duty and heavy-duty vehicles can use the same protocol) without creating potential conflicting requirements between future EPA and ARB heavy-duty OBD regulations and the existing OBD II regulation. And while this will not resolve BAR's desire to maintain a single protocol throughout light- and medium-duty applications, it will ensure that if medium-duty applications do differ from light-duty, they will be common with heavy-duty applications (another group of vehicles not currently subject to BAR Smog Check testing but under investigation for possible future inclusion).

B. Readiness status

Readiness status has become a major issue in I/M testing, especially with the recent publishing of U.S. EPA's final rule requiring the use of OBD II checks in state I/M programs (and recommending it be done in lieu of traditional tailpipe emission tests). The readiness status of several major emission control systems and components is checked to determine if the OBD II monitors have performed their system evaluations. When the vehicle is scanned, the monitor reports a readiness status of either "complete" (if the monitor has run since the memory was last cleared), "incomplete" (if the monitor has not yet had the chance to run since the memory was last cleared), or "not applicable" (if the monitored component in question is not contained in the vehicle). The readiness information allows a technician or I/M inspector to determine if the memory in

¹⁸ Subsequent to learning of staff's proposal to eliminate specific reference to SAE J1939, two manufacturers have indicated that future product plans currently exist that would utilize SAE J1939 on engines sold for use in medium-duty vehicles in California. It is anticipated, however, that these products would only utilize SAE J1939 if EPA and ARB allow SAE J1939 in the heavy-duty OBD requirements. As the proposed regulatory change would allow a common (but not yet determined) protocol for heavy-duty OBD and medium-duty OBD, these two manufacturers would not be affected if SAE J1939 is ultimately determined to be the required protocol for heavy-duty OBD in California.

the on-board computer has been recently cleared (e.g., by a technician clearing fault codes or disconnecting the battery).

Readiness flags were developed to prevent fraudulent testing. Prior to their development, drivers or technicians have tried to avoid “fail” designations by disconnecting the battery and clearing the computer memory prior to an I/M inspection. In such occurrences, any pre-existing fault codes are erased and the malfunction indicator light (MIL) is extinguished. The presence of unset readiness flags will cause the vehicle to be rejected from testing and required to return for a re-test at a later date. Unfortunately, the presence of unset readiness flags may also be due to circumstances beyond the driver’s control (i.e., the car was not driven under the conditions necessary to run some of the monitors) and these drivers will also be rejected from testing. In addition, as they should, technicians routinely clear the computer memory after repairing an OBD II-detected fault in order to erase the fault code and extinguish the MIL, which consequently also resets the readiness status. As in the previous cases, a vehicle that has not had sufficient time to operate after repair services by a technician may have unset readiness flags and be rejected from I/M testing.

To address these issues, the staff is proposing several provisions to help technicians determine if the memory had recently been cleared, either after repairs or fraudulently. Beginning with 2005 model year vehicles using the CAN communication protocol, vehicles would be required to make available data on the distance elapsed and the number of warm-up cycles since the fault memory was last cleared. By accessing these data, technicians would be able to determine if unset readiness flags or an extinguished MIL are due to recent clearing of the memory or circumstances beyond the driver’s control. This would allow an I/M program to be setup to allow I/M technicians to reject only those vehicles with recently cleared memories from the I/M inspection.

Provisions have also been added to make it easier for technicians to prepare the vehicle for an I/M inspection following a repair by providing real time data which indicates whether certain conditions necessary to set all the readiness flags to 'complete' are currently present. This data will indicate whether a particular monitor still has an opportunity to run on this driving cycle or whether a condition has been encountered that has disabled the monitor for the rest of the driving cycle. While this data won’t provide technicians with the exact conditions necessary to exercise the monitors (only service information will do that), this information in combination with the service information should facilitate technicians in verifying repairs and/or preparing a vehicle for inspection.

The revised OBD II-I/M program has raised issues regarding the effect on consumers because of possible rejection from I/M testing due to unset readiness flags. To address this, some manufacturers have requested the option to communicate the vehicle’s readiness status directly to the vehicle owner without the use of a scan tool. This would allow the vehicle owner to be sure that the vehicle is ready for inspection prior to taking the vehicle to an I/M station. As such, the staff is proposing to allow

manufacturers the option of communicating readiness status to the vehicle owner using the MIL as an indicator. If manufacturers choose to implement this option, though, they would be required to do so in the standardized manner prescribed in the proposed regulation. On vehicles equipped with this option, the vehicle owner would be able to initiate a self-check of the readiness status, thereby greatly reducing the possibility of being rejected at the I/M inspection.

C. Use of manufacturer-specific fault codes

Fault codes are the means by which malfunctions detected by the OBD II system are reported and displayed on a scan tool for service technicians. The current OBD II regulation requires manufacturers to report all emission-related fault codes using a standardized format whenever possible and to make them accessible to all service technicians, including the independent service industry. SAE J2012 (“Recommended Practice for Diagnostic Trouble Code Definitions”) defines many generic fault codes to be used by all manufacturers. If a manufacturer cannot find a suitable fault code in J2012, unique “manufacturer-specific” fault codes can be used. However, these manufacturer-specific fault codes are not as easily interpreted by the independent service industry. As the use of manufacturer-specific fault codes increases, the time and cost for vehicle repair may also increase.

The ARB is proposing to further restrict the use of manufacturer-specific fault codes. If a generic fault code suitable for a given malfunction cannot be found in J2012, the regulation would require the manufacturer to pursue SAE approval of additional generic fault codes to be added to J2012. This proposal would affirm the original intent of the OBD II regulation to standardize as much information as possible and would benefit the independent service industry and vehicle owners by potentially reducing the time and costs required to repair vehicles.

D. Access to additional data through a generic scan tool

Currently, manufacturers are required to report approximately 15-20 “real-time” data parameters in a format that a generic scan tool can process and read. These parameters, which include information such as engine speed and oxygen sensor voltages, are used by technicians to help diagnose and repair emission-related malfunctions by watching instantaneous changes in the values while operating the vehicle. The set of 15-20 standardized parameters is, however, only a subset of all the information that is actually available on a vehicle. Scan tools designed and built specifically for dealer technicians sometimes offer access to over 300 different parameters.¹⁹ While the standardized items available through a generic scan tool were never intended to duplicate the function of a vehicle-specific scan tool, they were

¹⁹ It should be noted that, while the generic scan tool does not provide for access to these additional data parameters, separate service information regulations require manufacturers to make information available to scan tool designers so that they may incorporate the additional features into their tools.

intended to provide a technician with the minimum amount of information necessary to perform emission-related repairs.

As technology has advanced, new components that do not fit well in the previously defined standardized definitions are becoming more commonplace. Additionally, feedback from technicians in the field has identified the need for some additional standardized parameter definitions. As such, the proposed regulation defines over 20 additional parameters that manufacturers would be required to report to generic scan tools. These parameters should provide technicians with the additional information necessary to make cost-effective emission-related repairs. The new parameters should also provide technicians and I/M inspectors with valuable information that will enable them to more easily prepare a vehicle for an OBD II-based I/M inspection. Lastly, the proposed regulation would provide further clarification for two existing parameters (engine load and throttle position) to ensure consistent use by all manufacturers. To provide a smooth transition, the staff is proposing that manufacturers be required to make the additional information available on all 2005 and subsequent model year vehicles equipped with CAN as the generic scan tool communication protocol.

E. Reporting of pending fault codes

For most OBD II strategies, the same malfunction must occur on two separate driving events to illuminate the MIL. This “double” detection ensures that a malfunction truly exists before alerting the owner. The first time a malfunction is detected, a “pending” fault code, which identifies the failing component or system, is stored in the on-board computer. If the same malfunction is again detected the next time the vehicle is operated, the MIL is illuminated and a “confirmed” fault code is stored. When the MIL is illuminated (alerting the vehicle operator to a problem) and a vehicle is brought in for service, a technician uses the “confirmed” fault code to determine what system or component has failed. A “pending” fault code, however, can be used by service technicians to help diagnose intermittent problems as well as to verify that repairs were successful. In these instances, a technician can use the “pending” fault code as a quicker, earlier warning of a suspected (but as yet unconfirmed) problem.

Presently, manufacturers are allowed to use two different strategies to report “pending” malfunctions to a scan tool, but this has led to unnecessary confusion and difficulty for repair technicians. In some instances, the “pending” malfunction is reported as a numeric fault code in the same manner that “confirmed” fault codes are reported. In other instances, however, the “pending” malfunction is reported as a numeric test result and a numeric maximum or minimum allowable limit for the test result. In the latter case, a technician must translate the test result and limits to engineering units using manufacturer specific conversion factors and determine if the test result is a “passing” value or a “failing” value. The proposed regulation would require manufacturers to report all “pending” malfunctions in the form of a “pending” fault code so technicians will not need to interpret test results to determine if a “pending” fault has been detected. Additional clarification is also added to ensure that all manufacturers

store and erase pending fault codes in a manner that provides a consistent message that technicians can understand and rely on.

F. Software Calibration Identification Number (CAL ID) and Calibration Verification Number (CVN)

OBD II diagnostics are comprised of software routines and calibrated limits and values to determine if a component or system is malfunctioning. Manufacturers often release updates to the software in the on-board computer to add new features and improvements or to correct errors or “bugs” found in the system. To determine if the correct software has been installed, amendments were adopted in 1996 that required manufacturers to phase-in reporting of two additional items. The first item, Calibration Identification Number (CAL ID), identifies the version of software installed in the vehicle. The second item, Calibration Verification Number (CVN), helps to ensure that the software has not been inappropriately corrupted, modified, or tampered with. CVN requires manufacturers to develop sophisticated software algorithms that can verify the integrity of the emission-related software and ensure that the diagnostic routines and calibration values have not been modified inappropriately.

Both CAL ID and CVN requirements were adopted to ensure the integrity of the OBD II system during I/M inspections. As pilot OBD II-based I/M programs have been tested across the nation, several improvements have been identified as necessary to allow for effective use of the CVN in an I/M inspection. Therefore, several changes are proposed for the CVN requirements that would help an I/M technician access and correctly use the CVN results. Most notably, these changes include a requirement that the CVN result be available at all times to a generic scan tool (instead of allowing manufacturers to only generate a result during key on, engine off conditions). Due to other factors, OBD II-based I/M testing is currently being performed only during engine running conditions, which creates an incompatibility with CVN results that are only calculated when the engine is off. Accordingly, the proposal includes a delay in the current CVN requirements from the 2002 to the 2005 model year to allow manufacturers additional time to meet the proposed changes.

G. Vehicle Identification Number (VIN)

The Vehicle Identification Number (VIN) is a unique, 17-digit, alphanumeric number assigned by the manufacturer to every vehicle built. The VIN is commonly used for purposes of ownership and registration to uniquely identify every vehicle. As such, the VIN is also used during an I/M inspection to identify the exact vehicle being tested. Current I/M programs require the inspector to enter the VIN at the time of inspection by manually typing it in or, in some cases, using a bar code reader to “scan” it in. However, when the VIN is manually entered, errors can and do occur. In addition, a long standing criticism of current I/M programs, including California’s Smog Check program, is that it is very easy for an inspector to fraudulently pass failing vehicles by entering the VIN of one vehicle and performing an emissions test on a known “clean” vehicle (a practice known as “clean-piping”).

In order to reduce the number of errors related to VIN entry, to facilitate entry of the VIN, and to further deter fraud during I/M inspections, the proposed regulation would require the VIN to be stored in the vehicle's on-board computer and accessible electronically via a generic scan tool. This would be required on all 2005 and newer model year vehicles. While this would not eliminate the possibility of a technician performing a fraudulent inspection, it would make it significantly more difficult.

H. Service Information

OBD II requirements have traditionally required manufacturers to make all emission-related vehicle service information available to all service technicians, including independent and after-market service technicians. Amendments adopted in 1996 and scheduled to take effect for the 2002 model year further required that service information be made available in an SAE-defined standardized electronic format to try and improve the accessibility of the information.

With the advances in Internet technology, however, recent legislation has been adopted in California that requires service information to be made available through the Internet. As a result, the Board recently approved the adoption of a stand-alone service information regulation in December 2001 that identifies, in a single regulation, all of the service information requirements that manufacturers must meet. The service information regulation, however, does not require manufacturers to make service information available before January 1, 2003, whereas the OBD II regulation requires service information to be available before then, although not via the Internet. The staff is proposing inclusion of language in the OBD II regulation to clarify that, to the extent the service information regulation is effective and operative, it would supercede any redundant service information requirements in the OBD II regulation.

V. REVISIONS TO DEMONSTRATION TESTING REQUIREMENTS

Some manufacturers have raised issues regarding the demonstration testing requirements in the OBD II regulation in light of recently adopted abridged certification procedures. The current regulation requires a manufacturer to provide OBD II-related emission test data from one certification durability vehicle per model year. With Executive Officer approval, a representative high mileage vehicle may be used instead of the certification durability vehicle. Manufacturers indicate that certification durability vehicles are not readily accessible to their OBD II engineering groups and that it is often difficult to obtain suitable high mileage vehicles for OBD II demonstration purposes prior to emission certification. In addition, new alternative durability programs (ADP) that simulate high mileage by bench aging only a few of the vehicle components reduce the number of actual high mileage vehicles available for OBD II demonstration testing. Further, the ARB has concerns regarding the effect the trend in industry toward consolidation of manufacturers will have on the representativeness of the relatively small number of demonstration vehicles. Consolidation reduces the number of

demonstration test vehicles that the ARB can select each year (one per manufacturer) although the number of different engine families/test groups remains much the same.

In considering these issues, the ARB proposes to increase the number of demonstration vehicles to be tested by a manufacturer each year. The required number of demonstration vehicles would vary from one to three depending on the total number of test groups a manufacturer plans to certify in a particular model year. Additionally, the proposal expands the required testing to include nearly all monitors calibrated by the manufacturer to indicate a fault prior to a prescribed tailpipe emission level (e.g., 1.5 times the FTP standards). However, to minimize the testing burden this places on manufacturers who are required to test more than one vehicle per year, the proposed regulation would allow manufacturers to use a less rigorous test procedure (e.g., internal 'sign-off' quality testing as opposed to official FTP test procedures) for some of the testing. Manufacturers would still be liable for meeting the emission thresholds if ARB conducted confirmatory testing using the official FTP test procedures. But the manufacturers would be able to save considerable time and resources during the certification process by using less rigorous, but still representative, test procedures.

To address industry's concern regarding the reduced availability of certification durability or appropriate high mileage vehicles, the staff is proposing that manufacturers be allowed to submit data from vehicles aged to high mileage with an approved ADP process. It should be noted, however, that even though the proposal would allow the OBD II system to be demonstrated on a simulated high mileage vehicle, manufacturers would remain liable for compliance with OBD II emission thresholds on vehicles in-use. For this reason, the ARB encourages manufacturers to continue to calibrate their OBD thresholds on high mileage vehicles where all components are deteriorated to some degree. Actual high mileage vehicles could result in relatively higher emissions when a single component fails than if a low mileage vehicle is used with only a couple of bench-aged components present. If a high mileage vehicle is not used during calibration, a manufacturer would likely need to allow more margin when determining its malfunction thresholds.

VI. REVISIONS TO CERTIFICATION REQUIREMENTS

A. Certification Application

At the time of adoption of the LEV II program, modifications to the certification, assembly-line, and in-use test requirements were also adopted. These modifications, known as CAP 2000²⁰, provide manufacturers with added control and flexibility in the certification process. Previously, certification procedures required manufacturers to submit all certification information prior to certification. Under CAP 2000, only the most essential certification information is required before Executive Officer approval is issued. The remainder of the information has to be submitted either by January 1st of the model year or upon request by the ARB, depending on the information. In developing the CAP

²⁰ Refer to title 13, CCR sections 2037, 2038, 2062, 2106, 2107, 2110, 2112, 2114, 2119, 2130, 2137, 2139, 2140, and 2143-2146.

2000 requirements, changes to the OBD II approval process and certification submittal requirements were also negotiated. The proposed regulation reflects changes to the number of applications required to be submitted each model year and the deadlines by which specific information must be submitted.

The proposal would allow manufacturers to establish OBD II groups consisting of test groups with similar OBD II systems and submit only one set of representative OBD II information from each OBD II group. The staff anticipates the representative information will normally consist of an application from a single representative test group. In selecting the representative test group, the manufacturer would need to consider tailpipe and evaporative emission standards, OBD II phase-in requirements (i.e., if a representative test group meets the most stringent monitoring requirements), and the exhaust emission control components for all the test groups within an OBD II group. For example, if one test group within an OBD II group has additional emission control devices such as secondary air or EGR, that test group should be selected as the representative test group. If one test group does not adequately represent the entire OBD II group, the manufacturer may need to provide information from several test groups within a single OBD II group to ensure the submitted information is representative.

The proposal would also require only the OBD II information necessary for certification evaluation of the OBD II systems to be submitted prior to certification. Requirements for the additional information currently required to be submitted at the time of certification have been modified to allow submittal by January 1 of the model year for some of the information and upon request by the ARB for other portions.

Lastly, the proposal would require manufacturers to submit a portion of the certification documentation in a standardized table format previously issued by the ARB in a mail-out regarding OBD II compliance guidelines (Mail-Out #95-20). In combination with the standardized table format, manufacturers would be required to use a common set of engineering units to simplify and expedite the review process by the ARB staff.

B. Model Year Designation for Certification

In the existing OBD II regulation, manufacturers of medium-duty vehicles that utilize engines certified on an engine dynamometer have additional flexibility in designating the appropriate model year (and thus, the requirements that the engine must be certified to). Specifically, engine manufacturers are allowed to determine the appropriate model year not based on the model year of the vehicle in which the engine is installed and sold but rather on the calendar year in which the engine was built. Originally, this requirement was to permit engine manufacturers to continue to build and certify engines on a calendar year basis rather than conforming to the conventional model year designations used by vehicle manufacturers (e.g., the introduction of new 2002 model year vehicles near the end of the 2001 calendar year). For engine manufacturers, this flexibility also makes it easier for them to sell the same engine to

numerous chassis or vehicle manufacturers no matter what model year the chassis or vehicle manufacturer will ultimately designate on the vehicle.

However, this additional flexibility has caused some confusion during certification as well as presents additional difficulty for the inclusion of medium-duty vehicles into the California Smog Check program. For instance, vehicle manufacturers of full-size pick-ups will typically have 2001 model year engines installed in trucks designated as 2002 model year vehicles and built before January 1, 2002. The same truck model built after January 1, 2002, will also be designated a 2002 model year vehicle but will have a 2002 model year engine installed. In situations where the certification requirements have substantially changed (e.g., lower emission standards, phase-in of other requirements, etc.), the two “versions” of the same vehicle are quite different. And, with California Department of Motor Vehicle (DMV) registration records as well as BAR records typically tied to the model year of the vehicle, not the engine, this can result in vehicles being tested to inappropriate standards. For example, when Smog Check inspections are performed, the standards (or in some cases, type of testing) are typically based on the model year of the vehicle, not the engine.

To avoid further confusion and simplify introduction into the Smog Check program, the proposed regulation would eliminate this flexibility for medium-duty vehicles beginning with the 2004 model year. From that time on, engines would be required to be certified to the OBD II requirements applicable to the designated vehicle model year. Like vehicle manufacturers, engine manufacturers would be required to phase-in new monitoring requirements with the same leadtime as provided for vehicle manufacturers. As the OBD II requirements only apply to engines installed in medium-duty applications, the requirements for engines produced for heavy-duty applications are unaffected. Likewise, since this change is only used for purposes of determining compliance with the OBD II monitoring requirements, all other certification requirements for engines (e.g., emission standards) would remain unaffected and would continue to be applied as they are currently.

VII. PRODUCTION VEHICLE EVALUATION AND VERIFICATION TESTING

A. Verification of Standardized Requirements

An essential part of OBD II systems is the numerous standardized requirements that manufacturers have to design to. These standardized requirements include items as simple as the location and shape of the diagnostic connector (where technicians can “plug in” to the on-board computer) to more complex subjects concerning the manner and format in which fault information is accessed by technicians via a “generic” scan tool. The importance of manufacturers meeting these standardized requirements is essential to the continued success of the OBD II program, since it would ensure access for all technicians to the stored information in the on-board computer in a consistent manner. The need for consistency is even higher now as states across the nation, including California, are moving towards implementation of OBD II into the I/M program (which relies on access to the information via a “generic” scan tool). In order for I/M

inspections to work effectively and efficiently, it is essential that all vehicles are designed *and built* to meet all of the applicable standardized requirements.

While the vast majority of vehicles are indeed complying with all of the necessary requirements, some problems involving the communication between vehicles and “generic” scan tools have occurred in the field. The cause of the problem can range from differing interpretations of the existing standardized requirements to oversights by the design engineers to hardware inconsistencies or last minute production changes on the assembly line. Due to some of these problems, EPA has proposed "special handling," or recommended procedures to be taken by I/M technicians, for a few makes and models of vehicles in an OBD II-based I/M program. To try and minimize the chance for such problems on future vehicles, the staff is proposing that manufacturers be required to test a sample of production vehicles from the assembly line to verify that the vehicles have indeed been designed and built to the required specifications for communication with a “generic” scan tool.

Under the proposal, manufacturers would be required to test one vehicle per software "version" released by the manufacturer to ensure it complies with some of the basic “generic” scan tool standardized requirements, including those that are essential for proper I/M inspection. With proper demonstration, manufacturers would be allowed to group different calibrations together and demonstrate compliance on a single vehicle. Such testing should occur early enough to provide manufacturers with early feedback of the existence of any problems and time to resolve the problem prior to the vehicles being introduced into the field.

To verify that all manufacturers are testing vehicles to the same level of stringency, the proposed regulation would require the vehicle manufacturers to get ARB approval of the testing equipment used by the manufacturer to perform this testing. ARB approval of the testing equipment would be based upon whether the equipment can verify that the OBD II system complies with the standardized requirements and will likely communicate properly with any off-board test equipment (e.g., generic scan tools) that is also designed to meet the standardized requirements. Staff anticipates that the vehicle manufacturers and scan tool manufacturers will likely develop a common piece of hardware and software which could be used by all vehicle manufacturers at the end of the assembly line to meet this requirement. In fact, both SAE and ISO have workgroups considering the development of standards for such equipment. This "gold standard" equipment would be designed exactly to the applicable SAE and ISO specifications for “generic” scan tools and would serve as a "check-valve" at the end of assembly line. Consistent with the proposal to eliminate all protocols except one (CAN) by the 2008 model year, this testing will only be required on 2005 and subsequent model year vehicles using CAN as the generic communication protocol.

It is important to note, however, that this "gold standard" equipment would not replace the function of existing “generic” scan tools used by technicians or I/M inspection stations. This equipment would be custom designed and used expressly for the purposes of this assembly line testing and would not include all of the necessary

features for technicians or I/M inspectors. While this verification testing would not completely eliminate the chance for problems in the field, it would be expected to greatly reduce the number of problems that dictate "special" handling in an I/M test.

B. Verification of Monitoring Requirements

The OBD II regulation requires comprehensive monitoring of virtually every component on the vehicle that can cause an increase in emissions. To accomplish this task, manufacturers develop sophisticated diagnostic routines and algorithms that are programmed into software in the on-board computer and calibrated by automotive engineers. This translates into thousands of lines of software programmed to meet the diagnostic requirements but not interfere with the normal operation of the vehicle. While most manufacturers have developed extensive verification or "sign-off" test procedures to ensure that the diagnostics function correctly, problems can and do happen. Moreover, many times the majority of this validation testing is focused on finding problems that will cause the MIL to falsely illuminate when no malfunction really exists rather than verifying that the MIL will indeed illuminate when a malfunction does exist.

The problems that occur can vary greatly in severity from essentially trivial mistakes that have no noticeable impact on the OBD II system to situations where significant portions of the OBD II system and normal vehicle fuel and emission control system are disabled. Furthermore, it is often very difficult to assess the impact the problem may or may not have on vehicles that will be on the road for the next 10-30 years. The cause of the problems can also vary from simple typing errors in the software to carelessness to unanticipated interactions with other systems or production or component supplier hardware changes.

In an attempt to minimize the chance for significant problems going undetected and to ensure that all manufacturers are devoting sufficient resources to verifying the performance of the system, the staff is proposing that manufacturers be required to perform a thorough level of validation testing on one to three actual production vehicles per model year and submit the results to ARB. Manufacturers would be required to individually implant or simulate malfunctions to verify that virtually every single diagnostic on the vehicle correctly identifies the malfunction. The testing would be required to be completed and reported to ARB within 120 days after a manufacturer begins full-scale production to provide early feedback on the performance of every diagnostic on the vehicle. As an incentive to perform this thorough testing, a manufacturer could request that any problem discovered during this self-testing be evaluated as a deficiency. In contrast, problems discovered later by the ARB staff during in-use testing would become noncompliance issues and handled in accordance with the proposed OBD II-specific enforcement regulation (discussed in detail in section XIII of this report).

C. Verification and Reporting of In-use Monitoring Performance

The staff is proposing that manufacturers track the performance of several of the most important monitors on the vehicle to determine how often they are executing during in-use operation. These requirements are discussed in more detail in section IX. Essentially, the proposed regulation would standardize a method for measuring and determining how often monitors are executing in the real world and set a minimum acceptable performance level. Monitors that perform below the acceptable levels would be subject to remedial action including potential recall.

In conjunction with the proposal to measure in-use monitoring frequency, the staff is also proposing that manufacturers be required to collect this in-use data during the first six months after production begins. This information would provide the ARB with early indication as to whether or not the system is performing adequately. Manufacturers would be required to submit frequency data from a sample of at least 30 vehicles that are representative of California driving. Before acquiring this data, manufacturers would be required to gain ARB approval of the manufacturer sampling plan to assure the data collected would be representative, as judged by the ARB staff. This would allow each manufacturer to identify the most cost-effective way to obtain the data. Some manufacturers may find it easiest to collect data from vehicles that come in to its dealerships for routine maintenance or warranty work during the initial six months, while others may find it more advantageous to hire a contractor to collect the data. Further, upon good cause, the Executive Officer may extend the time period for the collection of data from six months to one year to cover situations where manufacturers have difficulty in gathering the required data in the first six months.

The data collected in this program is not intended to be a substitute for testing performed by the ARB to determine if a manufacturer is complying with the minimum acceptable performance levels established in the OBD II regulation. In fact, the data collected under this program would not likely meet all the required elements for testing by ARB to make an official determination that the system is noncompliant. Rather, this data is primarily intended to provide an early indication that the systems are working as intended in the field and provide information to "fine-tune" (if necessary) the proposed requirements for tracking the performance of monitors.

VIII. DEFICIENCIES

One important aspect to the success of the OBD II program so far is the allowance for deficiencies. Originally adopted in 1993, this allows manufacturers who make a good-faith attempt to design compliant systems but fall short of one or more of the requirements to still certify vehicles for sale. To prevent manufacturers from abusing the deficiency allowance by using it for product planning purposes or subjecting the OBD II system to cost-cutting efforts just to avoid monitoring, several criteria have been established: (1) to qualify for a deficiency, manufacturers are required to demonstrate that a good-faith effort was made to comply with the requirements in full; (2) limitations have been set on how many model years a manufacturer may "carry-over" the deficiency before it has to be corrected; and (3) manufacturers are subject to fines for every vehicle built with more than two deficiencies.

The current requirements allow two "free" deficiencies through 2003 before dropping to one "free" deficiency thereafter. As can be expected, the deficiency provisions were used most often in the early model years of OBD II implementation. However, as new OBD II requirements have been continually added or phased-in and as tailpipe emission standards continue to go lower, manufacturers continue to occasionally encounter situations where deficiencies are needed.

To address this, the staff is proposing to continue indefinitely the existing provisions that allow two "free" deficiencies before vehicles and manufacturers are subject to fines. The existing fine structure, qualifications for a deficiency, and limitations on carry-over would continue to apply.

The proposed regulation would modify the existing deficiency provisions in section 1968.1 of title 13, CCR to clarify that deficiencies, with one exception, are only available prior to certification and cannot be applied retroactively (e.g., if a problem is discovered later in the field, etc.). The exception allows manufacturers that discover a problem within the first four months after production begins to apply for a deficiency retroactive to the start of production. All of the other deficiency qualifications (e.g., good faith effort, etc.) would still have to be met in addition to the manufacturer demonstrating that the problem could not have reasonably been anticipated. This should provide additional incentive to manufacturers to more thoroughly test production vehicles and inform the ARB of any identified problems discovered during this testing rather than gamble on whether or not the problem may be discovered later by ARB during in-use testing.

The proposed regulation would also clarify that carry-over of deficiencies would not be automatically granted. As mentioned above, one of the primary qualifications necessary to receive a deficiency is a demonstration of a good faith effort by the manufacturer to meet the requirements in full. As part of this good faith effort, ARB takes into account the manufacturer's efforts to remedy the deficiency in a timely manner. Accordingly, manufacturers would only be allowed to carry-over deficiencies when the situation warrants the additional time.

Lastly, the proposed deficiency provisions would explicitly prohibit the Executive Officer's authority to grant a deficiency in some situations. As discussed in more detail in section XIII, the proposed enforcement test procedures would mandate the recall of the most serious nonconforming OBD II systems (section 1968.5(c)(3)(A)). Accordingly, the proposed regulation would specifically prohibit the granting of a deficiency in situations where a recall would be subsequently mandated under the proposed enforcement test procedures.

IX. A STANDARDIZED METHOD TO MEASURE REAL WORLD MONITORING PERFORMANCE

A. Background

In designing an OBD II monitor, manufacturers must define enable conditions that bound the vehicle operating conditions where the monitor will execute and make a judgment as to whether a component or system is malfunctioning. Manufacturers must design these enable conditions so that the monitor is: (a) robust (i.e., accurately making pass/fail decisions), (b) running frequently in the real world, and, (c) in general, also running during an FTP emission test. If designed incorrectly, these enable conditions may be either too broad and result in inaccurate monitors, or overly restrictive and prevent the monitor from executing frequently in the real world. While the vast majority of manufacturers have been successful in designing monitors that meet all three goals, a few have not. Additionally, some manufacturers have asked for increased specificity as to how frequently monitors are required to run in the real world. Since the primary purpose of an OBD II system is to continuously monitor for and detect emission-related malfunctions while the vehicle is operating in the real world, a standardized methodology for quantifying real world performance would be beneficial to both the ARB and vehicle manufacturers. Furthermore, it would better ensure that all manufacturers are held to the same standard for real world performance. Lastly, while the current OBD II regulation requires monitoring to occur frequently during real world driving, it does not explicitly state a minimum acceptable monitoring frequency. In-use testing conducted by the ARB has indicated that some manufacturers have designed systems with excessively restrictive enable conditions preventing routine execution of the monitors. Accordingly, the staff believes it is necessary to propose procedures that will ensure that monitors operate properly and frequently in the field.

Staff is therefore proposing that all manufacturers be required to use a standardized method for determining real world monitoring performance and hold manufacturers liable if monitoring occurs less frequently than a minimum acceptable level, expressed as minimum acceptable in-use performance ratio. The proposed amendments would also require manufacturers to implement software in the on-board computers to track how often several of the major monitors (i.e., catalyst, oxygen sensor, exhaust gas recirculation, secondary air, and evaporative system) execute during real world driving. The on-board computer would keep track of how many times each of these monitors has executed as well as how often the vehicle has been driven. By measuring both these values, the ratio of monitor operation relative to vehicle operation can be calculated to determine monitoring frequency.

The proposed requirements would establish a minimum acceptable frequency that was derived from a two week time period. More specifically, a monitor that can illuminate the MIL in less than two weeks of driving after a malfunction occurs would meet the minimum frequency requirement. As stated before, the vast majority of manufacturers have been able to successfully design compliant OBD II monitors for the past five years and, as such, the proposed minimum acceptable frequency should be consistent with the performance of most of the current monitors. For those manufacturers that are unsuccessful, however, the proposal would likely make it easier for the ARB to identify problematic monitors.

The proposed minimum acceptable frequency requirement would apply to many of the OBD II system monitors. Currently, most monitors are required to operate either continuously (e.g., all the time) or “once-per-driving-cycle” (e.g., once per driving event). For components or systems that are more likely to experience intermittent failures or failures that can routinely happen in distinct portions of a vehicle’s operating range (e.g., only at high engine speed and load, only when the engine is cold or hot, etc.), monitors are required to be continuous. Examples of continuous monitors include the misfire monitor, fuel system monitor, and most electrical/circuit continuity monitors. For components or systems that are less likely to experience intermittent failures or failures that only occur in specific vehicle operating regions or for components or systems where accurate monitoring can only be performed under limited operating conditions, monitors are required to be run “once per driving cycle”. Examples of “once-per-driving-cycle” monitors include catalyst monitors, EGR system monitors, and evaporative system leak detection monitors.

Monitors that run continuously, by definition, will always be running and a minimum frequency requirement is unnecessary. The new frequency requirement would essentially apply only to those monitors that were previously designated as “once-per-driving-cycle”. For all of these monitors, manufacturers will be required to define monitoring conditions that ensure adequate frequency in-use. Specifically, the monitors will need to run often enough that the measured monitor frequency on in-use vehicles would exceed the minimum acceptable frequency. However, even though the minimum frequency requirement would apply to nearly all “once-per-driving-cycle” monitors, manufacturers would only be required to implement software to track and report the in-use frequency for a few of the major monitors. These few monitors generally represent the most critical emission control components and the most difficult to run monitors. Standardized tracking and reporting of only these monitors should, therefore, provide sufficient indication of monitoring performance.

In order to ensure that a standardized methodology is used by the ARB and manufacturers to determine if this level of performance is met, the proposed amendments would also include a test procedure to be used for compliance testing of real world vehicles. This test procedure would identify how vehicles are selected, how many vehicles are selected, how the data are gathered, and what criteria are used to analyze the data and make a determination. The test procedure would ensure that a sufficient number of cars are sampled to accurately determine if vehicles do or do not comply with the minimum acceptable frequency.

B. Detailed description of software counters to track real world performance

As stated above, manufacturers would be required to track monitor performance by counting the number of monitoring events (i.e., how often each diagnostic has run) and the number of vehicle driving events (i.e., how often has the vehicle been operated). The ratio of the two would give an indication of how often the monitor is operating relative to vehicle operation. Thus:

$$\text{In - Use Performance (Ratio)} = \frac{\text{Number of Monitoring Events (Numerator)}}{\text{Number of Driving Events (Denominator)}}$$

To ensure all manufacturers are tracking performance in the same manner, the proposed amendments include very detailed requirements for defining and incrementing both the numerator and denominator of this ratio. Manufacturers would be required to keep track of separate numerators and denominators for each of the major monitors, and to ensure that the data are saved every time the vehicle is turned off. The numerators and denominators would be reset to zero only in extreme circumstances when the non-volatile memory has been cleared (e.g., when the on-board computer has been reprogrammed in the field, when the on-board computer memory has been corrupted, etc.). The values would not be reset to zero during normal occurrences such as when fault codes have been cleared or when routine service or maintenance has been performed.

Further, the numerator and denominator would be structured such that the maximum value each can obtain is 65,535, the maximum number that can be stored in a 2-byte location, to ensure manufacturers allocate sufficient memory space in the on-board computer. If either the numerator or denominator for a particular monitor reaches the maximum value, both values for that particular monitor will be divided by two before counting resumes. In general, the numerator and denominator would only be allowed to increment a maximum of once per driving cycle because most of the major monitors are designed to operate only once per driving cycle. Additionally, incrementing of both the numerator and denominator for a particular monitor would be disabled (i.e., paused but the stored values would not be erased or reset) only when a fault has been detected (i.e., a pending or confirmed code has been stored) that prevents the monitor from executing. Once the fault is no longer detected and the pending fault code is erased, either through the allowable self-clearing process or upon command by a technician via a scan tool, incrementing of both values would resume.

To handle many of these issues, staff has been and continues to work with industry and SAE to develop standards for storing and reporting the data to a generic scan tool. This would also help ensure that all manufacturers report the data in an identical manner and thus help facilitate data collection in the field.

1. Number of monitoring events (“numerator”)

For the numerator, manufacturers would be required to keep a separate numeric count of how often each of the particular monitors has operated. However, this is not as simple as it may seem. More specifically, manufacturers would have to implement a software counter that increments by one every time the particular monitor meets all of the enable/monitoring conditions for a long enough period of time such that a malfunctioning component would have been detected. For example, if a manufacturer requires a vehicle to be warmed-up and at idle for 20 seconds continuously to detect a malfunctioning catalyst, the catalyst monitor

numerator can only be incremented if the vehicle has actually operated in all of those conditions simultaneously. If the vehicle is operated in some but not all of the conditions (e.g., at idle but not warmed-up), the numerator would not be allowed to increment because the monitor would not have been able to detect a malfunctioning catalyst unless all of the conditions were simultaneously satisfied.

Another complication is the difference between a monitor reaching a “pass” or “fail” decision. At first glance, it would appear that a manufacturer should simply increment the numerator anytime the particular monitor reaches a decision, be it “pass” or “fail”. However, many monitoring strategies have a different set of criteria that must be met to reach a “pass” decision versus a “fail” decision. As a simple example, a manufacturer may appropriately require only 10 seconds of operation at idle to reach a “pass” decision but require 30 seconds of operation at idle to reach a “fail” decision. Manufacturers would only be allowed to increment the numerator if the vehicle was at idle for 30 seconds even if the monitor actually executed and reached a “pass” decision after 10 seconds. This is necessary because the primary function of OBD II systems is to detect malfunctions (i.e., to correctly reach “fail” decisions, not “pass” decisions), and thus, the real world ability of the monitors to detect malfunctions is the parameter that needs to be measured. Therefore, monitors with different criteria to reach a “pass” decision versus a “malfunction” decision would not be able to increment the numerator solely on the “pass” criteria being satisfied.

It is imperative that manufacturers implement the numerators correctly to ensure a reliable measure for determining real world performance. “Overcounting” would falsely indicate the monitor is executing more often than it really is, while “undercounting” would make it appear as if the monitor is not running as often as it really is. Manufacturers would be required to demonstrate the proper function of the numerator incrementing strategy to the ARB prior to certification, and to verify the proper performance during production vehicle evaluation testing. Additionally, the ARB plans to conduct in-use testing to verify performance in the field.

2. Number of driving events (“denominator”)

The proposed amendments would also require manufacturers to separately track how often the vehicle is operated. In the simplest of terms, the denominator would be a counter that increments by one each time the vehicle is operated.

There has been considerable discussion with industry concerning a standardized definition for vehicle operation to ensure all manufacturers increment the denominator in the exact same way. The ARB originally proposed a simple definition where the denominator would be incremented every time the vehicle is started (e.g., ignition key on, engine speed > 400 rpm for one second, etc.). This is often referred to as “key-starts” or “ignition cycles”. While this is the most basic measure of vehicle operation and would ensure all vehicle operation is counted in the denominator, it does not exclude data from some extremely short trips (e.g.,

repeated engine start and immediate shut-down events, re-parking from garage to driveway events, etc.) or trips at extreme conditions (e.g., above 8000 feet in elevation, ambient temperature below 20 degrees Fahrenheit, etc.), when most monitors are legitimately disabled or have little chance of completing.

Industry, on the other hand, suggested the use of a definition that “filters out” these particular driving events. It proposed the denominator only be incremented when certain criteria are met that indicate the vehicle was operated in a manner that should have allowed most monitors to run. The proposed “filtered” denominator includes a minimum trip length of 10 minutes, a minimum of 5 minutes at vehicle speeds above 25 mph, at least one continuous idle of 30 seconds or longer, ambient temperature between 20-100 degrees Fahrenheit, and an altitude less than 8000 feet. Additionally, industry proposed the use of separate denominators for each of the specific monitors and some additional criteria for the secondary air monitor and evaporative system monitor denominators.

Despite the added complexity involved with industry’s proposal, staff concurs with industry that the “filter” denominator definition should provide more meaningful data. Thus, the proposed requirements, including the calculation of the minimum acceptable in-use performance ratio, are structured around industry’s proposed definition of a “filtered” denominator. However, to ensure that the dynamics of this “filtering” are accurately understood, the staff is proposing that manufacturers be required to implement both the ARB’s definition for an ignition cycle counter and the industry’s definition for a “filtered” denominator. This would allow data to be collected during the first few years of implementation, which would be used to better quantify how often the “filtered” denominator occurs in the real world. The data collected would provide valuable information needed to “fine-tune” the minimum acceptable in-use performance ratio to closely agree with the design target of a malfunction indication in two weeks for the majority of the people.

C. Proposed standard for the minimum acceptable in-use performance (“ratio”)

Determining how frequent is “frequent enough” for monitors to operate is a complex task that requires consideration of several different factors, including the technical capability of OBD II systems, the severity of the malfunction, the consequences of delayed detection and repair of the malfunction, and expected driving patterns and habits. The proposed amendments would attempt to simplify this task by specifying a minimum acceptable monitoring frequency in a quantifiable format, known as the minimum acceptable in-use performance ratio. In establishing the appropriate value for this ratio, the factors listed above were considered as well as the monitoring frequency of typical current monitors and estimated consumer response/reaction in responding to detected malfunctions.

Industry in general supports a lower monitoring frequency than the ARB deems adequate. Some in industry believe that since the biennial Inspection and Maintenance (I/M) program, also known as Smog Check, is the only real mechanism that requires OBD II-related repairs to be made, consumers will tend to ignore MILs when they

illuminate and will only be inclined to get these repairs done just prior to such inspections. For that reason, they suggest that having OBD II monitors run at a lower frequency (e.g., once every two years) is sufficient, since the air quality benefits are not fully realized until repairs are done. However, OBD II is not designed solely as a replacement for the current biennial I/M program, but to ensure that vehicles meet the increasingly stringent tailpipe and evaporative standards throughout their entire lives. If the OBD II monitors do not run frequently and emission-related malfunctions are not readily corrected, the emission benefits of the Low Emission Vehicle II program would not be met. In fact, the results of a recent survey showed that at least 50 percent of consumers would contact a dealer or a mechanic in response to an illuminated MIL, and that only five percent of consumers would ignore the MIL.²¹ In other words, the findings suggest that consumers are more likely to readily respond to illuminated MILs and get their vehicles repaired rather than ignore the MIL until forced to repair it at a later date. Further, the interaction of monitored components is such that “failure of one component will more than likely have a noticeable adverse effect on engine performance, forcing the vehicle owner to bring the car or truck in for service”.²²

Taking this and other factors into account, the ARB staff has set the proposed minimum acceptable in-use performance ratio to ensure that most monitors would be capable of detecting malfunctions within two weeks for the vast majority of drivers. While most monitors only require a day or two to detect a malfunction, when real world variability in driving habits is factored in, it is reasonable to expect that essentially all drivers would have encountered enough driving within two weeks to execute the monitors and allow for detection of a malfunction. This should provide a reasonable time for drivers to cover the majority of their particular driving patterns (e.g., weekday commuting, errands, weekend excursions, etc.). As such, the proposed amendments would define a minimum acceptable in-use performance ratio that was derived from in-use driving data to try and ensure a malfunction is detected within two weeks for 90 percent of the population. By deriving the minimum ratio around “90 percent of the population” instead of “100 percent”, manufacturers would not be held liable for vehicles operated in extremely unique or rare manners, and the ARB would not have to accept a minimum ratio that is extremely low to account for these last/remaining 10 percent of vehicles. Additionally, as a reminder, the in-use performance ratio only accumulates data when the vehicle has been operated on trips that meet the filtered trip definition (e.g., longer than ten minutes and within certain ambient temperature regions). This further limits (or essentially eliminates) manufacturers’ liability for vehicles that are operated very infrequently, primarily on trips shorter than ten minutes, or during extreme ambient temperatures.

1. Frequent monitoring is important

²¹ From the “Human Factors Research” study conducted by the National Center for Vehicle Emissions Control and Safety (NCVECS). More information can be found on Colorado State University’s OBD II Research Center website at www.obdiicsu.com.

²² From “What The Heck’s The Problem”, Xpressions, DaimlerChrysler Corporation’s Trade Magazine for Aftermarket Professionals, November/December 2001.

As stated before, it is important that monitors run frequently to ensure early detection of emission-related malfunctions and, consequently, maintain low emissions. Allowing malfunctions to continue undetected, and thus go without repair, for long periods of time allows emissions to increase unnecessarily. In other words, the sooner the emission-related malfunction is detected and fixed, the fewer the excess emissions that are generated from the vehicle.

Frequent monitoring can also help assure that intermittent emission-related faults (i.e., faults that are not continuously present, but occur for days and even weeks at a time) are detected. The nature of mechanical and electrical systems is that intermittent faults can and do occur, and the less frequent the monitoring, the less likely these faults will be detected and repaired. Additionally, for both intermittent and continuous faults, earlier detection is equivalent to preventative maintenance in that the original malfunction can be detected and repaired prior to it causing subsequent damage to other components. This can help consumers avoid more costly repairs that would have resulted had the first fault gone undetected.

2. Two weeks is the appropriate standard

Industry has questioned the basis for setting the in-use performance ratio based on a time period of two weeks to illuminate the MIL, arguing that a longer time period, such as four weeks, would be just as sufficient from an air quality standpoint. However, as identified above, the emission benefit is only one of the factors that must be considered in determining how often monitors should run. Additional factors were considered in determining the appropriateness of the proposed in-use performance ratio, including the typical capability of current monitoring strategies, the effectiveness of the requirement in assuring all vehicles achieve some acceptable level of monitoring in-use, and the impact on the service and repair industry as well as vehicles owners.

Regarding the impact on the service and repair industry, monitors that have unreasonable or overly restrictive enable conditions (i.e., that are unlikely to detect a malfunction and illuminate the MIL within two weeks) could hinder vehicle repair services. In general, upon completing an OBD II-related repair to a vehicle, a technician will attempt to verify that the repair has indeed fixed the problem. Specifically, a technician will ideally operate the vehicle in a manner that will exercise the appropriate OBD II monitor and allow the OBD II system to confirm that a malfunction is no longer present. This affords a technician the highest level of assurance that the repair was indeed successful.

However, if OBD II monitors operate infrequently and are therefore difficult to exercise, technicians may not be able (or may not be likely) to perform such testing. Despite current and pending U.S. EPA and ARB service information regulations that require manufacturers to make all of their service and repair information available to all technicians, including the information necessary to exercise OBD II monitors, technicians will have difficulty in exercising monitors that require infrequently

encountered vehicle operating conditions (e.g., abnormally steady constant speed operation for an extended period of time). Furthermore, this information and the time required by the technician to perform this verification are not free. Ultimately, vehicle owners pay for this information and labor time through their repair bills. Additionally, to execute OBD II monitors in an expeditious manner or to execute monitors that require unusual or infrequently encountered conditions, technicians may be required to operate the vehicle in an unsafe manner (e.g., at freeway speeds on residential streets or during heavy traffic, etc.). If unsuccessful in executing these monitors, technicians may even take shortcuts in attempting to validate the repair while maintaining a reasonable cost for consumers. These shortcuts, however, will likely not be as thorough in verifying repairs and could increase the chance for improperly repaired vehicles being returned to the vehicle owner or additional repairs being performed just to ensure the problem is fixed. In the end, monitors that operate less frequently can result in unnecessary increased costs and inconvenience to both vehicle owners and technicians.

While technicians (and/or consumers) may elect not to spend the additional time and money to validate a routine repair, repairs made in the context of passing an I/M (Smog Check) test require this validation. For an OBD II-based I/M inspection, the driver or technician must exercise the OBD II monitors and verify that the repairs are successful before the inspection can be performed. This is because this inspection requires specific internal flags in the OBD II system known as readiness flags to be set before the vehicle can pass the inspection. These flags would only set upon each of the major OBD II monitors executing and completing at least once since the last time fault codes were erased. Vehicles failed during an I/M inspection (due to the presence of a malfunction) are required to have malfunctions repaired (and thus, fault codes cleared) before returning for re-testing to verify the repairs. If OBD II monitors are incapable of executing frequently and verifying repairs in a timely manner, technicians would have a difficult time preparing a vehicle for re-inspection or would be able to do so only with considerable effort, and thus, at considerable cost to the vehicle owner. With especially troublesome monitors, vehicle owners may have to wait several weeks or months before the repair is verified, the readiness flag is set by the OBD II system, and the vehicle can be re-inspected at the I/M station.

In contrast, monitors that function frequently would be easier for technicians and even vehicle owners to exercise. Clearly, monitors that function infrequently would subject vehicle owners to unnecessary delays and/or increased repair costs that would hinder the effectiveness and efficiency of the I/M program. The proposed standard of two weeks for the majority of vehicles would ensure that monitors run in just a few days for the average driver and no longer than two weeks for the vast majority of drivers. Given the common practice of consumers taking their vehicle in for inspection shortly before their registration expires, even slightly less frequent standards such as four weeks would have a substantial impact on the I/M program. Such reduced frequency would lengthen the period of time required between completion of repair and re-inspection (which is necessary to complete their

registration renewal) resulting in registration delays and/or additional costs to consumers.

Based on the current performance of OBD II monitors, most manufacturers should already be able to meet the proposed in-use performance ratio. Since the beginning of the OBD II program, staff has periodically tested vehicles to verify compliance with the OBD II requirements. Staff has compiled these in-use testing data and investigated the frequency at which current OBD II monitors are performing. The data were collected from a total of 29 different 1997-2002 model year vehicles from various manufacturers that were operated by the ARB staff in their normal commute, evening, and weekend driving. The results, which are displayed in the table below, consist of the average number of days it took for a particular monitor to execute (“Avg. days/monitor execution”) and, consequently, the average number of times the MIL would illuminate every two weeks (“Avg. MILs/two-weeks”).²³

Monitor	Avg. days /monitor execution	Avg. MILs/two-weeks for 90% of drivers	Avg. MILs/two-weeks for 50% of drivers
Equivalent Result for Proposed Minimum In-use Performance Ratio	-	≥1.00	≥1.00
Oxygen Sensor	1.32	5.31	-
Catalyst	1.64	4.26	-
Exhaust Gas Recirculation (EGR)	1.23 (1.75)*	5.71 (4.00)*	-
Secondary Air	1.75	-	4.00
Evaporative System (0.020 inch leak)	2.34	-	2.99

* Two sets of data were available for the EGR monitor: the first set was for those reaching “pass” decisions, and the second set (in parenthesis) was for those reaching “fail” decisions.

While these data are not proof that all current monitors will meet the required ratio, they do indicate that many monitors, when tested by the staff, operated three to five times more frequently than the ratio proposed by the staff. Again, these data are not intended to be representative of actual population sample data, but rather to show that current OBD II monitors exist that are very likely able to meet the ARB’s proposed ratio. Further, these data were collected for some of the “major” monitors that generally involve some of the most restrictive enable criteria (i.e., are the

²³ The “Avg. MILs/two-weeks” values were calculated based on the fact that most monitors require two trips (i.e., monitor executions) to make a decision.

hardest to run). Many of the other monitors that would be required to meet the in-use ratio use much simpler and broader enable criteria (i.e., easier to run) and would easily meet the minimum ratio.

Two weeks is also appropriate because monitoring frequency can depend to some extent on vehicle operator habits. Two drivers with identical vehicles may have entirely different driving habits and patterns, which can affect how often some monitors run. And directionally, the less frequently that monitoring occurs, the higher the risk that some drivers may rarely or even never get a monitor to run. In fact, by establishing the requirements around the time it takes most drivers (i.e., 90 percent) to detect a malfunction, a portion of the population is already excluded (or, allowed to have a much lower monitoring frequency). For these vehicles, it is possible that monitoring may rarely, if ever, operate. To minimize the potential for this to happen, it is essential that monitoring occur frequently on the majority of vehicles so that even vehicles that are not part of the “majority” would still have some level of monitoring during in-use driving. A further reduction in monitoring frequency would not only increase the time it takes for most drivers to detect a malfunction but would increase the likelihood that a portion of the population would never get certain monitors to run.

During discussions, some manufacturers have indicated a concern that an increase in monitoring frequency would result in an increase in false MILs (e.g., the MIL inappropriately illuminating when no malfunction is present). They contend that forcing monitors to run under broader conditions (to ensure adequate in-use performance) would result in decreased accuracy. However, the data compiled by the staff, and as seen in the table above, indicate that many current monitors are likely already operating on a more frequent basis than the ARB’s proposed minimum in-use performance requirement. Further, the data are from actual monitors put into production by vehicle manufacturers -- monitors that would not have been put into production if they had “false MIL” problems from running so frequently. As a reminder, the proposed in-use performance requirement is not intended to force all manufacturers to design more frequent monitors, but rather to adopt an objective standard and an easier way to identify monitors that are operating unnecessarily infrequently during in-use driving. It is expected that the majority of monitors for most manufacturers would not require any changes to meet this requirement.

3. Derivation of the minimum ratio values

For purposes of defining an appropriate minimum in-use performance ratio for monitors, the ARB staff analyzed in-use driving data known as the Tri-City database, which was used as a representative collection of driver habits (for detailed analyses of the Tri-City database, refer to Appendix IV and V of the staff report). This database, which was initiated by the U.S. EPA, consisted of collecting data of driving habits from three different cities by equipping vehicles with equipment that logged time, engine speed, and vehicle speed. Using this database, analysis was carried out that derived the minimum in-use performance ratio necessary to ensure monitors completed for most drivers in two weeks.

Working with the manufacturers, a definition for the denominator of the ratio was developed to measure vehicle activity (referred to hereafter as “filtered trips” or “f-trips”). Then, from the data, the distribution of vehicle activity was analyzed to determine how often vehicles encountered “f-trips” (i.e., trips meeting the denominator criteria). The distribution of vehicle activity was calculated and found to have a mean of 1.79 f-trips per day with a standard deviation of 1.11.

Populations of vehicles with different mean ratios were then modeled to determine what minimum ratio was necessary to ensure 90 percent of the vehicles would detect a malfunction within two weeks time. From the analysis, a mean ratio of 0.336 was found to be the minimum acceptable ratio that would ensure 90 percent of the vehicles would detect a malfunction within two weeks.

Though the minimum acceptable in-use performance ratio calculated above (i.e., 0.336) is appropriate for most monitors, it may not be appropriate for monitors that are more dependent on ambient conditions or cold starts (i.e., engine starts after the vehicle has been shut-off for more than six to eight hours) such as the secondary air system and 0.020 inch and 0.040 inch evaporative system monitors. For these monitors, a cold start is usually essential for accurate detection. Further, ambient temperatures and seasonal changes can have a more significant impact on how often these monitors function, especially the 0.020 inch evaporative system monitor. To eliminate manufacturers’ liability for the large discrepancies between vehicles operated in various regions of the state (e.g., Palm Springs, Lake Tahoe, etc.), it is appropriate to modify the denominator (or measure of vehicle activity) for these monitors. As such, further “filtering” of the denominator is done by only counting vehicle trips that meet certain cold start criteria and occur during more restricted ambient conditions (i.e., between 40 and 95 degrees Fahrenheit).

Lastly, because of the larger ambient temperature and driver habit (e.g., cold starts) influence on these monitors, an accurate ratio can only be calculated if there is a high level of confidence in the representativeness of the in-use driving data. While the Tri-City database is the best existing database available to staff for vehicle activity, it does have limitations because it was generated from a rather small number of vehicles (~200) over a fairly short time (~ one week of data per car). To account for the larger impact of driver habits and ambient temperatures on these two monitors, the minimum ratio was conservatively derived to ensure that a malfunction is detected within two weeks for 50 percent of the drivers instead of 90 percent. This substantially reduces the minimum monitoring frequency for these monitors, effectively providing manufacturers a significantly higher margin of error for these more difficult monitors.

Following the methodology outlined above, the minimum ratio for secondary air and 0.020 inch leak detection evaporative system monitors was found to be 0.260. However, 0.040 inch leak detection evaporative system monitors (which were completely phased-in by the 1998 model as opposed to the 2003 model year for 0.020 inch monitors), have undergone significant improvements and most run much

more frequently than 0.020 inch monitors. In fact, these systems usually run much more than twice as often as the 0.020 inch monitors. This increased frequency is essential to help quickly identify large leaks in the evaporative system (such as disconnected hoses, missing gas caps, etc.) that have substantial emission impacts. In accordance with the less restrictive monitoring conditions used by manufacturers for 0.040 inch monitors and the very conservative ratio established for 0.020 inch monitors, the proposed requirements establish an 0.040 inch monitor minimum ratio of 0.520 (exactly double that of an 0.020 inch monitor). It is also important to remember that this does not mean that the 0.040 inch monitor has to operate on half of all driving cycles. The denominator in the ratio simply represents a measure of vehicle activity and is not incremented on every key start. In fact, the denominator is not even incremented on every cold start (the condition most 0.040 inch monitors require). It is expected that the 0.040 inch monitor will often complete (and increment the numerator of the ratio) on many trips that do not also meet the denominator criteria. This will result in the numerator being incremented much more frequently than the denominator and should be consistent with the monitoring frequency of many 0.040 inch monitors today. As more data become available during the first few years of implementation, staff will revisit the calculated minimum frequency and modify it accordingly to ensure sufficient monitoring frequency for these monitors.

4. Manufacturers can design a system to comply with the in-use performance ratio

Some manufacturers have questioned how they would be able to confirm compliance with the in-use performance requirement. More specifically, they wanted to know what methodology or test procedure they would need to conduct to verify that the minimum in-use performance ratio is met or exceeded, if it is at all possible. The ARB staff believes that such confirmation is achievable and would not require much deviation from current practices used by the manufacturers.

With the establishment of a standardized ratio and defined measure of monitor frequency, manufacturers can develop a test procedure that specifically assesses the performance of monitors. Currently, manufacturers conduct testing over various cycles to simulate emissions on high-mileage vehicles in order to verify compliance with the tailpipe and evaporative emission standards. By developing test cycles that simulate “real world” driving, manufacturers can evaluate the frequency of monitor operation. In fact, manufacturers likely already have such driving cycles used for assessing driveability, durability, and OBD II or other emission control system performance.

Additionally, because OBD II monitors have been required to operate in-use from the start of the OBD II program in 1994, manufacturers already have a level of investigative experience regarding the frequency with which their monitors perform. Manufacturers have been making design decisions and improvements based on test findings of in-use performance, among other factors. By testing the monitors that have the most restrictive enable criteria, manufacturers would be able to use

engineering analysis to determine the monitoring frequency for monitors that have less restrictive enable conditions. For many monitors, the enable conditions required to execute them may be so broad (i.e., would result in very frequent execution of the monitors during in-use driving) that this kind of validation testing would not even be needed.

Even today, most manufacturers (if not all) already perform some sort of OBD II verification testing that includes operation of vehicles in-use by various drivers in all different kinds of environmental conditions (e.g., temperature, altitude, etc). Manufacturers also perform exhaustive testing under a vast array of driving conditions and patterns to ensure adequate driveability and OBD II system performance. When a manufacturer identifies inadequate performance (be it insufficient frequency of monitoring, inaccurate monitoring results, etc.), calibration or design changes are made to improve the system performance to acceptable levels. The proposed requirements would not fundamentally change this process. The changes would, however, establish a much more objective and measurable parameter for manufacturers to use to determine if monitors are indeed performing adequately during development, and subsequently, in-use.

Since implementation of this requirement would not start until the 2005 model year, manufacturers would have a few years to collect data on the performance of the monitors, and adjust the monitoring conditions accordingly based on the feedback from the field. Data collected during this time period may also be used by manufacturers to ensure their development process provides sufficient assurance of in-use compliance. Further, manufacturers' liability for in-use monitor frequency is greatly reduced for 2005 and 2006 model years giving them even more time to gather data on a larger scale and make any necessary modifications. For 2005 and 2006 model year vehicles, manufacturers would not be subject to remedial action for insufficient monitoring frequency unless the measured ratio was extremely low relative to the required minimum ratio. Again, this should also allow manufacturers extra time to refine and adjust monitors such that compliance with the minimum ratio is achieved.

D. Compliance testing sampling procedure

The last part of this real world monitoring performance proposal includes provisions that would define a test procedure to be followed by the Executive Officer in determining compliance with the minimum ratio. The proposed procedures are detailed in section XIII of this report.

E. Monitoring requirements for vehicles produced prior to phase-in of the ratio

While the proposed regulation adopts a standardized methodology for determining acceptable levels of in-use performance to be phased-in on 2005 and subsequent model year vehicles, vehicles produced prior to or not included in the phase-in would be certified to the same monitoring condition requirements used since

the 1996 model year. The language for these monitoring conditions has, however, been clarified from the language that exists in the current regulation. And while the existing language has been adequate to communicate to manufacturers what is expected of OBD II system monitors, the language has been criticized for not explicitly stating the obvious.

Specifically, despite the clear intent of the OBD II requirements to have manufacturers monitor emission-related components during in-use driving (e.g., the “real world”), the existing language does not explicitly state that monitoring is required during operation of a vehicle in-use. To eliminate the notion that monitoring is not required during operation of the vehicle in the real world, the monitoring conditions language would be modified to explicitly state monitoring is required during conditions “which may reasonably be expected to be encountered in normal vehicle operation and use.”²⁴ This language is copied directly from language used by ARB and the U.S. EPA regarding the prohibition of defeat devices.²⁵ Determinations as to whether a manufacturer’s monitoring conditions meet this requirement would continue to be made in the same manner as they are today. That is, manufacturers would discuss proposed monitoring conditions with staff, determine conditions that meet the requirements, and submit the conditions in their certification applications for staff review. During the review, the determinations would be made case by case based on the expert judgment of staff. In the same process as used today, in cases where staff is concerned that the documented conditions may not be met during reasonable in-use driving conditions, the staff would ask the manufacturer for data or other engineering analysis used by the manufacturer to determine that the conditions will occur in-use. Further, even though this language does not impose a specific minimum monitoring frequency as the proposed ratio would for future vehicles, the monitoring condition requirements would continue to be enforced in the same manner as the existing OBD II requirements.

X. ANALYSIS OF ENVIRONMENTAL IMPACTS AND ENVIRONMENTAL JUSTICE ISSUES

The proposed regulations help ensure that forecasted emission reduction benefits from adopted motor vehicle exhaust and evaporative emission standards programs are achieved. Monitoring of a motor vehicle’s emission control system through the use of OBD II systems helps guarantee that vehicles initially certified to the very low and near-zero emission standards maintain their performance throughout the entire vehicle life. It would make little sense to require very low emissions from new vehicles and then allow them to deteriorate to much higher levels as they age. The proposed regulations achieve these emission benefits in two distinct ways. First, to avoid customer dissatisfaction that may be caused by frequent illumination of the MIL because of emission-related malfunctions, it is anticipated that the manufacturers will produce increasingly durable, more robust emission-related components. Second, by

²⁴ Section (d)(3.1.1) of the proposed title 13, CCR section 1968.2.

²⁵ See 40 CFR Part 86, section 86.094-2 and the well-established requirement that vehicles are expected to comply with federal regulations in-use.

alerting vehicle operators of emission-related malfunctions and providing precise information to the service industry for identifying and repairing detected malfunctions, emission systems will be quickly repaired. The benefits of the OBD II regulation become increasingly important as certification levels become more and more stringent and as a single malfunction has an increasingly greater impact relative to certification levels.

Most recently, the ARB identified emission reductions of 57 tons per day from the Low Emission Vehicle II program in the South Coast Air Basin (see Appendix I for Environmental Impact Analysis from “Staff Report: Initial Statement of Reasons for Proposed Amendments to California Exhaust and Evaporative Emission Standards and Test Procedures for Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles” (LEV II), September 18, 1998). In developing the emission benefits for the LEV II program, the integration of an OBD II system check into the California Inspection and Maintenance (I/M) program (“Smog Check”) was assumed. Therefore, in calculating the approximate 57 tons-per-day emission benefits from the Low Emission Vehicle II program in the South Coast Air Basin, the ARB staff assumed vehicle emissions would remain within the OBD II thresholds contained in the present proposal (and which have generally been carried over from previous OBD II thresholds applicable to Low Emission Vehicle I program vehicles). Given the substantial shortfall in emission reductions still needed to attain the National and State Ambient Air Quality Standards and the difficulty in identifying further sources of cost-effective emission reductions, it is vital that the emission reductions projected for the LEV II program be achieved. The proposed regulation, which specifically modifies the requirements of OBD II systems to better address LEV II vehicles, is necessary to accomplish this goal.

Having identified that the proposed regulations will not result in any adverse environmental impacts but rather will help ensure that measurable emission benefits are achieved both statewide and in the South Coast Air Basin, the regulations should not adversely impact any community in the State, especially low-income or minority communities.

XI. COST IMPACT OF THE PROPOSED REQUIREMENTS

A. Cost of the Proposed Requirements

The vast majority of the requirements in the proposed regulation (section 1968.2) are already required under the current regulation (section 1968.1). For the few that are newly proposed, most will only necessitate revisions to existing software and/or development of new software. In general, because the proposed regulation carries over the OBD II requirements of 1968.1, no new hardware will be required to be added to 2004 and subsequent model year vehicles. Implementation of the proposed changes would generally be accomplished during development of new software that will have to take place for vehicles complying with the Low Emission Vehicle II emission standards (i.e., 2004 to 2007 model years). It is also not unusual for manufacturers to upgrade their controllers to more advanced versions during extensive emission control revisions to achieve higher communication speed, greater processing capability, increased

memory, and cost reduction. The staff has been receptive to manufacturers' requests for leadtime to permit implementation of the proposed revisions during regularly scheduled new model software development and computer upgrades to minimize any need for additional resources. Additionally, it is expected that the proposed requirements would be addressed primarily with the existing motor vehicle manufacturer workforce, although in some cases additional employees may be required. Overall, however, the proposal is not expected to significantly affect per vehicle cost considering the high number of vehicles utilizing each software set.

As stated above, the proposed requirements are generally not expected to result in additional vehicle hardware since most revisions would involve computer software. However, as one exception, certain manufacturers may utilize a linear (also described as a wide range) oxygen sensor instead of a conventional one to accomplish secondary air injection monitoring during cold starts.²⁶ The use of this sensor, however, would have other benefits that offset the \$3 - \$5 incremental cost relative to a conventional oxygen sensor. For example, the linear oxygen sensor provides improved fuel control during the cold start and initial warm-up period that may permit a reduction in catalytic converter precious metal loading. Many Asian and European manufacturers have already incorporated linear oxygen sensors in their products to take advantage of these other benefits. For diesels, it appears that linear oxygen sensors, as well as pressure transducers and NOx sensors, will be incorporated into the control strategies for particulate matter traps, NOx adsorbers, oxidation catalysts, selective catalytic reduction systems, and other components. These sensors should also be capable of performing OBD II monitoring without additional hardware. The staff will continue to closely analyze diagnostic requirements for diesels and will adjust the requirements proposed in this rulemaking as needed when developing heavy-duty vehicle OBD requirements next year. The requirements applicable to light- and medium-duty diesels in this proposal, however, do represent the direction the staff will be taking in the heavy-duty rulemaking based on a current review of rapidly evolving technology.

B. Cost Effectiveness of the Proposed Requirements

In conducting the cost-effectiveness analysis for these proposed requirements, the staff revisited the cost estimates of the Low Emission Vehicle II program and updated that analysis to include the effects of OBD II, the staff's proposed MIL illumination thresholds, and industry's proposed thresholds. Using EMFAC2001, ARB's model for estimating real world emissions, the staff has augmented its analysis of the cost-effectiveness in dollars per pound of pollutant reduced that was reported in the 1998 Low Emission Vehicle II Staff Report (see Appendix III). The 1998 analysis generally covered the first 120,000 miles of vehicle operation, which is the useful life period for most Low Emission Vehicle II applications. In updating this portion of the 1998 analysis, the staff has also taken into account changes to the Zero Emission Vehicle (ZEV) requirements at the January 2001 Board hearing that allowed for increased numbers of Partial Zero Emission Vehicles (PZEVs) to satisfy a portion of the ZEV requirement. For the useful life period, cost-effectiveness for the light-duty fleet

²⁶ It should be clarified that not all vehicles use or are expected to use secondary air systems.

was determined to be \$2.18.

The staff has additionally determined the cost-effectiveness of Low Emission Vehicle II applications beyond 120,000 miles attributable to repairs resulting from the proposed MIL illumination thresholds. The results from these analyses were then summed to determine total cost-effectiveness over the full vehicle lifetime. The cost-effectiveness beyond 120,000 miles was determined to be \$4.57 per pound of pollutant reduced, which is well within the range of other emission measures adopted by the Board. The methodology used for the analysis is detailed in the attachment to the staff report.

The staff also examined the impact that would occur if higher MIL thresholds were adopted as suggested by the motor vehicle manufacturers (see section XIV.B. below). This analysis was conducted again using EMFAC2001 to simulate the emission thresholds proposed by industry (generally 7 or more times the tailpipe emission standards) by removing the emission benefits of the Smog Check Program from the model for Low Emission Vehicle II applications. Under this scenario, more vehicles are permitted to remain at high emission rates, simulating vehicles attaining higher emission levels (i.e., the higher thresholds proposed by industry) before repair and some reduction in repair rate. For this, the staff assumed approximately 25 percent fewer repairs would be made.²⁷ The emissions of reactive organic gas (ROG) plus NOx lost in the South Coast Air Basin in 2010 would be 3.9 tons-per-day (tpd) and 31.4 tpd in 2020. Cost-effectiveness for this scenario averaged \$5.43 per pound, which is worse than the staff proposal. This is because the industry proposal achieves substantially fewer emission reductions than the staff's proposal relative to their reduced repair costs. Even if the staff assumed that industry's proposal would achieve a 50 percent reduction in repairs, the cost-effectiveness would be \$3.84 per pound. This would mean that the emissions lost from their proposal would need to be recovered by a program that would cost less than \$1.00 per pound, which is highly unlikely anymore. Given the considerable need for additional emission reductions, the industry proposal would set back the ARB's efforts at achieving all cost-effective emission reductions.

XII. ECONOMIC IMPACT ANALYSIS

Overall, the proposed regulations are expected to have no noticeable impact on

²⁷ It should also be mentioned that only the major monitors (e.g., fuel system, catalyst efficiency, oxygen sensor performance, exhaust gas recirculation flow, etc.) have associated thresholds for illuminating the MIL that are linked to some multiple of the emission standards. The vast majority of the typically more than 120 fault codes in an OBD II system are linked to components that are determined to need service based on evaluations of circuit continuity, functional response to computer commands, rationality of electronic signals or other similar approaches apart from their level of emission consequence (e.g., throttle position sensors, manifold absolute pressure sensors, thermal sensors, purge valves, shift solenoids, etc.). For most OBD II components, then, the evaluation of adequate performance is based on criteria that are no different for LEV category vehicles or SULEV category vehicles. This is why staff estimates that repair rates under the industry proposal would not be more than 25 percent fewer than the rates under staff's proposal. If manufacturers were to take advantage of higher thresholds and build less durable parts, there might well be no change in repair rates.

the profitability of automobile manufacturers. These manufacturers are large and are mostly located outside California although some have some operations in California. The proposed changes involve development and verification of software already incorporated into OBD II systems. Because manufacturers would be provided sufficient lead time to incorporate the proposed changes when redesigning vehicles that comply with the Low Emission Vehicle II (LEV II) program, incorporation and verification of the revised OBD II software would be accomplished during the regular design process at virtually no additional cost. Any additional engineering resources needed to comply with the proposed program would be small, and when spread over several years of vehicle production, these costs would be negligible. Staff believes, therefore, that the proposed amendments would cause no noticeable adverse impact in California employment, business status, and competitiveness.

A. Legal requirements

Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. Section 43101 of the Health and Safety Code similarly requires that the Board consider the impact of adopted standards on the California economy. This assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California business to compete.

B. Affected businesses and potential impacts

Any business involved in manufacturing, purchasing or servicing passenger cars, light-duty trucks and medium-duty vehicles could be affected by the proposed amendments. Also affected are businesses that supply parts for these vehicles. California accounts for only a small share of total nationwide motor vehicle and parts manufacturing. There are 34 companies worldwide that manufacture California-certified light- and medium-duty vehicles and heavy-duty gasoline engines. Only one motor vehicle manufacturing plant is located in California, the NUMMI facility, which is a joint venture between GM and Toyota.

The proposed regulations would also affect the California licensed I&M service facilities that perform emission verification testing using OBD II systems. There are approximately 10,000 I&M stations in California. It is anticipated that licensed I&M service stations will experience a one-time pretax cost of approximately \$500 to upgrade existing equipment to test vehicles equipped with the Controller Area Network (CAN) OBD II communication protocol. Based on financial data from Dun & Bradstreet, the ARB staff has concluded that the cost of the equipment upgrade should have a negligible economic impact on the State's I&M test facilities.²⁸

²⁸ "Industry Norms & Key Business Ratios, Desk-Top Edition 1999-2000", Dun & Bradstreet, p.178. The report shows that the typical automotive repair facility had gross revenues in excess of \$1 million dollars and net profits in excess of \$43,000. Most likely, facilities will pass on the after-tax cost (approximately \$300) of the equipment upgrade to consumers; but, even assuming that a typical facility elects to absorb the full after-tax cost, it should result in a one-time reduction in profitability of less than

C. Potential impacts on vehicle operators

The proposed requirements would provide improved OBD II information and encourage manufacturers to build more durable vehicles, which should result in the need for fewer vehicle repairs and savings for consumers. Additionally, as stated above, the OBD II regulations are anticipated to have a negligible impact on manufacturer costs and new vehicle prices. Similarly, if I&M facilities decide to pass the anticipated one-time equipment upgrade cost to consumers, the cost should be negligible when spread over several years and number of vehicles tested.

D. Potential impacts on business competitiveness

The proposed regulations would have no adverse impact on the ability of California businesses to compete with businesses in other states as the proposed standards are anticipated to have only a negligible impact on retail prices of new vehicles. The one-time equipment upgrade cost for I&M test facilities will have no impact on their ability to compete with businesses in other states in that California vehicles must be tested by California licensed I&M facilities.

E. Potential impacts on employment

The proposed regulations are not expected to cause a noticeable change in California employment because California accounts for only a small share of motor vehicle and parts manufacturing employment. Since the regulations are not expected to have an adverse impact on California I&M test facilities, the proposed regulations should not impact on employment at such facilities.

F. Potential impact on business creation, elimination or expansion

The proposed regulations are not expected to affect business creation, elimination or expansion.

XIII. PROPOSED ADOPTION OF ENFORCEMENT PROVISIONS SPECIFIC TO OBD II SYSTEMS

A. Overview

The staff is proposing that the Board adopt a comprehensive in-use enforcement protocol that applies specifically to the OBD II regulation, title 13, CCR section 1968.2, pursuant to the Board's general and specific authority to adopt procedures that ensure compliance.²⁹ Among other things, the staff is proposing procedures for the in-use testing of OBD II systems installed in motor vehicles and engines. The proposal would

one percent.

²⁹ Health and Safety Code, sections 39600, 39601, 43013(b), 43018, 43102, 43104, and 43105.

further provide the Executive Officer with authority to order motor vehicle manufacturers to take remedial action when in-use testing indicates that a class of motor vehicles is equipped with OBD II systems that do not meet the OBD II certification requirements of title 13, CCR section 1968.2.

The staff is proposing the specific enforcement protocol for OBD II systems after more than eight years of experience in implementing and enforcing the OBD II requirements. The staff believes that the general enforcement procedures found at title 13, CCR, Section 2, Articles 2.0 through 2.4, and the specific provisions set forth at title 13, CCR section 1968.1(i) do not adequately address the unique issues involved in enforcing the OBD II regulation. This fact was underscored in a recent administrative enforcement action conducted under the above provisions, which were initially adopted for the purpose of in-use enforcement of the California tailpipe and evaporative emission standards. In that case, contrary to the position taken by the ARB, it was determined that motor vehicles with a nonconforming OBD II system should not be recalled because, among other things, the motor vehicles, on average, still met the applicable exhaust (tailpipe) and evaporative emission standards for such vehicles despite not meeting the OBD II requirements.

B. The Need for OBD II-Specific Enforcement Procedures

The staff believes that specific OBD II enforcement provisions are necessary to better address and identify the special circumstances involved in in-use testing and remedying identified nonconformities with OBD II systems. Experience has revealed that the existing general enforcement procedures, which were specifically adopted to enforce noncompliance with tailpipe and evaporative emission standards, do not allow for effective enforcement of the OBD II requirements and standards. Accordingly, attempting to apply the provisions to OBD II-related noncompliance has apparently led to some confusion as to the applicability of specific sections of the existing procedures to OBD II-related enforcement. For example, over the past several years, questions have arisen as to whether a noncomplying OBD II system is a failure of an emission-related component or a failure to conform to an emission standard, which requires a completely different analysis.³⁰ With the existing requirements, the distinction is crucial because if a noncomplying OBD II system is considered a failure of an emission-related component, it is then presumed under title 13, CCR section 2123(b) that the failure would result in an exceedance of a tailpipe or evaporative emission standard of the affected vehicle class. In such cases, a recall of the affected vehicle class would be appropriate unless the manufacturer could overcome the presumption by showing that emissions of the vehicle class, on average, comply with applicable tailpipe emission standards.³¹ On the other hand, if the noncompliance was found to be a failure to conform to an OBD II emission standard, the Executive Officer could order an emission-related recall upon finding that the nonconformity applied to the vehicle class, on

³⁰ Emission-related component failures are analyzed under the first part of section 2123(a) of title 13, CCR, whereas the second type of failure is analyzed under the second part of that same section.

³¹ See title 13, CCR section 2147.

average. In such a case, recall would be appropriate irrespective of whether the affected vehicle class also complied with tailpipe and evaporative certification levels.

The two-part approach of section 2123 does not neatly apply to the OBD II regulation. First, the OBD II regulation includes both emission standards and other non-emission-related requirements, such as test procedures and standardization requirements. Second, OBD II systems are comprehensive and exceedingly complex. In-use enforcement of OBD II systems involves a myriad of issues that do not arise in the enforcement of tailpipe and evaporative emission standards. Over time, it has become apparent that the simplified enforcement approach of section 2123 does not address the unique issues involved in the in-use operation of OBD II systems. Distinct testing and enforcement procedures will allow the Executive Officer to perform more appropriate testing of OBD II systems to assure that they properly perform in-use. Defined protocols will likewise provide manufacturers with notice and guidance on how such testing will be conducted and applied.

The adoption of OBD II-specific enforcement provisions would also help clarify that a manufacturer cannot escape liability for failing to comply with the OBD II standards and requirements by demonstrating that vehicles with the nonconforming OBD II system, on average, comply with certification standards for tailpipe and evaporative emissions. As set forth elsewhere, the OBD II emission standards and requirements serve very different purposes from the tailpipe and evaporative emission standards, and compliance with the latter two standards should not excuse noncompliance with the former.

Further, to allow a manufacturer to overcome the need to remedy a nonconforming OBD II system by showing that the failure would not result in the motor vehicle class, on average, failing to conform to the tailpipe and evaporative emission standards would undermine the purpose and intent of the OBD II requirements. In adopting the OBD II regulation, the Board specifically determined that functional OBD II systems were necessary and should be equipped on all 1996 and subsequent model year vehicles. In so determining, the Board found that functional OBD II systems are a vital complement to the success of the ARB's motor vehicle emission reduction programs in general. For example, all vehicles certified to the Low Emission Vehicle II emission standards are required to be equipped with OBD II systems. The system is intended to insure that all the Low Emission Vehicle II applications achieve forecasted emission reductions in-use by alerting motor vehicle operators of malfunctions to the vehicles' emission control systems and providing the service and repair industry with information that will assure expeditious and proper repairs. To apply the provisions of section 2147 and not require the remedying (recall and repair) of nonconforming OBD II systems would be speculative (section F below) and effectively reverse the Board's prior determination that functional OBD II systems are necessary. Thus, it is imperative that OBD II-related violations be enforced under OBD II-specific enforcement provisions that would make it clear that OBD II requirements are not interchangeable with tailpipe or evaporative emission standards.

Similarly, the proposed enforcement procedures would supersede the provisions at title 13, CCR section 1968.1(i) for in-use testing and recall of noncomplying OBD II systems. In attempting to implement and enforce the existing OBD II requirements, the staff has become aware that the provisions of section 1968.1(i) have not been fully understood by all stakeholders and need to be clarified. The proposal addresses these problems by setting forth clear and specific criteria for in-use testing of OBD II systems and when remedial action would be appropriate.

C. Applicability of the Proposed Enforcement Procedures

The proposed enforcement procedures would, in general, apply to 2004 and subsequent model year vehicles that are equipped with OBD II monitoring systems that have been certified for sale in California, pursuant to the requirements of title 13, CCR section 1968.2. Most, if not all, of the requirements for the 2004 model year have been carried-over from the requirements set forth in section 1968.1 for vehicles manufactured prior to the 2003 model year. Those requirements became operative in September 1997 and manufacturers will have had six years or more of leadtime in developing and incorporating all of the monitoring requirements into the 2004 model year vehicles. Additionally, for most requirements, the OBD II systems have been in production for at least several years, and manufacturers have been able to observe the performance of the systems in the field.

It is equally true that manufacturers have been on notice since the initial adoption of the OBD requirements in 1990 that the ARB staff would enforce the OBD II regulation after its effective date, and that appropriate remedies, including recall, could be ordered for noncompliance. Manufacturers, however, argue that the proposed enforcement procedures “substantially alter the legal effect of past events.” Seemingly, the concern of the manufacturers is the perceived belief that the proposed enforcement procedures substantially change existing protocol. That is, manufacturers would not be allowed to overcome the recall of a nonconforming OBD II system by showing that emissions of the affected vehicle fleet, on average, comply with the applicable tailpipe and evaporative emission standards. The staff does not agree with the manufacturers’ concerns, believing that, for the most part, the proposed enforcement protocol only seeks to clarify existing Board authority to enforce the OBD II regulation. However, even accepting for purposes of argument the manufacturers’ position, the proposed enforcement procedures, as stated, are intended to only apply prospectively, and not before the 2004 model year. By that time, manufacturers should have sufficient opportunity to make certain that their systems are in full compliance with the OBD II requirements.

D. Authority to Adopt Enforcement Procedures

Depending upon the nature of the nonconformity of the OBD II system and the circumstances surrounding the nonconformity’s existence, recall may be an appropriate remedy. Health and Safety Code section 43105 authorizes the Executive Officer to order recalls, if a manufacturer has violated emission standards or test procedures and has failed to take corrective action.

The adopted OBD II regulation, title 13, CCR sections 1968.1, and the proposed regulation for 2004 and subsequent model year vehicles, title 13, CCR section 1968.2, establish both emission standards and test procedures for certification to those standards. The ARB expressly adopted title 13, CCR section 1968.1 pursuant to authority granted by the Legislature to adopt and implement emission standards and test procedures under the Health and Safety Code.³² Likewise, the staff is proposing that section 1968.2, title 13, CCR be adopted pursuant to the same authority. In so acting the Board has not, and will not have, exceeded its authority under the statute. The existing and proposed regulations clearly establish quantitative emission standards for most, if not all, of the major monitoring systems (e.g., detection of malfunctions before emissions exceed 1.5 times the applicable tailpipe emission standard). These malfunction criteria establish specified limitations on the discharge of air contaminants into the atmosphere and thus meet the definition of “emission standards” as defined at section 39027 of the Health and Safety Code.

In adopting Senate Bill 1146, the Legislature expressly recognized that the OBD II requirements are emission standards, stating:

Recent emission standards adopted and implemented by the State Air Resources board for motor vehicles manufactured after 1993 have resulted in the development by vehicle manufacturers of “on board diagnostic computers” that interface with the many component parts of a vehicle’s emission control system. (Stats. 2000, Ch. 1077, Sec. 1; emphasis added.)

In granting California a waiver of federal preemption, pursuant to section 209(b) of the federal Clean Air Act, to adopt the OBD regulation, the U.S. Environmental Protection Agency (EPA) expressly found that the requirements of the California OBD II regulation were emission standards.³³ Indeed, in the proceedings to determine California’s request for a waiver, the Association of Automobile Manufacturers (AAMA)³⁴

³² See “Notice of Public Hearing to Consider Adoption of Regulations Regarding On-Board Diagnostic System Requirements for 1994 and Later Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles with Feedback Fuel Control,” July 18, 1989, and subsequent notices of public hearings to consider technical status update and proposed revisions to malfunction and diagnostic system requirements, issued on July 16, 1991, October 11, 1994, and October 15, 1996; see also Resolutions 89-77, 91-42, 93-50, 94-67, and 96-60.

³³ For purposes of the waiver only, recognizing the special nature of the OBD II requirements, the Executive Officer contended that the OBD regulation, when considered as a whole, might be described as an enforcement procedure. EPA rejected this position, finding that, for purposes of a waiver determination, both California and federal OBD regulations should be considered emission standards. It should be noted that the definition of “emission standard” set forth at section 302(k) of the CAA, is similar to the definition found at section 39027 of the Health and Safety Code. As defined under the CAA, an emission standard “means a requirement established by the State or the Administrator which limits the quantity, rate, or concentration of emissions of air pollutants on a continuous basis”

³⁴ AAMA was the automobile manufacturers association representing General Motors Corporation, Ford Motors Corporation, and the former Chrysler Corporation at the time of the OBD II waiver request hearing.

recognized that the California OBD II requirements are emission standards. As the U.S. Environmental Protection Agency (EPA) summarized in its decision granting the waiver:

AAMA states that the requirements for OBD systems are emission control standards under section 202 of the [Clean Air] Act. AAMA notes that Congress' inclusion of the OBD requirements in the emission standards section of the Act (section 202) is a clear indication of its intent that OBD is to be considered an emission control standard [citation omitted] . . . AAMA states that EPA has referred to the federal and California OBD regulations as being requirements for which vehicles are certified, and, as AAMA points out, vehicles are certified to applicable standards, not to enforcement procedures.³⁵

In granting California its waiver of federal preemption for the OBD II regulation, EPA concurred with AAMA, finding:

OBD requirements appear to be closer in their application and effect to standards than to enforcement procedures: they establish specific levels of emissions that beyond which the MIL must be illuminated and fault codes be stored; they create direct requirements on the manner in which manufacturers build their vehicles; the OBD II requirements set forth how a vehicle must operate at time of certification and in use, and not how the state would ensure that the vehicle is operating properly as is typical of an accompanying enforcement procedure.

Beyond being emission standards, the OBD II regulation sets forth specific test procedures that manufacturers must follow to assure certification and compliance to the established standards. For example, sections 1968.2(g), (h), and (j) set forth specific requirements for demonstration test vehicles, certification documentation, and production vehicle evaluation testing. Accordingly, Health and Safety Code section 43105 expressly authorizes the ARB to adopt regulations regarding corrective actions, including recall, that the Board may take for violations of the OBD II emission standards and the test procedures established to certify vehicles to those standards.

In addition to the express authority of Health and Safety Code section 43105 to adopt enforcement procedures, the Board has unmistakable implied authority to adopt such regulations. The general powers granted to the Board in Health and Safety Code section 39600 provides that the Board shall do such acts as may be necessary for the proper execution of the powers and duties granted to it. The OBD II requirements were adopted pursuant to general authority granted under sections 43013, 43018, and 43101 among others. Specifically, sections 43013(a) and 43101 authorize the Board to adopt

³⁵ California State Motor Vehicle Pollution Control Standards; Waiver of Federal Preemption; Decision (October 11, 1996), at 18-19, citing AAMA comments, dated December 1, 1995, to Robert Maxwell, Director, Vehicle Program Compliance Division, EPA.

and implement motor vehicle emission standards. And section 43018 directs the Board to take whatever actions are necessary, cost-effective, and technologically feasible in order to achieve specific emission reductions, including the adoption of standards and regulations that will result in, among other things, reductions in motor vehicle in-use emissions through improvements in emission system durability and performance.

Although the Legislature did not expressly authorize the adoption and implementation of OBD II requirements, the Legislature recently gave its imprimatur to the regulation.³⁶ Having implicitly authorized the Board to adopt the OBD II regulations in furtherance of the Board's mission, it cannot reasonably be argued that the Legislature has not also entrusted the Board with authority to properly enforce the adopted standards and test procedures to ensure compliance.³⁷

E. In-Use Testing Procedures

The proposed in-use enforcement test procedures set forth the testing protocol to be followed by staff to assure that OBD II systems on production motor vehicles and engines comply with the requirements of section 1968.2 and conform with motor vehicles and engines certified by the ARB. To this end, the ARB is proposing that it periodically evaluate vehicles for compliance with the OBD II regulation.

The proposed procedures set forth how enforcement testing to determine OBD II compliance would be conducted, including, among other things, how the Executive Officer would initially determine the scope of vehicles to be tested, the number of vehicles to be tested (i.e., the size of the test sample group), and the type of testing to be conducted. OBD II enforcement testing would be grouped into three different categories depending on the nature of the OBD II noncompliance issue to be tested. Specifically, the protocol proposes that separate guidelines and procedures be followed for OBD II emission testing, OBD II ratio testing, and "other" OBD II testing.

The OBD II emission testing procedures would be used when the measurement of tailpipe emission levels relative to the tailpipe emission standards is essential to determining OBD II system compliance. Emission testing for OBD II compliance is comprised of two distinct parts: (1) emission testing in accordance with the test procedures used by the Executive Officer for in-use testing of compliance with tailpipe emission standards in accordance with title 13, CCR sections 2138 and 2139; and (2) on-road and/or dynamometer testing with the vehicle being driven in a manner that reasonably ensures that all of the monitoring conditions disclosed in the manufacturer's certification application for the tested monitor are encountered. The latter testing will be conducted to determine the MIL illumination point and the former testing will be conducted to determine the tailpipe emission level at the MIL illumination point.

³⁶ See section 43105.5(a)(4), Stats. 2000, Ch. 1077, Sec. 4; see also Sec. 1.

³⁷ See *California Drive-In Restaurant Ass'n v. Clark* (1943) 22 Cal.2d 287, 302 [140 P.2d 657], "the authority of an administrative board or officer, . . . to adopt reasonable rules and regulations, which are deemed necessary to the due and efficient exercise of the powers expressly granted, cannot be questioned."

Together, these two parts of testing are necessary to determine if the MIL illuminates prior to exceeding the tailpipe emission levels as required in the OBD II regulation.

For this testing, the vehicle selection process -- e.g., size of test sample group and protocol for procuring vehicles -- would be essentially similar to the procedures presently used by ARB staff in determining compliance with tailpipe emission standards. The only differences between the procedures used for tailpipe emission standard enforcement testing and OBD II emission testing would be those that are needed specifically for OBD II testing. For example, the proposed OBD II emission test procedures allow the Executive Officer to group like vehicles together into a single "class" based on OBD II system similarities rather than solely on certification emission standard similarities. Additionally, in contrast to vehicles subject to in-use tailpipe emission testing, vehicles to be OBD II emission tested would be scrutinized by staff to ensure that there are no signs of tampering or use of aftermarket parts that would cause the OBD II system not to comply with the OBD II requirements.

Of course, to properly conduct OBD II emission testing, the Executive Officer must implant a malfunction into the vehicle and then determine if the OBD II system properly detects the malfunction at the required tailpipe emission levels. To perform this testing, the Executive Officer would implant actual or simulated malfunctions consistent with the malfunction criteria established in the OBD II regulation. However, this testing is often easiest accomplished by using sophisticated simulation test equipment and/or specially developed aged or deteriorated components. To facilitate the Executive Officer's ability to perform this testing and reproduce results generated by manufacturers during development, the proposed regulation would require manufacturers to retain specific test equipment and/or aged components used during the calibration and development process. Upon request by the Executive Officer, the manufacturer would be required to make such equipment available for the Executive Officer's use in enforcement testing. And, as such testing must be performed by the Executive Officer within a vehicle's full useful life (e.g., 10 years and 100,000 miles), the manufacturer would only be required to retain the components for the useful life period. It is important to note that this does not require manufacturers to retain every single component or simulator ever used during calibration but is limited only to "threshold" components that are used for one of the major monitors (e.g., the component that produces emissions at or just below 1.5 times the standard for a monitor calibrated to 1.5 times the standards).

The OBD II ratio testing procedures would be used when the in-use monitor performance is tested for compliance with the minimum acceptable in-use monitor performance requirements (i.e., does the monitor run often enough?). Under these procedures, the Executive Officer would follow some of the same procedures that are proposed for use in OBD II emission testing. The test sample group for ratio testing, however, would require collecting data from at least 30 vehicles in contrast to the minimum of 10 vehicles that would be required for OBD II emission testing. Also, because tailpipe emission testing is not part of the ratio testing, the vehicle selection criteria and sampling process for ratio testing would differ from that which would be

used in OBD II emission testing. Those areas would be modified to eliminate items that are only essential for tailpipe emission performance. Specifically, the criteria for including vehicles in the sample for ratio testing would be targeted solely to exclude vehicles that have problems (e.g., tampering, abuse, aftermarket parts, etc.) that would affect the OBD II system performance. Criteria that are used to weed out vehicles with problems that would affect tailpipe emission levels (e.g., proper maintenance, tampering that affects tailpipe levels but not OBD II monitor performance, etc.) would not be used for ratio testing. It is necessary to eliminate the above criteria because they are not relevant to ratio testing and the pared criteria will help assure that a sufficient number of representative vehicles are available for procurement and testing.

In cases where the monitor being tested has a ratio that is required to be tracked and reported to a scan tool in standardized manner, the actual ratio testing of procured vehicles would be a rather expeditious and straightforward process. The data used to determine compliance with in-use monitor performance are required, under title 13, CCR 1968.2, to be stored in the on-board computers of the vehicles themselves. The “testing” of the 30-plus vehicles will be as simple as electronically downloading the stored data from the vehicles with a diagnostic tool (e.g., an OBD II scan tool).

For testing of monitors that are required to meet the ratio but are not required to track the data in the on-board computer or report it in a standardized manner, the process would be lengthier and slightly more involved. In these cases, rather than downloading information stored in the on-board computer, each test vehicle would be equipped with instrumentation that would record and collect vehicle activity data and monitor activity. Each test vehicle would then be returned to the vehicle operator for accumulation of data. After collection of sufficient data (the same amount of data as required for the ratios that are tracked and reported), the data would be analyzed to determine the ratio for the tested monitor for each vehicle. This method is directly analogous to that used for the ratios that are required to be tracked and reported in the on-board computer by effectively tracking and reporting the ratio in an “off-board” computer (i.e., the instrumentation attached to the vehicle).

The final area of OBD II testing would cover in-use testing of all other OBD II requirements that cannot effectively be grouped into one of the other two categories (i.e., emission or ratio testing). The selection and testing procedures for such testing would be determined on a case-by-case basis. This is necessitated because of the breadth of this residual category and the many nuances of the complex systems that may affect some aspects of the system performance. Given this complexity, it is impossible to predict every possible permutation or noncompliance that might occur in the future. As such, it is also impossible to prescribe exact test procedures that will adequately address every possible noncompliance scenario. For example, a problem could be as simple as a system not complying with the MIL wording requirements (e.g., using “check emissions” instead of “check engine” on the dashboard light). In such a case, the number of vehicles tested and how they are procured would essentially be irrelevant. The noncompliance would likely be confirmed by using a visual examination of as few as one or two vehicles obtained through a car rental agency. As another

example, the problem could be the inability of the OBD II system to properly detect malfunctioning thermostats that cause the engine to warm up too slowly. Such a malfunction could cause a vehicle to have increased emissions and/or cause the disablement of other diagnostics. As manufacturers have attested, dynamometer testing of the thermostat monitor in a laboratory is not representative of the performance of the monitor in the real world because the airflow over the vehicle on a dynamometer is significantly different than the airflow that occurs during on-road driving. And this difference in airflow can significantly affect the warm-up characteristics of the thermostat. In contrast to the first example, testing could not be conducted to confirm noncompliance by performing a visual inspection on as few as two vehicles. Accordingly, for the “other” OBD II testing category, the proposed regulation, rather than setting forth specific selection and testing procedures as for emission and ratio testing, defines general guidelines to be followed by the Executive Officer when conducting testing in this area. The Executive Officer would have discretion to determine, on a case-by-case basis, the most appropriate procedures for selection and testing of vehicles based on the nature of the OBD II noncompliance and the projected number of affected vehicles. The Executive Officer would be required to provide notice of the selection and testing procedures to the manufacturer of the vehicles subject to such testing (see discussion below).

The proposed regulation would also set forth the decision criteria that would be used by the Executive Officer to determine if a system is noncompliant for each type of testing. For example, for OBD II emission testing, the regulation specifies that the system would be determined to be noncompliant if 50 percent or more of the tested sample vehicles are unable to properly detect a malfunction and illuminate the MIL before tailpipe emissions exceed the malfunction criteria thresholds set forth in title 13, CCR section 1968.2(e). For OBD II ratio testing, the system would be noncompliant if the average in-use performance of the sample vehicles is below a critical ratio that indicates the average ratio for the entire motor vehicle class is below the required minimum in-use monitor performance ratio set forth in title 13, CCR section 1968.2(d)(3.2). And, for the “other” testing, the system would be determined to be noncompliant if 30 percent or more of the sample vehicles fail to meet the same requirement that falls within the residual-testing category.

The last-mentioned criterion is consistent with the criterion set forth in the existing tailpipe emission enforcement procedures, which provides that a test group or sub-group of vehicles shall be considered nonconforming when a specific emission-related failure occurred in three or more test vehicles from a sample that includes a minimum of 10 in-use vehicles (see title 13, CCR sections 2137 and 2140³⁸). Additionally, the staff believes that use of the definitive 30 percent criterion is preferable to the use of the term “substantial number of a class or category of vehicles that ...experience a failure of the same emission-related component...”, that is used in the

³⁸ As discussed elsewhere in this staff report, the tailpipe or evaporative emissions of the fleet as a whole are not relevant when considering nonconformance of an OBD II system.

definition of nonconformity in the existing enforcement procedures.³⁹ The specific percentage will provide clear notice to all parties of what is expected for compliance with the regulations.

If any of the above testing indicates that the OBD II system is suspected of being noncompliant, the Executive Officer would be required to provide the manufacturer with a notice of the test results. The proposed regulation would require that such notice include all relevant supporting information that the Executive Officer relied upon in making his or her determination of nonconformance of the OBD II system.

Manufacturers would have the opportunity to respond to the preliminary notice and present test results and other data that they believe rebut the preliminary findings of noncompliance. Upon consideration of the information submitted by the manufacturer, the Executive Officer may decide to perform additional in-use testing if necessary. The Executive Officer would consider all information submitted by the manufacturer in ultimately determining whether an OBD II system is nonconforming.

Lastly, the Executive Officer would be required to issue a notice of final determination to the manufacturer as to whether the OBD II system is nonconforming. If the Executive Officer finds the OBD II systems to be nonconforming, the regulation would require the notice to set forth the factual bases for the determination.

F. Remedial Action

1. Introduction

After notification of noncompliance from the Executive Officer, a manufacturer would have 45 days to elect to conduct an influenced recall and repair of the affected vehicles. If the manufacturer takes no action, the Executive Officer could order the manufacturer to take appropriate remedial action scaled to the level of noncompliance. The regulation would set forth a detailed set of factors that the Executive Officer would consider in determining the appropriate remedy.

2. Emissions Impact.

As explained in section B. above, the proposed regulation would clarify that in ordering a recall of a nonconforming OBD II system, the Executive Officer would not need to demonstrate that the nonconforming system directly causes a quantifiable increase in the tailpipe or evaporative emissions of the entire group of affected vehicles nor would a manufacturer be able to overcome the recall by making such a showing. The recall of an effectively nonfunctional monitoring system is necessary because the existence of such a noncomplying system effectively defeats the purposes and objectives of the OBD program and potentially undermines the emission reduction benefits that have been projected from adopted motor vehicle emission reduction programs. It has been the long-standing position of the ARB that it is necessary to

³⁹ title 13, CCR section 2112(h)

repair or replace such nonconforming systems because they are not capable of detecting future malfunctions of the vehicle's emission control systems and that this would likely lead to future emission increases.⁴⁰ This position is consistent with the Senate Committee on Environment and Public Works when considering federal adoption of onboard diagnostic regulations.⁴¹

California's problems with ozone pollution continue to be the worst in the nation. In an effort to meet federal and state ambient air quality standards and comply with the federally mandated State Implementation Plan (SIP) to meet those standards, California has continued to be in the forefront in adopting the most stringent motor vehicle emissions control program in the nation. The OBD II regulation is an essential part of that program. In recent years, the ARB adopted the most stringent tailpipe and evaporative emission certification standards for new motor vehicles (Low Emission Vehicle II). The proposed OBD II requirements are an essential part of this emission reduction program. The proposed requirements of title 13, CCR section 1968.2, which guarantee that the new motor vehicle emissions systems will be properly monitored in-use, are necessary to assure that new motor vehicles continue to meet California's stringent emission standards in-use over the life of the vehicle. This will ensure that the emission reduction benefits from the Low Emission Vehicle II program and other new motor vehicle emission regulations are realized, a crucial step towards compliance with the ambient air quality standards.

As stated, it is beyond dispute that as motor vehicles age and accumulate high mileage, their emission control systems deteriorate and increasingly malfunction,

⁴⁰ See Manufacturers Advisory Correspondence No. 87-06 (July 1, 1987), in which the ARB stated.

A recall . . . would be appropriate based on . . . the underlying defect identified by the OBD system even where the vehicles could pass the FTP, assuming a substantial number of vehicles in the class or category being tested contained that defect.

⁴¹ P.L. 101-549, Clean Air Act Amendments of 1989, S.Rep. 101-228, 101st Cong., 1st Sess. 1989, 1990 U.S.C.C.A.N. 33855, 1989 WL 2326970 et seq. , in which the Committee reported:

The amended section 202 of the [CAA] authorizes the Administrator to promulgate regulations for [emission control diagnostics (ECD)]. Existing section 207(c) of the [CAA] provides for recall of vehicles which do not conform to the regulations adopted under section 202, thus providing clear authority for the Administrator to recall classes or categories of vehicles determined to have malfunctioning ECD systems during their full useful life. This authority will enable EPA to ensure that the emission components and the ECD system operate properly. A vehicle will be recalled or repaired if, during the useful life of the vehicle, the ECD system itself is broken or malfunctions such that it would no longer be able to serve its intended function of alerting the vehicle operator to the need for emission related maintenance and properly storing such information for subsequent retrieval by inspection or maintenance personnel. The ECD system is intended to alert the operator to the need for maintenance which may head off further emission deterioration or damage to the emission control system. Therefore, the Administrator may order a recall and a repair of the ECD system in cases wherever there is systematic misdiagnosis, even if the vehicle is passing emission standards, either by not alerting the operator to the need for necessary repair or by flagging a repair which is not necessary.

causing emissions from motor vehicles to increase.⁴² The ARB adopted the OBD II requirements to address this problem and, specifically, to provide assurance that when malfunctions in emission control systems do occur, they will be expeditiously discovered and repaired. To properly perform these objectives, the OBD II system itself must be functional and capable of detecting malfunctions when they occur. To minimize potential emission increases in future years, it is imperative that the identified, effectively nonfunctional OBD II systems be recalled and repaired at the time noncompliance of the systems is discovered. No one knows or can accurately predict how well emission control systems of different manufacturers will work 10, 20, or more years from now. This is especially true when vehicles are being required to meet increasingly stringent emission standards, requiring new and complex technologies to be utilized.

Contrary to the contentions of the automobile manufacturers, any forecasting of future compliance with tailpipe and evaporative emissions standards would be much more difficult to do in the case of an OBD II nonconformity than in the case of failed emission related component.⁴³ In the latter case, the manufacturer knows specifically what emission-related component has failed (and the manner in which it has failed) and can conduct in-use emission testing of the vehicle fleet with the known failed part. In the case of the nonconforming OBD II system, the only thing known is that the OBD II monitor is not working. At the time of such failure, neither the Executive Officer nor the manufacturer knows what emission-related part or combination of parts might fail in the immediate or distant future without illumination of the MIL. Such an evaluation, which entails the ability to accurately predict which part(s) will fail, in what manner, at what failure rate, and at what point in the vehicle's life, would be, at best, extremely speculative. As stated before, appropriate remedial action should be based solely on compliance (or lack of) with the OBD II requirements.

The ability of the Executive Officer to order appropriate remedies, including recall, irrespective of a finding of direct emissions consequences, is also necessary so that California can continue to meet its obligations under the federal CAA that the states incorporate OBD checks as part of their inspection and maintenance (I/M) programs.⁴⁴ This has been an objective of the OBD II regulation since its inception.⁴⁵ The ARB agrees that requiring OBD checks in the state's I/M program will improve the I/M program and obtain greater emission reductions. The ARB further believes that OBD-

⁴² California Department of Consumer Affairs, Bureau of Automotive Repairs, Executive Summary Report, January to December, 2000.

⁴³ See title 13, CCR section 2147.

⁴⁴ Refer to section 202(m)(3) of the CAA; 40 CFR part 51, subpart S.

⁴⁵ See Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider New Regulations Regarding Malfunction and Diagnostic System Requirements Applicable to 1994 and Later New California Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles With Feedback Fuel Control Systems (OBD II), July 28, 1989 (1989 Staff Report).

I/M checks are the most reliable and cost-effective means for testing the increasingly lower emission standards that California requires for certification. A pilot program conducted by EPA found that OBD technology is a viable I/M test and that emission reductions that can be achieved from using OBD checks are at least as large if not larger than the emission reductions obtained from I/M tailpipe tests.⁴⁶ The study found that in addition to identifying the same high emitters as the tailpipe emission test, the OBD checks additionally identify components that have degraded and may cause future emission problems. The motor vehicle manufacturers themselves share many of these same views and conclusions.⁴⁷

To protect the benefits of an OBD-based I/M check, it is imperative that functional and viable OBD II systems are installed in all certified vehicles. To assure that they are, it is necessary to assure that all OBD II systems that are found to be effectively nonfunctional be recalled and repaired, irrespective of whether one can make a showing that the vehicles, equipped with such nonfunctioning systems, on average comply with applicable tailpipe certification standards.

3. Mandatory Recall

⁴⁶ Evaluation of On Board Diagnostics for Use in Detecting Malfunctioning and High Emitting Vehicles, August 2000.

⁴⁷ See September 28, 2000 letter from the Alliance of Automobile Manufacturers and the Association of International Automobile Manufacturers to the Wisconsin Division of Motor Vehicles, a copy of which was submitted to EPA as part of the Associations' October 13, 2000 response to Amendments to its Vehicle Inspection Maintenance Program Requirements Incorporating On-Board Diagnostics (OBD) Checks, Notice of Proposed Rulemaking, September 20, 2000. In the September 28, 2000 letter, the Associations stated in relevant part:

We are writing to support changes to your vehicle inspection and maintenance (I/M) program that replace conventional I/M testing with a check of the on-board diagnostic (OBD) system for 1996 and later model year gasoline vehicles....Such changes would not only benefit air quality but also drastically reduce test times for consumers.

The OBD system continuously monitors the vehicle's emission control system for any failure that could cause emissions to increase beyond the failure threshold. In contrast, conventional I/M programs take a one-time snapshot of the vehicle's emissions either annually or biennially. Furthermore, the OBD system is more accurate than conventional I/M tests, and the OBD failure thresholds are based on the certification standards applicable to that particular vehicle model (LEV, Tier I, Tier II, etc.). Thresholds for conventional I/M testing are grouped based on model year or even multiple model years. Finally, in the event of failure, the vehicle's OBD system stores information about the failure, allowing a technician to diagnose and repair the vehicle faster and with more accuracy. If a vehicle fails a conventional test and does not have any OBD information stored, it may be very difficult to diagnose and repair.

From the customer's standpoint, OBD checks reduce test times and allow I/M check stations to focus on the detection and repair of vehicles with emissions equipment not functioning as designed. Herein lies the greatest potential for air quality improvement, which is the primary reason for the existence of I/M programs.

The staff is proposing that the most seriously design-flawed nonconforming OBD II systems be subject to mandatory recall. Under section 1968.5(c)(3)(A) of the proposed regulation, the Executive Officer would be required to order the recall of OBD II systems that have at least one major monitor that performs so egregiously that it cannot effectively detect malfunctions or cannot be validly tested in accordance with the procedures of the California I/M program. Requiring mandatory recall of systems that cannot effectively function in-use is consistent with the objectives of the OBD II regulation that motor vehicles be certified with OBD II systems that monitor all emission-related components so that malfunctions may be quickly detected and repaired.⁴⁸ The regulation was developed to provide assurance that vehicles retain their emission control capabilities near certification levels throughout their life in-use by alerting vehicle operators and service technicians that emission-related components are deteriorating, if not fully failing. To be viable and to obtain the benefits of the OBD II program, OBD II systems must be able to function with reasonable frequency in-use and detect malfunctions at or near the in-use thresholds established by the regulation. Monitors that perform at levels significantly below the established criteria thresholds in-use run the risk of undermining the potential benefits of the OBD II program. In proposing the cut-points for mandatory recall, the ARB staff has relied on their expert judgments regarding system performance and the years of experience in development, certification, and enforcement of the OBD II regulation. The ARB staff has concluded that systems that operate below these levels are essentially nonfunctional and need to be repaired or replaced.

By specifying minimum performance levels, below which a system would be considered nonfunctional and in need of recall, the Executive Officer would be providing manufacturers with clear notice and direction as to what the ARB considers to be a totally unacceptable system. With such knowledge, manufacturers can better plan and design their product lines and perform necessary internal testing to assure proper performance of the OBD II systems that they manufacture and distribute. The minimum performance levels that would be established by the regulation for recall are fair and reasonable. The levels have been set so as to provide a liberal margin of error that distinguishes between a monitor that fails to meet the threshold levels required for proper detection of malfunctions and a monitor that performs so poorly that it cannot be considered functional.

4. Discretionary Remedial Action

Additionally, section 1968.5(c)(3)(B) of the proposed regulation would provide the Executive Officer with discretionary authority to order remedial action when he or she finds an OBD II system to be nonconforming for reasons other than those requiring mandatory recall. The Executive Officer would have discretion to order a graduating scale of remedies. In determining appropriate remedial action, the Executive Officer would consider all relevant circumstances surrounding the existence and discovery of

⁴⁸ Refer to the 1989 Staff Report and 1991 Staff Report: Initial Statement of Reasons for Proposed Rulemaking, July 26, 1991.

the nonconformity, including the factors specifically set forth in sections 1968.5(c)(3)(B). For example, in cases where the nonconformity is limited, the OBD II system is largely functional, and the manufacturer has voluntarily identified the nonconformity, the Executive Officer would have authority to order a lesser form of remedial action, comparable to a deficiency. In the most serious cases, where the Executive Officer determines that the OBD II system, when considered in its totality, is unacceptably ineffective, he or she would have discretion to order the recall of the nonconforming systems.

5. Monetary Penalties

Pursuant to authority granted under the Health and Safety Code, the Executive Officer may seek monetary penalties against a manufacturer for a nonconforming OBD II system on a case by case basis.⁴⁹ In determining whether to seek penalties, the Executive Officer would consider all relevant circumstances, including, but not limited to, the factors set forth in title 13, CCR, section 1968.5(c)(4).

G. Notice to Manufacturer of Remedial Order and Availability of Public Hearing.

The proposed regulation would also require the Executive Officer to notify the manufacturer of the ordered remedial action and/or his or her intent to seek monetary penalties in an administrative or civil court. The notice would be required to include a description of each class of vehicles or engines covered by remedial action and the factual basis for the determination. The notice would further provide a date at least 45 days from the date of receipt of such notice for the manufacturer to submit a plan outlining how it proposes to comply with the remedial order or to request a public hearing to consider the merits of the ordered remedial action.

H. Requirements for Implementing Remedial Action

The proposed regulation would also set forth requirements and procedures to be followed by the manufacturer in implementing either a voluntary, influenced, or ordered remedial action. Among other things, the regulation would establish specific provisions requiring manufacturers to establish remedial action plans, provide notice to owners of vehicles and engines affected by the remedial action, and maintain and make available specific information regarding the remedial action. The proposed requirements and procedures are similar, but not identical, to those required in title 13 CCR sections 2113 – 2121 and sections 2123 – 2132, the existing general recall provision.⁵⁰ As with the

⁴⁹ Refer to Health and Safety Code, section 43016, 43154, 43211-43212.

⁵⁰ The proposal includes a requirement that manufacturers subject to an OBD II recall shall report on the progress of the remedial action campaign by submitting reports for eight consecutive quarters. See section 1968.5(d)(B). Although the eight consecutive quarter requirement differs from the reporting requirements of title 13, CCR sections 2119(a) and 2133(c), the proposal is in fact consistent with ARB practice. See "Voluntary and Influenced Recall Recordkeeping and Reporting," MAC #96-08, July 26, 1996. Similarly, the proposed reporting requirements require manufacturers subject to vehicle recall to provide the ARB with a list of data elements and designated positions in the submitted reports that

existing enforcement provisions, the proposed requirements for implementing remedial action provide clear directions to a manufacturer subject to a remedial action on its obligations and responsibilities in carrying out a remedial action campaign. This should assure effective and expeditious implementation of proposed remedial action plans and compliance with the OBD II requirements. The proposed requirements also assure that all manufacturers follow consistent reporting requirements that allows for full and effective monitoring of the remedial action campaign by the ARB.

Although the requirements for implementing remedial actions are very similar to the existing provisions that manufacturers and the ARB staff alike have had years of experience working with, separate provisions for OBD II-related remedial actions are being proposed. This is being done for obvious reasons. As previously stated, the OBD II enforcement issues are considered, in many ways, unique, and for purposes of clarity should be self-contained. As noted, the existing enforcement requirements primarily focus on general failures of emission control components and general violations of the ARB tailpipe and evaporative emission regulations and do not specifically address the unique issues that pertain to OBD II systems. Finding a serious need for specific enforcement procedures, it makes sense that the requirements and procedures for implementing OBD II-related remedial actions should be included within the self-contained OBD II enforcement procedures. Having a single regulation with all OBD II enforcement provisions should prove helpful and convenient to both affected manufacturers and ARB staff. This will also avoid the need for the general tailpipe and evaporative emission implementation requirements to set forth specific exceptions that apply only to OBD II enforcement issues. The result should be a clearer, more readily understandable document.

I. Penalties for Failing to Comply with the Requirements of Section 1968.5(d).

The staff is proposing a regulation that would make it clear that a manufacturer could be subject to penalties for failing to comply with the proposed requirements for implementing remedial action. Such failures would be considered a violation of the Health and Safety Code and would subject the noncompliant party to penalties prescribed under Health and Safety Code section 43016. The proposed authority to assess monetary penalties should encourage compliance with the requirements and encourage thorough and timely implementation of both voluntary and ordered remedial action campaigns.

indicate all vehicles or engines subject to the recall that have not as yet been corrected. See section 1968.5(d)(6)(B)(ix). Although not expressly set forth in the existing recall reporting requirements, the information required under the proposed provision has a long-standing ARB requirement. See "Revision to Mail-Out 91-13 (Implementation of Air Resources Board's (ARB) and Department of Motor Vehicles' Registration Renewal/Recall Tie-In Program), Mail-Out 91-19, April 10, 1991.

XIV. ISSUES OF CONTROVERSY

A. Why shouldn't the ARB have the responsibility of identifying every failure mode that manufacturers are required to detect?

The automobile manufacturers have expressed concern about their liability for identification of all possible failure modes that could occur in a vehicle's emission control system. They contend that failure modes found in-use, but not anticipated by manufacturers nor identified as relevant by the ARB at the time of vehicle certification, should not be used as a basis for finding an OBD II system to be nonconforming.⁵¹ The ARB staff disagrees. From the onset of the OBD II program, the OBD II requirements have been structured to require manufacturers to identify components that perform outside design specifications for any reason as opposed to components that only malfunction due to commonly known failures. As such, neither the ARB nor the manufacturers are responsible (or "liable") for pre-identifying every possible failure mode to design a compliant OBD II diagnostic. Manufacturers are solely responsible for designing an OBD II system that can identify components performing outside of the defined performance criteria, otherwise known as the malfunction criteria.

To understand the issue, one must understand the distinction between the terms "failure mode" and "malfunction criteria." A "failure mode" is the specific mechanism or way in which a component can fail; in other words, it is the underlying cause of a component's inability to perform or work properly. "Malfunction criteria" are general objective performance criteria that are based on the output signal(s) and/or functional response of the component and define the boundaries for "good" operation (e.g., within design specifications) and "bad" operation (e.g., outside of design specifications) irrespective of the "failure mode." There are typically one or more different failure modes for a specific malfunction criterion. For example, an electronic sensor can experience a circuit continuity failure such as an open circuit. The open circuit is the defined "malfunction criterion." The "failure mode" which causes an open circuit can vary greatly, such as internal circuit failures of the sensor, loose, broken, or disconnected wiring between the sensor and the on-board computer, or an internal circuit failure of the on-board computer. The "malfunction criterion", on the other hand, is the same in all cases and simply requires manufacturers to detect an open circuit (typically sensed by a circuit within the on-board computer), regardless of where the open circuit occurred or what caused the open circuit.

Manufacturers have recently expressed the position that they believe that it is the responsibility of the ARB to identify all possible types of failure modes that OBD II systems are required to detect and to specify those, rather than the malfunction criteria, in the regulation. The ARB, however, does not possess the experience and intimate knowledge needed to be able to anticipate all potential failure modes that occur in every variation of emission control systems used by each manufacturer. Therefore, it would

⁵¹ All references to contentions raised by Industry refer to letters jointly submitted by the Alliance of Automobile Manufacturers and Association of International Automobile Manufacturers, dated August 21 and September 7, 2001.

be impossible for the ARB staff to identify the specific failure modes in the regulation that would adequately address every type of emission control system variation that manufacturers currently (or will ever in the future) use. Given the large variation in hardware, software, and emission control strategies used by manufacturers, a “one-size-fits-all” list of failure modes is inappropriate and not technically feasible. Moreover, requiring manufacturers to detect specific failure modes would necessitate significant redesigns of diagnostic systems since current diagnostic systems are generally unable to distinguish between the different failure modes of a component malfunction. On the other hand, by not detailing specific failure modes in the proposed OBD II regulation, the ARB staff is attempting to continue to allow manufacturers more flexibility in designing their own emission control and diagnostic systems.

The regulation currently defines fixed malfunction criteria to evaluate performance characteristics of a component, regardless of the unique variations of its implementation by different manufacturers. More specifically, the malfunction criteria are based on the same signals and/or information that the on-board computer uses for emission control and diagnostic purposes and do not vary based on the specific hardware or software strategy utilized by the manufacturer. Accordingly, the ARB believes that the malfunction criteria set forth in the proposed regulation are sufficient in identifying/diagnosing virtually all failure modes for the vast majority of the emission control components and systems and clearly define the extent of the manufacturer’s liability. For example, the OBD II regulation requires the exhaust gas recirculation (EGR) system monitor to detect a malfunction that results in low, high, or no flow through the system. This means manufacturers must ensure that any failure mode that results in the EGR system meeting any of the three malfunction criteria is detected by the OBD II system regardless of the underlying cause (i.e., failure mode) for the low, high, or no flow malfunction. Accordingly, manufacturers design diagnostics that determine or measure the flow and compare it to the low and high limits. In most cases, manufacturers are unable to separately determine the failure mode (e.g., a broken EGR valve, plugged flow delivery tubes, etc.) that caused the flow malfunction but can determine whether the overall flow of the system falls within acceptable bounds. Furthermore, manufacturers are only responsible for failure modes that meet or exceed the malfunction criteria specified in the regulation. If a failure mode exists that does not meet or exceed the specified malfunction criteria (e.g., erratic but not too high or too low flow), manufacturers are not required to detect it.

While the vast majority of the components monitored by the OBD II system have very specific malfunction criteria, there are a few instances where the relationship between the malfunction criteria and the failure mode is not as well-defined, which poses more difficulty in developing a monitoring strategy to detect when the component is no longer performing within acceptable limits. For example, the HC conversion efficiency of a catalyst system is generally inferred by the oxygen storage capability of the catalyst. As such, manufacturers rely on a correlation (which they determine during the development process) between HC conversion and oxygen storage. However, the failure mode of the catalyst (e.g., repeated exposure to overly high temperature due to misfire, poisoning, etc.) can, in some cases, alter the correlation. This requires

manufacturers to determine the most representative and “worst-case” failure modes and design their OBD systems accordingly. Manufacturers have now indicated that they cannot predict every possible failure mode and account for them in their design, especially since some failure modes may be due to vehicle operator actions beyond their control (e.g., the use of leaded gasoline in an unleaded vehicle which would cause irreversible poisoning of the catalyst). As such, they believe it is appropriate for the ARB staff to enumerate each of the specific failure modes for which the manufacturer will be held. Clearly, however, design engineers for the vehicle manufacturers and their suppliers are better qualified than the ARB staff to determine the specific failure modes for each of their unique catalyst systems since they are generally required to perform extensive investigation of all possible failure modes (commonly referred to as a Failure Mode and Effects Analysis (FMEA)) as part of their routine engineering duties. Further, manufacturers regularly require parts replaced under warranty at dealerships to be sent back to the manufacturer’s facility for analysis. These “real world” failed parts are typically studied and used to validate, verify, and adjust the manufacturer’s internal design process, failure analysis, and determination of representative and worst-case failure modes. Thus, as manufacturers have been successfully doing for the past six years, they will continue to be responsible for identifying catalysts that have a conversion efficiency below the minimum acceptable level. However, to alleviate manufacturers’ concerns regarding failure modes that are beyond their control, language has been added that clarifies that manufacturers will not be responsible for identifying catalysts or other components that have failed in a manner solely due to vehicle operator action.⁵²

In some cases the malfunction criteria are not well defined because they are dependent on how a component is used as part of the emission control system or the diagnostic system. For example, while the OBD II regulation identifies some specific oxygen sensor characteristics (response rate, voltage amplitude, and drift or bias that all manufacturers are responsible for monitoring), the malfunction criteria also require manufacturers to monitor for a malfunction of any “other characteristic(s)” that would cause emissions to exceed 1.5 times the applicable standards. In this case, manufacturers have the task of identifying any failure modes of other sensor characteristics that would fall under this category. Again, manufacturers’ design engineers are in the best possible position to determine the failure modes that could cause emissions to exceed the applicable standards. As in the case of catalysts, over the past six years, manufacturers have been successful at making such determinations. For instance, each manufacturer develops its own fuel control strategy, and therefore uses the oxygen sensor signals in slightly different ways from another manufacturer. While one characteristic of a sensor may be extremely crucial to proper fuel control for one manufacturer, it may be completely irrelevant for another manufacturer’s fuel control system. This places design engineers at a considerable advantage over the

⁵² Section (b)(4)(A) of the proposed OBD II enforcement regulation (1968.5), which states that for enforcement testing, the “Executive Officer may not use components deteriorated or simulated to represent failure modes that are solely caused by vehicle operator action(s) beyond the vehicle manufacturer’s control and that could not have been foreseen to occur (e.g., the use of leaded gasoline in an unleaded vehicle, etc.)”

ARB staff in being able to identify any other characteristics specific for the type or brand of sensor used and the manner in which they process the sensor signals for fuel control purposes. Based on these facts, manufacturers are in a much better position to identify other characteristics, if any, that could deteriorate without any corresponding deterioration in the characteristics specifically identified in the regulation.

B. MIL illumination thresholds are too stringent and not cost-effective.

The automobile manufacturing industry contends that the proposed MIL illumination thresholds are too stringent and impose unfair economic costs on consumers. In this regard, some manufacturers have suggested that the low malfunction criteria thresholds would result in consumers having to replace components that would produce minimal emission benefits and would not be cost-effective. The staff has reexamined this issue in light of comments received and believes that the proposed MIL illumination thresholds are necessary to ensure that manufacturers design durable emission control systems whose emissions remain close to the certification standards for the entire life of the vehicle. This must occur in order to achieve all the potential emission benefits of the Low Emission Vehicle II program. Further, the staff believes that this can be done cost-effectively.

Although the manufacturers suggest the thresholds proposed by the ARB staff are too small, allowing higher emission thresholds could substantially reduce the emission benefits of the Low Emission Vehicle II program. Additionally, with higher MIL illumination thresholds, vehicle manufacturers may forsake improving durability of emission control components for cost savings since such components would be allowed to deteriorate to a greater extent. For example, additional precious metal loading is generally used to improve durability of catalytic converters by providing more active sites for catalytic activity. However, given the high cost of precious metals, there is currently a very intense activity in the industry to minimize or “thrift” the precious metal content in catalysts. Under the higher thresholds proposed by industry, manufacturers would likely continue this “thrift” effort, further undermining the long-term effectiveness of catalysts and the benefits of the Low Emission Vehicle II program.

In so finding that the proposed malfunction emission criteria levels are appropriate, the staff also rejects the motor vehicle industry’s objections that the proposed levels do not provide a sufficient emission compliance margin. The manufacturers contend that the proposed MIL illumination thresholds affect an OBD II monitor’s ability to report valid test results (i.e., to correctly detect a malfunction as opposed to indicating a malfunction when no fault is actually present). They argue that if they fail to provide enough “separation” between the certification emission level of the vehicle and the emission level at which the MIL illuminates, the MIL could illuminate prematurely, leading to customer dissatisfaction. The staff, however, believes that the proposed thresholds provide a sufficient emission compliance margin to avoid such problems. Accordingly, the proposed MIL illumination thresholds would promote lower average emissions from the vehicle fleet.

Some manufacturers have suggested that higher MIL illumination thresholds would not affect their product designs and that their primary motivation for wanting more relaxed thresholds is to ensure that consumers can make more cost-effective repairs in I/M programs. Many believe that with higher MIL illumination thresholds, detection of malfunctions would not be as frequent, resulting in fewer replacements and repairs. However, as stated above, the ARB staff is concerned that higher thresholds would encourage manufacturers to reduce the long-term durability and performance of their emission control components. Given the intense competition in the automobile industry, the staff believes that any relaxation in the requirements will result in manufacturers trying to maximize vehicle cost savings. This may result in vehicles being equipped with less robust parts, requiring more frequent repair. Thus, the staff believes that higher MIL illumination thresholds will not necessarily result in less frequent detection of malfunctions and fewer replacements and repairs. Indeed, the fear is that vehicles would be able to operate at much higher emission levels in use, without any associated reduction in consumer service and repair costs. Even if higher MIL illumination thresholds did result in fewer vehicle repairs, the loss in emission benefits would be unacceptable in that they are essential in meeting the State Implementation Plan goals.

The staff further disagrees with motor vehicle manufacturers' contentions that the proposed malfunction criteria thresholds are not cost-effective. While the ARB staff proposes, in general, that components be replaced when they cause emissions to increase to 50 percent above the standards, manufacturers argue that it would be more cost-effective to repair vehicles when emissions increase to 7 times the standards or more. For example, they claim that under the ARB's proposed thresholds, a consumer would be required to replace a SULEV catalyst system when it is still 98 percent efficient at a cost of \$750. In contrast, under their proposed thresholds, the catalyst system would be replaced at 95 percent efficiency. However, such an example where cost-effectiveness is relatively low fails to demonstrate the overall program is not cost effective. In evaluating the cost-effectiveness of the OBD II program, the staff revised the analysis for the Low Emission Vehicle II program using average repair costs from current I/M programs and making assumptions about repair rates that could be expected from these advanced vehicles through 230,000 miles (the analysis can be found in Appendix III). During this analysis, the staff found that repair costs varied widely, with some repairs being very inexpensive while others were more costly. The staff concluded that proper assessment of a program cannot be based on worst case scenarios. Rather, a proper analysis requires that conclusions be drawn after thoroughly reviewing the program in its entirety.

The catalyst repair example cited above also misconstrues the efficiency level of the catalyst under the ARB's proposed thresholds as well as overstates catalyst repair costs. Generally, when conducting catalyst system monitoring on a SULEV, the OBD II system monitors only the front catalyst. Using ARB's proposed thresholds, a malfunction is typically indicated when the efficiency of the front catalyst drops substantially, not just a small amount (e.g., 1-2 percent) as the comment suggests. This is because the rear catalyst efficiency typically increases to effectively compensate decreases in front catalyst efficiency when the front catalyst is damaged or deteriorated.

Thus, the front catalyst efficiency typically drops substantially before the rear catalyst is unable to compensate enough to achieve near-SULEV emissions at 98 percent overall efficiency of the system. Also, replacement of a front catalyst alone would not cost the \$750 suggested by the industry. Rather, an aftermarket catalyst meeting new provisions currently being developed for application on OBD II vehicles would cost between \$200 to \$250.

There are other reasons for not delaying illumination of the MIL until further emission deterioration has taken place. For example, misfire problems can quickly lead to high emissions and consequent damage to other components if not caught quickly and repaired. Some misfire repairs might consist of reconnecting a loose cable, replacing a spark plug, or rebuilding a cylinder head assembly, all at very different costs. To wait for further emission consequence before making repairs, as industry is proposing, would be unwise since many faults could be repaired fairly inexpensively, and waiting would not necessarily lower costs, but could damage other expensive components, requiring more costly repairs. Also, it should be noted that most of the more than 120 fault codes in OBD II systems pertain to components for which there are no emission thresholds for determining a malfunction. They are judged on the basis of electrical checks, rationality evaluations, functionality, or other similar checks. Thus, any “relaxing” of the emission thresholds would have no impact whatsoever on the vast majority of OBD II diagnostics. This further mitigates the effects of emission thresholds on overall program cost-effectiveness.

By examining the overall program (as opposed to just one example), the staff determined that implementing industry’s proposed higher MIL illumination thresholds would be less cost-effective than ARB’s proposed thresholds (see Appendix III for more details). The higher thresholds proposed by industry would result in substantially lower emission reductions with little cost savings relative to the staff’s proposal. The shortfall in emission reductions substantially affects the cost-effectiveness of industry’s proposal, in that it is difficult to recover the loss in reductions at a comparable cost-effectiveness value. Further, as mentioned earlier, stricter emission thresholds lead to more durable components, which benefits consumers.

C. Is OBD II an emission standard, and if not, under what authority does ARB believe it can order a recall?

The motor vehicle manufacturers have posed a number of challenges to ARB’s authority to recall vehicles equipped with noncompliant OBD II systems. Among other things, they contend OBD II requirements are not emission standards, and the ARB consequently does not have authority to recall OBD II systems under section 43105 of the Health and Safety Code. According to the industry, that section provides that the ARB may only recall vehicles that fail to comply with either adopted emission standards or test procedures. Industry consequently asserts that it is unaware of any statutory basis that allows for the ARB to order a recall if a manufacturer can show that the subject motor vehicle fleet is not in violation of established emission standards or test procedures.

As explained in detail in section XIII above, the ARB's authority to adopt OBD II-specific enforcement procedures is pursuant to general and expressed authority vested to it under the Health and Safety Code.⁵³ Section 43105 expressly provides that the ARB has authority to order a manufacturer to undertake corrective action, including recall, on vehicles that fail to meet established emission standards or test procedures. Contrary to industry, the ARB believes that the OBD II regulation incorporates both emission standards and test procedures. Section 39027 of the Health and Safety Code defines "emission standards" as "specified limitations on the discharge of air contaminants into the atmosphere." For virtually all of the major OBD II monitors, the OBD II regulation requires malfunctions to be detected before emissions exceed 1.5 times the applicable tailpipe emission standards. In other words, the emission thresholds linked to these monitors specify the level of discharge of pollutants into the atmosphere beyond which a malfunction indicator light must illuminate to signal the need for repair. For many of the other monitors, inclusion of components under the monitoring requirements is based on whether a malfunction of the component could cause a "measurable increase" in emissions, so that comprehensive components are regulated, in part, relative to their ability to increase emissions by a measurable amount. These criteria clearly establish quantitative emission standards that govern a malfunction determination, thereby limiting the discharge of emissions into the atmosphere. Therefore, they meet the Health and Safety Code definition of "emission standards." Furthermore, these findings have been affirmed by the California Legislature and are consistent with findings by the United States Environmental Protection Agency (see section XIII above). Lastly, some OBD II requirements cover vehicle evaluation testing (e.g., monitoring system demonstration testing, production vehicle testing) and specify test procedures to be conducted either by the manufacturer or the ARB to ensure OBD II systems are working properly. Therefore, the ARB considers the OBD II requirements to be both emission standards and test procedures. Furthermore, as discussed in Section XIII and Issue of Controversy D. below, this inability of the OBD II requirements to fit "cleanly" into only one of these two categories is one of the very reasons the staff is proposing a stand-alone set of enforcement procedures (proposed section 1968.5 of title 13, CCR) specifically for OBD II.

In summary, given that the OBD II regulation establishes both emission standards and test procedures that are required for certification of new motor vehicles, the ARB has undisputed authority under Health and Safety Code section 43105 to adopt the OBD II-specific enforcement regulation. Beyond this express grant of authority, Health and Safety Code, section 39600 further entrusts the ARB with general powers to do such acts as may be necessary for the proper execution of the powers and duties granted to it under Health and Safety Code. The ARB adopted the OBD II regulation pursuant to the powers and duties granted to the ARB under Health and Safety Code sections 43013(a), 43018, 43101 and 43104. Accordingly, under its

⁵³ See Health and Safety Code sections 39600-39601, 43013(a), 43018, 43101, 43104, and 43105.

general powers, the ARB is authorized to adopt all necessary enforcement regulations to assure compliance with the OBD II requirements.

D. Has ARB demonstrated a “justifiable need” for OBD II-specific recall provisions?

Industry had questioned the need for a separate, OBD II-specific recall regulation (proposed section 1968.5 of title 13, CCR). They consider the general enforcement requirements set forth in title 13, CCR, Section 2, Articles 2.0 through 2.4, and the specific provisions contained in section 1968.1(i) sufficient for dealing with OBD II-related enforcement issues. Staff disagrees believing that the existing enforcement procedures do not adequately address the unique issues involved in enforcing the OBD II regulation. The staff’s conclusion is based on more than eight years of experience in implementing and enforcing the OBD II regulation under these provisions. The general enforcement provisions found at title 13, CCR section 2, Articles 2.0 through 2.4 were initially adopted for general enforcement of tailpipe and evaporative emission standards. The staff has found that application of these provisions to OBD II enforcement has resulted in confusion and uncertainty as to the applicability of certain of its provisions, which, in turn, has raised questions among manufacturers as to what is expected of them for purposes of compliance. This has impacted the ARB’s ability to enforce the regulation in an expeditious manner and has resulted in unnecessary litigation and delayed compliance. Similarly, the ARB has found the testing protocol found at section 1968.1(i) to be unclear to at least several manufacturers, resulting in unnecessary disputes as to its meaning and application, which has also impacted effective enforcement and compliance.⁵⁴

In proposing OBD II-specific enforcement provisions, staff recognizes the need and importance for properly functioning OBD II systems on in-use vehicles and the benefit of OBD II systems in ensuring that projected emission benefits from ARB motor vehicle emission reduction programs are achieved. Recent enforcement proceedings involving nonconforming OBD II systems under the existing recall regulations have highlighted the complexity and difficulty of applying the current enforcement procedures to OBD II compliance cases. As stated above, the central problem lies in the fact that the general recall enforcement procedures were not intended to apply to the unique issues that arise in cases involving OBD II noncompliance. Although, when first adopted, staff initially envisioned that OBD II enforcement could be effectively performed under the general enforcement provisions, experience has proven otherwise. Particular confusion under the existing enforcement provisions has occurred over the issue of whether nonconformance with OBD II requirements is, itself, a violation of an emission standard that subjects a manufacturer to recall or merely a defect of an emission related part that does not necessarily require such a remedy.⁵⁵

⁵⁴ See discussion in Issue of Controversy E. below.

⁵⁵ Refer to title 13, CCR section 2123, which provides that the ARB may directly recall of vehicles failing to comply with emission standards but provides manufacturers the opportunity to avoid recall if a faulty emission control component is discovered and average emissions of the vehicle fleet do not exceed the applicable tailpipe emission standards.

Admittedly, and perhaps belatedly, the ARB has come to realize that the language in the existing enforcement procedures, and specifically section 2123, does not address the special issues involved with nonconforming OBD II systems. Contrary to claims by some motor vehicle manufacturers, the ARB has intended since the OBD II regulation was first adopted that poorly designed and effectively nonfunctional OBD II systems should be subject to recall. The ARB has maintained that position regardless of whether a manufacturer can demonstrate that vehicles equipped with the nonconforming systems, on average, meet the tailpipe or evaporative emission standards.

To the extent that a reading of the existing enforcement procedures would not permit the recall of such poorly designed OBD II systems, the staff believes that it is necessary to adopt OBD II-specific enforcement procedures. The need for an OBD II specific protocol is readily apparent when one realizes that noncompliance with the OBD II requirements is not directly tied to emission control system failures that cause increased emissions or result in failure to meet the tailpipe or evaporative emission standards. Rather, the purpose of the OBD II system is to operate as an independent watch for emission control system failures and to notify the driver of any problems, when found, so that they may be immediately remedied. In adopting the regulation requiring OBD II systems, the Board was specifically concerned that failures in high mileage and older vehicles be detected. Many of these failures are not expected to occur for at least 10, 20, or more years into the future. Therefore, it is virtually impossible to forecast, with any degree of certainty, the size and scope of potential problems that the OBD II system may uncover and the emission consequences of those problems. This is especially true because the vehicles being evaluated today are being required to meet increasingly stringent emission standards that require the application of new and challenging technology.

E. Should fleet-average emissions be considered in requiring a recall for an OBD II noncompliance?

As stated above in Issue of Controversy D., the staff is proposing that manufacturers may not be able to overcome a finding that an OBD II system is nonconforming by showing that, on average, vehicles equipped with a noncomplying OBD II system comply with tailpipe and evaporative certification standards. Industry believes, however, that it must be provided an opportunity to demonstrate this, and that if successful, a recall could not be required. For example, if a particular monitor for a group of vehicles was not capable of detecting a component malfunction, then manufacturers want the opportunity to show the component is unlikely to fail at a rate such that emission standards would be exceeded on average. The staff, however, does not believe industry's position makes practical sense for OBD II systems. This is because it is not possible to reliably predict the failure rate of components on older vehicles or their emission impacts. Further, to limit any such analysis to the useful life period, as industry suggests, would be virtually meaningless since the primary usefulness of OBD II systems is to discover problems that occur later in the vehicle life.

Section XIII of the staff report sets forth in detail the reasons why evidence of compliance with tailpipe and evaporative emission standards is insufficient to overcome a finding of nonconformance with the OBD II requirements.

In contrast to the existing enforcement protocol, the proposed OBD II enforcement procedures do not excuse OBD II noncompliance if a manufacturer can show that the affected vehicles comply with the tailpipe and evaporative emission standards. The OBD II requirements are independent requirements for which compliance is mandated. This is not a change in ARB policy. As one example, ARB has requirements for the fuel filler pipe on gasoline vehicles that address physical dimensions and accessibility to the filler pipe to ensure proper mating with the vapor recovery refueling nozzles required at gas stations in California. This is a separate requirement from other tailpipe or evaporative emission standards and a noncompliance with the fuel filler pipe specifications cannot be excused by a showing of adequate tailpipe emissions from the manufacturer's vehicle fleet. Even within the context of "tailpipe emission standards", ARB has distinct standards such as the 50° Fahrenheit tailpipe emission standard and the normal FTP tailpipe emission standard (conducted between 68-86° Fahrenheit). Just as manufacturers are not excused from a violation of the ARB's 50° Fahrenheit tailpipe emission standards by demonstrating that the normal FTP tailpipe emission standards are being met, they cannot be excused from noncompliance with the OBD II standards by a showing of compliance with other emission standards such as tailpipe or evaporative emission standards. The OBD II regulation requiring the development and implementation of OBD II systems was adopted to fill an identified void in the ARB emission reduction program. As explained in section XIII, OBD II systems complement other programs, such as the Low Emission Vehicle program and the California Smog Check program, and help assure that the emission reductions that have been forecasted for those programs are, in fact, achieved. To allow a manufacturer to overcome the need to remedy a nonconforming OBD II system by showing that the failure would not result in the affected vehicles failing to comply with other emission requirements within their useful lives would undermine the specific purpose and intent of the OBD II regulation.

Moreover, as previously stated, the staff does not believe that manufacturers would ever be able to make such a showing, believing that the exercise would be too speculative. In contrast to the procedures that exist in title 13, CCR section 2147, which allow manufacturers to overcome a finding that an emission related part is failing, the complexity of OBD II systems and the myriad of potential failure modes that can be involved make the exercise far too speculative. This is especially true, at this time, when vehicles are being required to meet increasingly stringent tailpipe and evaporative emission standards, involving new and complex technologies.

As stated before, the ARB believes it is not possible to reliably predict the failure rate of components on older vehicles or their emission impacts. Once vehicles pass their useful life (120,000 to 150,000 miles), there are no formal requirements relative to emission control component durability. However, many vehicles in the fleet last 15, 20, or even more years and will accumulate in excess of 200,000 miles before retirement.

The effects of aging, high mileage, variability in quality of parts initially installed on the vehicle, latent parts design flaws, collisions, maintenance, repairs (by persons of varying skills), installation of used parts, changing fuel compositions, abuse, neglect, and many more make it virtually impossible to predict what components on older vehicles will deteriorate or fail and what the emission impacts would be. Industry has countered that if ARB is able to perform sophisticated analyses of emission inventories well into the future, then it should also be able to predict the failure rates of components on vehicles. Making a projection of future trends for large groups of vehicles as is done for estimating the emission inventory, however, is far different than identifying which components on a specific vehicle will fail and when the failures will occur for all the reasons cited above. If it were possible to identify which components on older vehicles will fail and when, then there would be no need for OBD II systems.

Contrary to the claims of industry, the ARB has not in the past considered compliance with other emission standards as a primary factor in determining compliance with the OBD II requirements and proposed remedies. Industry, however, asserts that title 13, CCR section 1968.1(i)(5) clearly indicates that compliance with tailpipe and evaporative standards has been relevant to the inquiry. This interpretation of the section is in error. Section 1968.1(i)(5) provides that in making a decision to recall vehicles for noncompliance with the OBD II regulation, the ARB would consider, among other factors, the level of emissions above applicable standards.

The reference to level of emissions above applicable standards does not refer, as industry contends, to whether the vehicle class, on average, complies with either the tailpipe or evaporative emission standards. In fact the section does not in anyway refer to vehicle fleet averages. Rather the reference is to the level of emissions above the malfunction criteria thresholds set forth in section 1968.1(c) that must be achieved before a monitoring system indicates a malfunction. For example, if the malfunction criterion threshold is 1.5 times the hydrocarbon emission standard, the ARB would consider the level that emissions exceed that standard before the malfunction indicator light (MIL) illuminates (e.g., 1.6 times the standard or 2.5 times the standard, etc.). This reading is consistent with the context of section 1968.1(i)(5) when read as a whole. The later part of the section specifically carves out an exception to recall, stating that “[f]or 1994 through 1997 model years, on-board diagnostic systems recall shall not be considered for excessive emissions without MIL illumination. . . until emissions exceed 2.0 times any of the applicable standards in those instances where the malfunction criterion is based on exceeding 1.5 times. . .any of the applicable standards.”

F. Should the cost-effectiveness of a remedial action be considered?

The automotive industry contends that remedies proposed in title 13, CCR section 1968.5 may not be cost-effective and suggests that perhaps the cost of an ordered remedy may be better spent in other ways that could result in greater emission reductions. The staff, on the other hand, believes that for certain nonconforming systems, remedial action, including recall, is undeniably appropriate and that the cost of the ordered remedy should not be a factor in the decision. The staff has identified

specific criteria in the proposed regulation for determining when a specific remedy should be required. In general, the criteria mandating recall reflect a serious lack of effort or commitment of resources on the part of the manufacturer in developing an OBD II monitor, with the consequence that the system is virtually non-functional. Some of these criteria include a monitor that operates rarely in-use, a malfunction that illuminates the MIL only after emissions far exceed the emission threshold at which the MIL should have been illuminated, an OBD II system that cannot be tested in an Inspection and Maintenance (I/M) program so that valid test results can be obtained, and others. For OBD II monitors that are noncompliant but are more functional, the proposed regulation would allow the Executive Officer to consider a number of factors in determining an appropriate remedy that may or may not require a recall.

In developing requirements such as those in title 13, CCR section 1968.2 for OBD II systems, the ARB staff does consider whether the regulation and the benefits derived therefrom are cost effective (see cost-effectiveness discussions above). But, the ARB is not required to consider, at the time of adopting the regulation, the cost-effectiveness of a future remedial order that would bring into compliance a manufacturer which has elected to ignore the regulation and to produce an essentially nonfunctional OBD II system. The Board has made it unmistakably clear since the OBD II regulation was first adopted that functional OBD II systems are to be installed on all motor vehicles produced for sale in California. To consider cost of compliance when ordering a nonfunctional system to be recalled would potentially undermine the purpose of the regulation. Moreover, if such systems were not replaced because of cost considerations, the effectiveness of the OBD II-based I/M program would also be jeopardized and that program is the only mechanism available to ensure that vehicles maintain low emissions in the latter part of their lives. For example, taking industry's position on remedial costs one step further, a manufacturer could potentially design an expensive non-reprogrammable computer that fails to incorporate a functional major OBD II monitor. If discovered by the ARB, the manufacturer could potentially argue that replacing the computer in all of its vehicles would be too expensive and not cost-effective and that the manufacturer should be excused from having to recall and replace the computers. If that were to occur, such vehicles would continue to be without a functional monitor and could not be effectively tested under the California I&M program. In other words, a manufacturer could knowingly design vehicles that would be too expensive to fix and could be potentially insulated from recall. In such cases, the manufacturer should bear the burden of not having complied with the regulation and taking the most cost-effective steps when designing the OBD II system in the first place. The onus for this failure should not be shifted to the general public.

G. Under what authority may ARB seek civil penalties when a manufacturer undertakes a recall corrective action?

Industry maintains that the ARB does not have authority to seek monetary penalties against a manufacturer for a nonconforming OBD II system once the agency has decided to address the nonconformity through a recall of affected vehicles. It

contends that subjecting a manufacturer to both recall liability and monetary penalties would violate due process.

The Health and Safety Code expressly provides in various parts that a motor vehicle manufacturer may be subject to civil or administrative penalties for violations under Part 5 of the Code.⁵⁶ That authority is not limited, as the industry implies, by the fact that a manufacturer has undertaken a corrective action by recalling nonconforming OBD II systems. The ARB's position that penalties may be appropriate is consistent with its long-established practice.⁵⁷

Industry's contention that penalties should only be assessed in recall cases where a manufacturer has not filed a request for a public hearing to contest a recall order, not pursued a recall hearing in good faith, or has refused to implement a final recall order, misses the mark. Penalties may be appropriate in addition to other corrective action for purposes of, among other things, deterring future violations, compensating the public for harm to the environment, and expelling any economic benefit realized by the violator.

The ARB's position would not violate due process. In seeking monetary penalties, the ARB would be obligated to pursue the action in a state judicial court or an administrative hearing. In such hearings, the manufacturer would be afforded notice and an opportunity to be heard in a full evidentiary hearing.

H. Changes to standardized communication protocols

One important standardized requirement for all OBD II systems is the communication protocol that the vehicle uses to "talk" to generic scan tools. This protocol, or "language", is used by the vehicle to send data to a scan tool used by a technician attempting to repair the vehicle. Currently, vehicle manufacturers are allowed to use any one of four different standardized protocols, and scan tools are designed to try each of the four until communication is established. The use of standardized protocols is essential to allow technicians to use a single scan tool to communicate with all makes and models without having to spend money on constant upgrades to or replacements of scan tools. However, technology continuously evolves, and newer technology is not always compatible with the older technology. In trying to maintain a reasonable balance between the costs to technicians to upgrade equipment and the advantages/added information available to technicians with the newer technologies, the ARB has rarely changed the allowable communication protocols. Accordingly, since the adoption of the first three protocols in 1989, no changes were made until a fourth protocol was added seven years later in 1996.

⁵⁶ E.g., Health and Safety Code sections 43016, 43023, 43154, 43211, and 43212.

⁵⁷ See Settlement Agreement with Ford Motor Company regarding Recall Nos. 91E01 and 91E03, October 16, 1991 and Settlement Agreement with General Motors Corporation regarding Recall No. 96-033.

With the proposed regulation, section 1968.2, the ARB staff is proposing the addition of a fifth protocol, ISO 15765, a Controller Area Network (CAN) protocol, beginning with the 2003 model year. While automobile manufacturers have generally supported the usage of CAN on their vehicles, they disagree with the ARB staff on the phase-in schedule for this implementation. Additionally, the California Bureau of Automotive Repair (BAR) has expressed concern that the ARB's proposed allowance for CAN will require a costly upgrade to inspection and maintenance (I/M) stations statewide and thus should not be included or, at a minimum, should be delayed until a later date. However, the ARB believes that the proposed implementation schedule allows sufficient time for both vehicle manufacturers and I/M stations, and that the implementation of CAN in nearly all vehicles is imminent, as indicated by manufacturers themselves, so that incorporation of CAN into I/M stations will become a necessity.

The ARB originally proposed requirements that would allow manufacturers to implement CAN as early as the 2003 model year and require vehicle manufacturers to implement CAN on all of their vehicles by model year 2007. However, industry proposed to extend this deadline to model year 2009, stating that the 2007 deadline did not allow enough time for full compliance. In response to comments received at the workshop, tentative phase-ins submitted by some manufacturers and meetings with individual manufacturers, the staff has revised the proposal to require all cars to comply by the 2008 model year instead of the 2007 model year. This time frame should provide manufacturers with sufficient lead time to make any necessary changes as well as avoid unnecessary delays in getting the benefits of CAN to service technicians (e.g., faster and more comprehensive trouble-shooting data).

As a result of allowing CAN to be one of the protocols vehicle manufacturers can use, I/M stations that incorporate a check of the OBD II system would need to upgrade their equipment to incorporate CAN software. BAR has expressed concern that such an upgrade would result in significant costs to I/M stations and that the allowance for CAN as early as the 2003 model year does not provide stations with sufficient time for this upgrade. BAR has also asked the ARB to reconsider whether or not to allow the use of CAN altogether. Lastly, BAR has asked the ARB to consider requiring all future vehicles to be "backwards-compatible" (i.e., no matter what technology any future vehicle uses, it will also be equipped with the hardware and software necessary to communicate using one of the existing four protocols).

The ARB staff has considered the cost of implementing the CAN protocol on California's I/M stations. It has determined that such stations would be required to purchase and install special equipment that could support the CAN protocol, and that such equipment would cost approximately \$500 per station. While not finding this amount to be inconsequential, the staff believes that the benefits of the CAN protocol outweigh this one-time upgrade cost. The faster information rate and greater repair information access available with the CAN protocol would benefit technicians when diagnosing and making repairs. The protocol would also provide improvements to the standardization requirements, thereby minimizing chances for problems that could cause a vehicle not to be inspected or repaired properly. Further, nearly all

manufacturers have indicated that they are going to use the CAN protocol on all vehicles in the near future as the “core” communication protocol between the various control modules on the car (ABS, air bag, climate control, engine control, etc.). They state that this will occur regardless of the position taken by the ARB on OBD II communication. Therefore, if the ARB were to reconsider the use of the CAN protocol for OBD II communication, manufacturers would be forced to continue the use of one of the existing communication protocols. In such a case, vehicles would be equipped with both this existing protocol for OBD II communication and the CAN protocol for all other communications. As a result, manufacturers would need to equip these vehicles with software and hardware that could support both protocols, which would result in additional costs. These costs, which are invariably passed onto consumers in the price of a new car, will far exceed the one-time upgrade cost to I/M stations.

Regarding the 2003 model year start date, the ARB had been working with industry and participating in ISO committee meetings for several years in the development of the CAN protocol and even stated its intent at the 1999 OBD II workshop to allow use of the protocol in 2003 model year vehicles. Consequently, some manufacturers have developed and designed their cars accordingly. Delaying the implementation of the protocol would not provide I/M stations significant relief, since all manufacturers will eventually be implementing the protocol, and would simply postpone the inevitable upgrade for the I/M stations.

There is also one notable exception regarding the standardized communication protocols. The existing OBD II requirements allow vehicle manufacturers to request ARB approval to use a different protocol for medium-duty vehicles. This protocol, SAE J1939, was originally designed for use in heavy-duty vehicles. However, many of the engines that are used in heavy-duty vehicles are also used in medium-duty vehicles. As such, the provision was put into the OBD II regulation to allow manufacturers who produce engines for medium-duty and heavy-duty applications to use a common protocol. While reducing complexity (and cost) to the engine manufacturer, a common protocol would also help minimize costs for repair technicians, since most medium-duty vehicles are serviced at the same repair shops as heavy-duty vehicles. Failure to allow the use of a common protocol would potentially require these heavy-duty repair technicians to incur additional cost by purchasing additional scan tools or scan tool upgrades to work on the medium-duty vehicles, even though they use the same engines as the heavy-duty vehicles.

BAR, however, has expressed a concern regarding the cost to upgrade the I/M stations to accommodate SAE J1939. Similar to CAN, this upgrade would require additional software and hardware at each I/M station. Accordingly, BAR has asked the ARB to eliminate the provision for SAE J1939 or any other alternate protocol for medium-duty applications. Further, since no manufacturer has yet used this provision, BAR argues that the provision could be dropped now, thus eliminating the need for this upgrade to the stations.

While the ARB appreciates BAR's desire to minimize costs to I/M stations, the ARB staff must also consider the associated costs to the vehicle manufacturer and to repair technicians. If the use of SAE J1939 was not allowed for medium-duty vehicles, a manufacturer of medium-duty and heavy-duty vehicles would have to implement one of the protocols required for light-duty applications solely for OBD II purposes. The associated costs to the vehicle manufacturer, and ultimately to a purchaser of a new medium-duty vehicle, would likely far outweigh the cost of the one-time upgrade to the I/M stations, much like the case for the CAN protocol. Further, though the individual cost to a repair technician to upgrade his/her equipment would likely be the same as the individual cost to an I/M station to upgrade the equipment, there are generally many more repair technicians than I/M inspection stations. Thus, the total cost to businesses or individuals in the State of California would be higher. These scenarios are also applicable for any alternate protocol other than SAE J1939 that is used for heavy-duty applications. In short, when the protocol used for heavy-duty applications is different than the one used for medium-duty applications, there will be additional costs associated with the presence of two protocols that would likely exceed the costs of upgrades to I/M stations to accommodate one common protocol.

As such, the proposed requirements would not completely eliminate the provision for medium-duty vehicles to use an alternate protocol. Though the proposed requirements eliminate the direct reference to SAE J1939 as the allowable alternate protocol, they still include an allowance for medium-duty vehicles to utilize an alternate protocol as long as it is the same protocol that the ARB adopts for use in heavy-duty applications (which will be decided in a separate regulatory item for heavy-duty OBD at a later date). This compromise would allow engine manufacturers and repair technicians to work with a common protocol on engines in both medium-duty and heavy-duty applications. Additionally, while this does not eliminate the need for I/M stations to upgrade, it does offer the potential for an upgrade that would allow heavy-duty vehicles, which are generally not required to undergo I/M inspections, to also be incorporated into the Smog Check program.

I. Issue of leadtimes

One of the main issues discussed between the ARB and industry has been the leadtime required for implementation of various aspects of the proposed requirements. In earlier drafts of the proposed regulation, the ARB originally proposed leadtimes that were generally more aggressive than those the ARB is presently proposing. In general, most of the proposed requirements for the catalyst, misfire, oxygen sensor, evaporative system, secondary air, and other monitors were originally required to be implemented either by model year 2003 (for some minor changes), or with a three-year phase-in starting with model year 2004. Industry believed this did not provide sufficient time for implementation of the proposed requirements. For most of the monitors, they proposed three-year phase-in periods starting with the 2005 or 2006 model years. During the July 2001 workshop, the ARB took the manufacturers' concerns into consideration, and, where warranted, extended the leadtime.

In general, the phase-ins have been revised to allow manufacturers to incorporate these changes at the same time they are implementing substantial software changes to meet the Low Emission Vehicle II standards (2004-2007 model years). This would allow manufacturers to incorporate the changes in the most cost-effective manner.

REFERENCES

Below is a list of documents and other information that the ARB staff relied upon in proposing the OBD II regulations.

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CAP 2000: title 13, CCR sections 2037, 2038, 2062, 2106, 2107, 2110, 2112, 2114, 2119, 2130, 2137, 2139, 2140, and 2143-2146.

A/C Test procedure, July 1997: title 13, CCR sections 1960.1(q) and 1961(r).

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40 CFR 86.094-17

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Clean Air Act, section 202(m)(3), 42 USC 7521(m)(3)

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Griffin, J. R., "Closed Loop Temperature Feedback for Controlled Catalyst Lightoff and Diagnostics for ULEV," SAE paper 1999-01-0311.

⁵⁸ Copies of Society of Automotive Engineers (SAE) papers are available through the SAE at :
SAE Customer Sales and Support
400 Commonwealth Drive
Warrendale, PA 15096-0001, U.S.A.
Phone: 724-776-4970
Fax: 724-776-0790
E-mail: publications@sae.org
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Technical Support Document, "Technical Status Update and Proposed Revisions to Malfunction and Diagnostic System Requirements Applicable to 1994 and Subsequent California Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles with Feedback Fuel Control Systems– (OBD II)", July 1991.

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Resolution 89-77, adopted September 14, 1989.

APPENDIX I

Section VII.A., "Air Quality Benefit," from Staff Report: Initial Statement of Reasons, "Proposed Amendments to California Exhaust and Evaporative Emission Standards and Test Procedures for Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles 'LEV II'," September 18, 1998.

A. AIR QUALITY BENEFIT

California's plan for achieving the one-hour federal ambient ozone standard is contained in the SIP that was approved by the Board in 1994. The SIP calls for emission reductions of 25 tpd of ROG plus NO_x by 2010 from light-duty vehicles (Mobile Source Measure M2) in the South Coast Air Basin and additional emission reductions in the South Coast Air Basin of approximately 75 tpd ROG plus NO_x (the inventory of these emissions is referred to as the "Black Box"). Although the emission reduction strategies identified in this report are designed to meet the ozone SIP commitment for the SoCAB, the remainder of the state would also achieve needed emission reductions in ozone and particulate matter precursor pollutants. The reductions will also ensure continued statewide progress toward meeting state and new federal air quality standards for ozone and particulate matter. The proposed emission standards will also provide additional reductions for CO.

Using EMFAC7G, the proposed LEV II amendments are estimated to provide approximately 57 tpd ROG plus NO_x emission reductions for the SoCAB in 2010. This proposal would meet the M2 SIP commitment, provide additional emission reductions to cover shortfalls in defined measures, and make progress in reducing the Black Box.

The emission reductions anticipated from the proposed tailpipe standards are:

**Table VII-1
PROJECTED IMPACT OF LEV II TAILPIPE PROPOSAL
(EMFAC7G; tpd SoCAB)**

2010	PCs	LDT2s <6000 lbs. GVW	LDT2s 6000 - 8500 lbs. GVW	MDVs >8500 lbs. GVW	Total Reduction
ROG	1.17	0.93	1.19	0.01	3.30
CO	45.33	41.73	32.44	0.94	120.44
NO _x	15.29	19.83	15.66	0.71	51.49

The emission reductions anticipated from the proposed evaporative standards are:

**Table VII-2
PROJECTED IMPACT OF THE EVAPORATIVE PROPOSAL (tpd ROG)**

	2010	2020
South Coast Air Basin	2.4	8.1
Statewide	6.4	24.4

1. Impact of Proposed LEV II Exhaust Emission Standards. In determining the anticipated emission reductions, staff relied on the current emission inventory model, EMFAC7G with minor adjustments.

In order to calculate the emission reductions, staff assumed a fleet average implementation rate for NMOG according to the Tables II-7 and II-8. For NOx emission reductions and implementation of the 120K standard, staff assumed a 25/50/75/100% implementation of the LEV II standards beginning in the 2004 model year. The emission rate for SULEVs was the same as that used for ULEVs times a ratio of the ULEV to SULEV standards. To account for the projected growth rates for trucks and SUVs the vehicle mix was adjusted to 51% for passenger cars, 33% for light-duty trucks, and 16% for medium-duty vehicles less than 8,500 lbs. GVW. The total population of these vehicles, the number of vehicle miles traveled per vehicle and the number of starts per vehicle were held constant. It should also be noted that the baseline includes the emissions attributable to the Supplemental Federal Test Procedure standards. The analysis for medium-duty vehicles over 8,500 lbs. GVW assumed a baseline emission standard of 0.230 g/mi NMOG, 5.5 g/mi CO and 0.7 g/mi NOx.

2. Impact of Proposed Evaporative Emission Standards. To estimate the emission benefits of the reduced diurnal-plus-hot-soak standards and proposed extended durability requirements, the emission inventory model EMFAC7G was used for the diurnal and hot soak analyses, and the model EMFACX (to be released in late 1998) was used for the running loss analysis (consisting only of the extended durability.) Adjustments to the model were made to account for the proposed phase-in schedule of 40 percent, 80 percent, and 100 percent beginning in the 2004 model year. Other adjustments include temperature and Reid vapor pressure correction factors to account for these conditions in the enhanced evaporative test procedure as compared to those in the model. The methodology was performed only for vehicles in SoCAB, and scaling factors were developed in order to project emissions for statewide purposes.

3. Impact of Proposed CAP2000 Amendments. The proposed CAP 2000 amendments would not be expected to result in any increase in emissions and thus would not be expected to adversely impact the environment. Rather, it is anticipated that the implementation of the manufacturer-conducted in-use test program would likely

decrease emissions because vehicles would be more likely to comply with the standards in-use, which would provide greater protection of our air quality.

4. Net Impact. The total estimated reductions from the LEV II proposal for passenger cars, light-duty trucks and medium-duty vehicles less than 8,500 lbs. GVW for 2010 are 6 tpd ROG (exhaust and evaporative emissions) and 51 tpd NO_x in the SoCAB in 2010.

APPENDIX II

Section II.D., "Cost Analysis," from Staff Report: Initial Statement of Reasons, "Proposed Amendments to California Exhaust and Evaporative Emission Standards and Test Procedures for Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles 'LEV II'," September 18, 1998.

D. COST ANALYSIS

The ARB staff has performed a comprehensive cost analysis of the proposed LEV II exhaust emission requirements applicable to passenger car, light-duty trucks and medium-duty vehicles. Specifically, staff estimated the incremental cost of a ULEV II compared to a ULEV I vehicle for passenger car, light-truck (3751 lb. LVW- 8500 lb. GVW), and medium-duty (8500-10,000 lb. GVW) applications and the incremental cost of a SULEV vehicle for four and six-cylinder passenger car and light-truck applications.

In performing the cost analysis, the cost of parts was not particularly difficult to obtain, but internal corporate costs would have been more difficult since accounting procedures within each company vary, and such costs are not generally revealed. Nonetheless, most vehicle manufacturers now rely increasingly on suppliers of many emission-related parts (e.g., catalysts, air pumps, and many others) to assume more of the engineering development costs and involve them very early in the vehicle development process. Manufacturers rely on these suppliers to produce the final components, rather than source the parts through its own internal facilities. By obtaining parts prices from suppliers, much of the internal costs of automobile manufacturers do not need to be calculated separately, since they are already included in the final cost of parts produced completely by suppliers.

From the following analysis, the following conclusions were drawn:

Incremental retail costs of ULEV II and SULEV vehicles compared to a ULEV I vehicle are:

Category	ULEV II (in \$)	SULEV (in \$)
PC	71	131
LDT 1	46	105
LDT 2	184	279
MDV 2	208	-
MDV 3	209	-
MDV 4	134	-

The cost-effectiveness of vehicles meeting the LEV II program requirements relative to the LEV I program would be favorable, averaging approximately \$1.00 per pound of pollutants reduced. Motor vehicle control measures typically range up to \$5 per pound of emissions while stationary source controls range up to \$10 per pound of emissions reduced. Further, the incremental cost-effectiveness of a SULEV light-truck compared to a ULEV II vehicle is reasonable, ranging from \$2.19 per pound to \$4.76 per pound, depending on the calculation method used.

1. Cost methodology. The ARB cost estimates reflect many of today's low cost producers that rely heavily on suppliers to assist in the development of vehicles from the initial concept stage through the final production process. The present supplier industry is highly competitive and usually incurs lower labor costs than the automobile manufacturers.

The first step taken by the staff in assessing costs was to define the systems and technologies that would likely be used by manufacturers to meet the required emission levels. The ARB continues to emission test the latest available hardware from component suppliers on numerous passenger-cars and light-trucks that have been assembled by ARB engineering staff. Based on ARB's testing, plus considerable discussion with industry engineers and component suppliers, consensus is forming on the most likely emission system configurations needed to meet the LEV II program requirements. From some of the discussions, and looking back at cost estimates provided for the LEV I program, it appears to ARB staff that manufacturers tend to overestimate the level of technology and amount of hardware needed to meet distant development goals.

For the most part, the cost to the manufacturers for the individual components in each of the systems currently under development are now fairly well established. Once emission systems have been defined and hardware costs determined, ARB's assessment of further costs to vehicle manufacturers becomes less clear since these costs are closely guarded by individual manufacturers and they may vary significantly within the industry, as noted above. Besides the cost of hardware, ARB considered additional variable costs including costs of assembly, shipping and warranty. Further, support costs (research, legal and administrative), investment recovery (machinery and equipment to manufacture the parts, assembly plant changes, vehicle development, and costs of capital recovery) and dealer costs (dealership operating costs and costs of capital recovery) are also included.

2. Cost Analysis. In performing this cost study, ARB departed from industry practice of assigning a fixed percentage of the manufacturer's variable cost to cover indirect costs (which include research, legal, and administrative costs), and instead, analyzed where such long term costs would actually occur. The reference vehicles for this cost study are 2003 model-year ULEV I vehicles for which ARB staff estimated the likely technology content based on early production current LEV I and ULEV I vehicles. For medium-duty vehicles, since currently there are very few engine families certified to

ULEV I standards, the likely technology content on a 2003 ULEV I vehicle was estimated based on some confidential pre-production information supplied by automobile manufacturers. Also, staff assumed that engines are generally 4, 6, and 8 cylinder designs, although there are small volumes of 3, 5, 10 and 12 cylinder engines as well. Staff also focused on assessing the cost of ULEVs, and did not analyze LEVs, which would only be less costly than ULEVs. LEVs are really a transitional technology since by 2010, nearly all vehicles will be ULEV II calibrations with some portion of SULEVs and/or ZEVs in order to meet the fleet average requirements. Staff also expects that in order to meet the fleet average requirements, any SULEVs produced would likely be 4-cylinder designs, or maybe some 6-cylinder designs since smaller engines are easier and less costly control than larger ones. Therefore, no SULEV estimate was made for 8-cylinder engines. For SULEVs, staff estimated that neither HC adsorbers or EHCs would be needed to meet a 0.01 g/mi NMOG standard (staff received some input from industry confirming this for at least the 4-cylinder engines).

Tables II-29 thru II-38 detail the cost analysis and since these tables are in Microsoft Excel format, they are attached to the end of the staff report instead of being interspersed in the text.

a) Variable Costs. In this section the cost of new parts added, additional assembly operations, any increases in the cost of shipping parts and any new warranty implications are addressed.

1) Cost of Part. In order to determine the increases in the cost of parts for meeting ULEV II and SULEV standards, an information gathering and analysis effort was conducted to determine the expected emission system configurations and technologies that would be utilized. Tables II-29-33 provide a detailed breakdown of component usage and costs for all of the emission control systems.

Universal Exhaust Gas Oxygen Sensors (UEGO). Discussions with manufacturers suggest that about half believe an UEGO sensor is important to helping achieve ULEV I or ULEV II emission levels (except for medium-duty vehicles greater than 8500 lb. GVW), while the remainder seem to believe they offer little additional benefit. In any event, the incremental cost of an UEGO continues to decrease, so that the latest estimate is a \$10 incremental cost compared to a conventional oxygen sensor. For SULEVs, staff estimated that all manufacturers would use UEGOs for their incremental benefit. They would be used only for primary fuel control, with conventional sensors used downstream.

Air Assist Fuel Injection. For ULEV I or ULEV II vehicles, manufacturers also appear split on the use of air assist fuel injection as well, so that staff estimated manufacturers using them for ULEV I vehicles would continue to use them for ULEV II vehicles. Air assist fuel injection is primarily a technology used for improved HC control, and HC emission requirements are unchanged for the passenger cars. It is expected that light-duty trucks would utilize them in the same proportion as passenger cars for meeting ULEV II requirements. For SULEVs, all vehicles will likely need to utilize this

technology in order to avoid more costly controls such as adsorbers or electrically heated catalysts. The cost of air assist fuel injection was estimated to be the same as in previous estimates, or about \$2 additional per injector.

Heated Fuel Injectors. Improved HC control for larger displacement engines could result from improved vaporization of fuel from heated fuel injectors. Achieving ULEV II and SULEV HC levels when heating larger exhaust volumes and associated catalysts of the larger light-trucks will possibly lead to utilization of this approach on about half of these vehicles. The incremental cost is estimated to be \$3 per injector.

Individual Cylinder Fuel Control. Perhaps one of the most important enablers for achieving ULEV II (including medium-duty vehicles in the 8500-10,000 lb. GVW category) or SULEV NOx emission levels will be the use of individual cylinder fuel control. Accordingly staff estimated all such future vehicles will use it. Although resources will be needed to develop this technology (research and development costs have been included under support costs), no additional hardware would be needed. Discussions with manufacturers indicated they would be utilizing computers with the processing capability needed to carry out this real time modeling for other purposes, so that additional computer costs were not included.

Retarded Spark Timing at Startup/ Electric Air Injection. Quick heating of the exhaust during the cold starting period will require use of retarded spark timing on all ULEV II and SULEV vehicles. In some cases it will be accompanied by modified fuel control and air injection. Modified timing and fuel control would not add hardware cost since these would require only calibration revisions. In those instances where electric air injection is used to further enhance this HC and NOx reduction strategy, staff assumed a cost of \$50 for 4-cylinder vehicles and \$65 for 6-cylinder and 8-cylinder vehicles for a complete system. The system cost was increased to \$75 for medium-duty applications greater than 8500 GVW to account for the higher capacity electric air pump required on such applications. Manufacturers indicated that injecting air at the exhaust valve outlet assisted significantly in reducing HC emissions. Accordingly staff assumed that manufacturers would utilize engine heads with cast air injection passages, and that each head would require its own check valve.

Abbreviated Engine Start-up. Some manufacturers are exploring faster engine cranking speed to achieve near instant engine starting and reduced HC emissions. This could be achieved with an integral starter/alternator design. Staff allowed an additional \$10 for this system relative to its emission benefits, although for the total system cost may be greater, especially in initial volumes (but there are cost savings from eliminating other mechanical/hydraulic systems that could all be electrically powered and, therefore, more efficient). This technology was estimated to be most important for SULEVs.

Low Thermal Capacity Exhaust Manifold. The lower thermal mass of these stainless steel manifolds aids retention of exhaust heat for quicker catalyst light-off, and was assumed to be used on about 75 percent of ULEV II vehicles (100 percent of 8 cylinder light-trucks) and all SULEVs.

Improved Catalyst Systems. For each vehicle category, staff considered whether any increases in catalyst volume, precious metal loading, and higher cell density were required in order to meet LEV II program standards and accordingly, estimated associated costs. Except for ULEV II passenger cars and 4-cylinder ULEV II trucks, catalyst volumes were increased for all other vehicles. All ULEV II and SULEV vehicles were assumed to use advanced thermally durable double-layer washcoats, increased precious metal loadings (including rhodium) and higher cell density substrates. ULEV II vehicles were assumed to use 600 cpi substrates while SULEV vehicles were assumed to use 900 cpi substrates. While passenger cars and LDT1 vehicles are estimated to achieve ULEV II standards without an increase in catalyst volume, six and eight cylinder light-trucks may require a significant increase in catalyst volume compared to that needed to meet ULEV I standards.

The specific increase in catalyst volume for various catalyst configurations was calculated by first estimating the sales-weighted catalyst volume of all 1998 models certified in a vehicle category and then applying to it an estimated percent increase applicable to that category. The estimated catalyst volume was then converted to a cost increase, by assuming that a typical catalyst would cost \$50/liter. For example, SULEV vehicles are expected to incorporate additional close-coupled pipe catalysts, equivalent to a 20 percent increase in catalyst volume in order to provide additional compliance margin with the standards. It was also assumed that the rhodium loading of the catalyst systems would be increased in order to achieve and maintain very low NO_x levels. ULEV II vehicles (including medium-duty vehicles 8500-10,000 lb. GVW) were assumed to use 12 gm/cu. ft. rhodium loading while SULEV vehicles were assumed to use 15 gm/cu. ft. loading. The additional rhodium costs were estimated using a price of \$675/troy ounce. The additional catalyst volume, rhodium, and increased cell density costs for the various categories are detailed in Table II-34. Some manufacturers have expressed concern that LEV II requirements can potentially cause shortages of precious metals, thereby driving prices to unacceptable levels. However, industry experts in precious metals have indicated to staff that given adequate leadtime, mines typically increase production to meet market demand with very little temporary price increases, if any. Looking at the time-period from 1969 to 1989, although the demand for precious metals increased many fold, production has been able to keep pace and market forces have continued to keep prices competitive. Consequently, in taking a historical perspective, it appears that concerns regarding the availability of precious metals may be overstated by the automobile industry.

Engine Modifications. Additional cost for engine modifications to improve emissions was ascribed to 6 and 8 cylinder ULEV II vehicles and 4 and 6 cylinder SULEV vehicles. In some cases manufacturers could place an additional spark plug in the combustion chamber for improved combustion stability (and on a 4 valve per cylinder engine, it could delete an exhaust valve and related hardware to partially offset the cost), or they may add a swirl control valve, or make other changes to further improve engine-out emissions and/or increase cold start exhaust temperatures. Ten dollars was allowed for 4 and 6 cylinder engines, \$15 for 8 cylinder engines and \$20 for

medium-duty applications greater than 8500 GVW that have typically lagged in sophistication relative to lighter-duty vehicles.

2) Cost of Assembly. As in the LEV I program, the LEV II program will rely on refinements to conventional technology. Judging from the detailed analysis in the LEV I program concerning increased assembly costs, which included a detailed evaluation of the likely array of catalyst designs and an associated estimate of increased catalyst welding costs, another detailed analysis for the LEV II program assembly costs would likely yield about the same small incremental assembly costs. Most of the assembly cost increase for LEV II program vehicles would be for the installation of greater numbers of electric air injection systems, where needed. Electrically heated catalysts do not seem likely to be needed. In comparing ARB's previous cost study of the LEV I program (April, 1994), staff estimated an incremental cost per vehicle of \$2 for assembling an air-injection system and \$0.25 for assembly of an additional catalyst per vehicle.

3) Cost of Shipping. Additional shipping costs were allowed for the increased number of vehicles using electric air injection systems (an additional \$0.25 per vehicle using an air pump system).

4) Cost of Warranty. Incremental warranty costs were added wherever air-injection systems were estimated to be utilized at the rate of \$150 per system (\$100 for parts and \$50 for labor) and a failure rate of 0.1 percent was assumed.

Assembly, shipping and warranty costs are detailed in Tables II-39-40.

b) Support Costs. Support costs affecting the retail price of emission requirement changes include research costs, legal coverage for new issues, and administrative increases.

1) Research Costs. Manufacturers have until 2007 to fully phase-in vehicles meeting the LEV II standards. Providing a long leadtime permits large cost savings to the vehicle industry. Incorporation of the required changes can take place systematically within the existing new vehicle development process without incurring redesign to accommodate planned revisions due to frequently changing emission requirements.

Despite the cost savings permitted by long range standards setting, allocation of some additional cost to manufacturers for performing advance system development work is justified when engineering new types of technologies. Consequently, staff has added development cost that includes personnel, overhead and other miscellaneous costs for new technologies such as individual cylinder fuel control and advanced catalyst evaluations. Allowance also has been made for the cost of a fleet of advance development vehicles to carry out the activity. Each advance development vehicle was assumed to cost \$100,000. Details of this assessment are shown in Table II-35. The

costs incurred under this category have been distributed over 100,000 vehicles per year for a total of 8 years.

2) Legal and Administrative Costs. The ARB does not believe that the most likely hardware to be used will introduce liability issues or administrative increases, especially since manufacturers have had considerable experience for some years now with technologies likely to be used to meet LEV II standards. Consequently, no extra cost beyond what has been included under the LEV I program has been included.

c) Investment Recovery. This portion of the cost analysis includes accounting for machinery and equipment to manufacture parts, assembly plant changes (automation), vehicle development (engineering), and cost of capital recovery.

1) Machinery and Equipment to Manufacture Parts. Since all of the new components will be produced by suppliers, the costs of machinery and equipment to manufacture the part are already included in the piece costs.

2) Assembly Plant Changes (Automation). The primary changes from an assembly point of view are in the exhaust system configuration. Since exhaust systems are usually installed as an assembly, this should not affect the current assembly plant operation. Installation of an electric air pump system (i.e., the pump, power switch, shut-off valve, hoses, tubing and check valves) on those vehicles requiring one probably would not lend itself to automation. Therefore, no additional investment in automatic tooling is expected for air-injection systems (labor costs for installation of the pumps and associated parts was covered earlier).

3) Vehicle Development. Once the vehicle development program is handed off from advance engineering, calibration/certification engineers complete the emission control system design process. Since the new parts expected to be required on LEV II vehicles are not substantially different from current systems, no additional costs have been added beyond those already included under the LEV I program. Please note substantial costs were included in the LEV I program for investment costs for vehicle development such as additional dynamometers, low-emission measurement upgrades and others.

4) Cost of Capital Recovery. The cost of capital recovery (return on investment) was calculated at six percent of the total costs to the manufacturer. At least one large-volume manufacturer employs such an approach to calculate the cost of capital recovery. Table II-36 & II-37 show the calculations for the various vehicle applications.

d) Dealer Costs. Dealership costs include accounting for operating costs and the cost of capital recovery. Since the price of the vehicle would increase due to the LEV II program, it is appropriate to account for the additional interest that the dealer would pay for financing the cost of the vehicle and to cover the commission sales

persons will receive as well. An interest rate of six percent was assumed on the incremental cost, and on average, vehicles were presumed to remain in the dealership inventory for one quarter. The increased commission paid to sales persons was calculated at three percent of the differential wholesale price. Dealer costs are shown in Tables II-39 & II-40.

3. Incremental Cost of the LEV II Standards. Tables II-39 & II-40 contain the incremental costs to the consumer of a ULEV II vehicle relative to a ULEV I vehicle for the various classes of vehicles and of a SULEV relative to a ULEV I vehicle.

Table II-29
Passenger Car and LDT1: Incremental Cost of a ULEV II Compared to a ULEV I Vehicle

Emission Control Technology	4-cylinder				6-cylinder				8-cylinder			
	Tech. cost est. (in dollars)	Tech. on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)	Tech. cost est. (in dollars)	Tech. on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)	Tech. cost est. (in dollars)	Tech. on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)
Universal exhaust gas oxygen sensor (a)	10.00	50	50	0	20.00	50	50	0	20.00	50	50	0
Air-assisted fuel injection (b)	8.00	50	50	0	12.00	50	50	0	16.00	50	50	0
Individual cylinder fuel control (c)	0	50	100	0	0	50	100	0	0	50	100	0
Retarded spark timing as start-up (c)	0	0	100	0	0	25	100	0	0	100	100	0
Low thermal capacity manifold (upgrade)	20.00	25	75	10.00	40.00	25	75	20.00	40.00	25	75	20.00
Greater catalyst loading (d)	13.59	0	100	13.59	22.02	0	100	22.02	36.59	0	100	36.59
Imp. double layer washcoat & 600 cpi cell density	1.80	0	100	1.80	2.92	0	100	2.92	4.86	0	100	4.86
Engine modifications (e)	0	0	0	0	10.00	0	100	10.00	15.00	0	100	15.00
Air injection (electric) (f)	50.00	0	0	0	65.00	0	50	32.50	65.00	25	75	32.50
Total incremental component cost				\$25.39				\$87.44				\$108.94

(a) Only the front oxygen sensor in an UEGO type sensor

(b) Air assisted fuel injection requires minor redesign of the idle air control valve at no additional cost and the addition of an adaptor to each injector at a cost of \$2 each

(c) Individual cylinder fuel control and retarded spark-timing at start-up constitute software changes only, at no additional hardware cost.

(d) Catalyst volume on a ULEV II vehicle is estimated to be virtually the same as on a ULEV I vehicle.

(e) Types of engine modifications may be less uniform throughout the industry and may include items such as additional spark plug per cylinder, addition of a swirl control valve or other hardware needed to achieve cold combustion stability, improved mixing and better fuel injector targeting.

(f) Cost of air injection includes an electric air pump with integrated filter and relay, wiring, air shut-off valve with integral solenoid, check valve, tubing and brackets

Table II-30
Light-Duty Truck (3751 lbs. LVW- 8500 lbs. GVWR): Incremental Cost of a ULEV II Compared to a ULEV I Vehicle

Emission Control Technology	4-cylinder				6-cylinder				8-cylinder			
	Tech. cost est. (in dollars)	Tech. on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)	Tech. cost est. (in dollars)	Tech. on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)	Tech. cost est. (in dollars)	Tech. on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)
Universal exhaust gas oxygen sensor (a)	10.00	50	50	0	20.00	50	50	0	20.00	50	50	0
Air-assisted fuel injection (b)	8.00	25	50	2.00	12.00	50	50	0	16.00	50	50	0
Heated fuel injectors	12.00	0	0	0	18.00	0	0	0	24.00	0	50	12.00
Individual cylinder fuel control (c)	0	25	100	0	0	25	100	0	0	0	100	0
Retarded spark timing as start-up (c)	0	0	100	0	0	25	100	0	0	100	100	0
Low thermal capacity manifold	20.00	25	75	10.00	40.00	25	75	20.00	40.00	25	100	30.00
Increase catalyst volume	0	0	100	0	55.50	0	100	55.50	35.10	0	100	35.10
Greater catalyst loading	21.15	0	100	21.15	34.03	0	100	34.03	49.66	0	100	49.66
Imp. double layer washcoat & 600 cpi cell density	2.81	0	100	2.81	4.52	0	100	4.52	6.59	0	100	6.59
Engine modifications (d)	0	0	0	0	10.00	0	100	10.00	15.00	0	100	15.00
Air injection (electric) (e)	50.00	0	0	0	65.00	0	50	32.50	65.00	50	100	32.50
Total incremental cost				\$35.96				\$156.54				\$180.85

(a) Only the front oxygen sensor in an UEGO type sensor

(b) Air assisted injection requires minor redesign of the idle air control valve at no additional cost and the addition of an adaptor to each injector at a cost of \$2 each

(c) Improved precision fuel control envisioned here and retarded spark timing at start-up constitute software changes only, at no additional cost

(d) Types of engine modifications may be less uniform throughout the industry and may include items such as an additional spark plug per cylinder, addition of a swirl control valve or other hardware needed to achieve cold combustion stability, improved mixing and fuel injector targeting.

(e) Cost of air injection includes an electric air pump with integrated filter and relay, wiring, air shut-off valve with integral solenoid, check valve, tubing and brackets

Table II-31
Medium-Duty Vehicle (8500-10000 GVW): Incremental Cost of a ULEV II Compared to a ULEV I Vehicle

Emission Control Technology	8-cylinder and higher			
	Tech. cost est. (in dollars)	Tech.on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)
Universal exhaust gas oxygen sensor (a)	20.00	0	0	0
Air-assisted fuel injection (b)	16.00	0	0	0
Heated fuelinjectors	24.00	0	0	0
Individual cylinder fuel control (c)	0	0	100	0
Retarded spark timing as start-up (c)	0	100	100	0
Low thermal capacity manifold	40.00	0	0	0
Increased catalyst loading	39.65	0	100	39.65
Greater catalyst loading	42.07	0	100	42.07
Imp. double layer washcoat & 600 cpi cell density	7.44	0	100	7.44
Engine modifications (d)	20.00	0	100	20.00
Air injection (electric) (e)	75.00	0	0	0
Total incremental cost				\$109.17

(a) Only the front oxygen sensor in an UEGO type sensor

(b) Air assisted injection requires minor redesign of the idle air control valve at no additional cost and the addition of an adaptor to each injector at a cost of \$2 each

(c) Improved precision fuel control envisioned here and retarded spark timing at start-up constitute software changes only, at no additional cost

(d) Types of engine modifications may be less uniform throughout the industry and may include items such as an additional spark plug per cylinder, addition of a swirl control volve or other hardware needed to achieve cold combustion stability, improved mixing and fuel injector targeting.

(e) Cost of air injection includes an electric air pump with integrated filter and relay, wiring, air shut-off valve with integral solenoid, check valve, tubing and brackets

Table II-32
Passenger Car & LDT1: Incremental Cost of a SULEV Compared to a ULEV I Vehicle

Emission Control Technology	4-cylinder				6-cylinder			
	Tech. cost est. (in dollars)	Tech. on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)	Tech. cost est. (in dollars)	Tech. on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)
Universal exhaust gas oxygen sensor (a)	10.00	50	100	5.00	20.00	50	100	10.00
Air-assisted fuel injection (b)	8.00	50	100	4.00	12.00	50	100	6.00
Individual cylinder fuel control (c)	0	50	100	0	0	50	100	0
Retarded spark timing at start-up (c)	0	0	100	0	0	25	100	0
Abbreviated engine start-up (d)	10.00	0	25	2.50	10.00	0	25	2.50
Low thermal capacity manifold (upgrade)	20.00	25	100	15.00	40.00	25	100	30.00
Close-coupled pipe catalyst(s) (e)	14.78	0	100	14.78	23.94	0	100	23.94
Greater catalyst loading	20.38	0	100	20.38	33.03	0	100	33.03
Imp. double layer washcoat & 900 cpi cell density	4.33	0	100	4.33	10.56	0	100	10.56
Engine modifications (f)	10.00	0	100	10.00	10.00	0	100	10.00
Air injection (electric) (g)	50.00	0	0	0	65.00	0	50	32.50
Total incremental cost				\$75.98				\$158.53

(a) Only the front oxygen sensor in an UEGO type sensor

(b) Air assisted fuel injection requires minor redesign of the idle air control valve at no additional cost and the addition of an adaptor to each injector at a cost of \$2 each

(c) Improved cylinder fuel control and retarded spark-timing at start-up constitute software changes only, at no additional cost

(d) Abbreviated engine start-up utilizes a higher speed starter or integral starter/alternator system to achieve quicker engine cranking at start-up.

(e) Catalyst volume on a SULEV is estimated to be 20 percent greater than that on a ULEV I vehicle.

(f) Types of engine modifications may be less uniform throughout the industry and may include items such as an additional spark plug per cylinder, addition of a swirl control valve or other hardware needed to achieve cold combustion stability, improved mixing and fuel injector targeting.

(g) Cost of air injection includes an electric air pump with integrated filter and relay, wiring, air shut-off valve with integral solenoid, check valve, tubing and brackets

Table II-33
Light-Duty Truck (3751 LVW-8500 GVW): Incremental Cost of a SULEV Compared to a ULEV I Vehicle

Emission Control Technology	4-cylinder				6-cylinder			
	Tech. cost est. (in dollars)	Tech. on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)	Tech. cost est. (in dollars)	Tech. on 2003 MY ULEV I (%)	Proj. Tech. on ULEV II (%)	Inc. Cost (in dollars)
Universal exhaust gas oxygen sensor (a)	10.00	50	100	5.00	20.00	50	100	10.00
Air-assisted fuel injection (b)	8.00	25	100	6.00	12.00	50	100	6.00
Heated fuel injectors	12.00	0	0	0	18.00	0	0	0
Individual cylinder fuel control (c)	0	25	100	0	0	25	100	0
Retarded spark timing as start-up (c)	0	0	100	0	0	25	100	0
Abbreviated engine start-up (d)	10.00	0	25	2.50	10.00	0	25	2.50
Low thermal capacity manifold	20.00	25	100	15.00	40.00	25	100	30.00
Close-coupled pipe catalyst(s) (e)	23.00	0	100	23.00	92.50	0	100	92.50
Greater catalyst loading	31.73	0	100	31.73	51.04	0	100	51.04
Imp. double layer washcoat & 900 cpi cell density	6.74	0	100	6.74	10.84	0	100	10.84
Engine modifications (f)	10.00	0	100	10.00	10.00	0	100	10.00
Air injection (electric) (g)	50.00	0	50	25.00	65.00	0	50	32.50
Total incremental cost				\$124.97				\$245.38

(a) Only the front oxygen sensor in an UEGO type sensor

(b) Air assisted fuel injection requires minor redesign of the idle air control valve at no additional cost and the addition of an adaptor to each injector at a cost of \$2 each

(c) Improved cylinder fuel control and retarded spark-timing at start-up constitute software changes only, at no additional cost

(d) Abbreviated engine start-up utilizes a higher speed starter or integral starter/alternator system to achieve quicker engine cranking at start-up.

(e) Catalyst volume on a SULEV is estimated to be 20 percent greater than that on a ULEV I vehicle.

(f) Types of engine modifications may be less uniform throughout the industry and may include items such as an additional spark plug per cylinder, addition of a swirl control vane or other hardware needed to achieve cold combustion stability, improved mixing and fuel injector targeting.

(g) Cost of air injection includes an electric air pump with integrated filter and relay, wiring, air shut-off valve with integral solenoid, check valve, tubing and brackets

**Table II-34
Increased Catalyst Cost Estimates for LEV II Vehicles**

		Sales Wtd. Eng. Disp. (liter)	Proj. ULEV I Cat. Vol. (liter)	Proj. ULEV II Cat. Vol. (liter)	Inc. Cat. Vol. Cost (a) (dollars)	Inc. Rh. (b) (grams)	Add. Rh Cost (c) (dollars)	Higher cpi coct (c) (dollars)
Passenger Cars								
ULEV II compared to ULEV I	4-cylinder	2.0	1.5	1.5	0	0.626	13.59	1.80
	6-cylinder	3.2	2.4	2.4	0	1.015	22.02	2.92
	8-cylinder	4.5	4.0	4.0	0	1.686	36.59	4.86
Light-duty trucks (0-8,500 lbs. GVWR)								
ULEV II compared to ULEV I	4-cylinder	2.3	2.3	2.3	0	0.975	21.15	2.81
	6-cylinder	3.7	2.6	3.7	55.50	1.568	34.03	4.52
	8-cylinder	5.4	4.7	5.4	35.10	2.288	49.66	6.59
Medium-Duty Vehicles (8500-10000 GVW)								
ULEV II	8-cylinder	6.1	5.3	6.1	39.65	2.585	42.07	7.44
Passenger Cars								
SULEV compared to ULEV I	4-cylinder	2.0	1.5	1.8	14.78	0.939	20.38	4.33
	6-cylinder	3.2	2.4	2.9	23.94	1.522	33.03	7.01
Light-duty trucks (0-8,500 lbs. GVWR)								
ULEV II compared to ULEV I	4-cylinder	2.3	2.3	2.8	23.00	1.462	31.73	6.74
	6-cylinder	3.7	2.6	4.4	92.50	2.352	51.04	10.84

(a) Catalyst cost is estimated to be approximately \$50/liter

(b) Assumes increase in rhodium loading of 12 g/ft³ for ULEV II and 15 g/ft³ for SULEV

(c) Cost of rhodium = \$675 per troy ounce.

(d) Assumes ULEV II vehicles use 600 cpi catalysts and SULEVs use 900 cpi catalysts. Cost of 600 cpi catalyst compared to 400 cpi catalyst is 2 cents/in³ in large volumes. Corresponding cost for 900 cpi catalyst is 4 cents/in³.

**Table II-35
SUPPORT COSTS**

(A) Engineering Development Cost of Advanced Vehicle Technology (Research)

Emission Control Technology	Eng. Staff for Tech. Dev.		Eng. Staff Cost (a) (in dollars)	Dev. Vehicle Cost (in dollars)	Addtl. Equipment (in dollars)	Cost/Vehicle (c) (dollars/veh.)
	(Person yrs.)	(Person hrs.)				
Catalyst evaluation	4	8,320	499,200	400,000	0	1.12
Engine modifications	6	12,480	748,800	500,000	0	2.19
Individual cylinder fuel control	4	8,320	499,200	500,000	0	1.87
Heated fuel preparation	3	6,240	374,400	400,000	0	1.47
EHC + HC adsorber eval. (D)	10	20,800	1,248,000	500,000	0	2.81
Low thermal capacity manifold	4	8,320	499,200	400,000	0	1.12
Total						\$10.59

(B) Legal and Administrative Costs

	No. Of Staff	Number of years	Staff Cost (in dollars)	Cost/Veh. (c) (dollars/vehicle)
Legal	0	0	0	0
Administrative	0	0	0	0

(a) Development cost includes personnel, overhead and other miscellaneous costs at a total rate of \$60/hr.

(b) Prototype development vehicles are estimated to cost \$100,000 each.

(c) Cost has been distributed over 100,000 vehicles per year for 8 years.

(d) For advanced engineering work in contrast to vehicle calibration/certification effort.

**Table II-36
Passenger Car: Incremental Consumer Cost of a ULEV II Compared to a ULEV I**

		4-cylinder (in dollars)	6-cylinder (in dollars)	8-cylinder (in dollars)
Variable costs	Component	25.39	87.44	108.94
	Assembly	0.00	1.00	1.00
	Warranty	0.00	0.08	0.08
	Shipping	0.00	0.13	0.13
Support costs	Research	10.59	10.59	10.59
	Legal	0.00	0.00	0.00
	Administrative	0.00	0.00	0.00
Investment recovery costs	Mach & equipment	0.00	0.00	0.00
	Assembly plant changes	0.00	0.00	0.00
	Vehicle development	0.00	0.00	0.00
Capitol recovery		2.16	5.95	7.24
Dealership costs	Operating costs	1.14	3.16	3.84
	Capitol recovery	0.59	1.63	1.99
Total incremental cost to consumer		\$39.87	\$109.98	\$133.81

Light-Duty Truck (0-8500 lbs. GVWR): Incremental Consumer Cost of a ULEV II Compared to a ULEV I

		4-cylinder (20%) (in dollars)	6-cylinder (59%) (in dollars)	8-cylinder (21%) (in dollars)
Variable costs	Component	35.96	156.54	180.85
	Assembly	0.00	1.00	1.00
	Warranty	0.00	0.08	0.08
	Shipping	0.00	0.13	0.13
Support costs	Research	10.59	10.59	10.59
	Legal	0.00	0.00	0.00
	Administrative	0.00	0.00	0.00
Investment recovery costs	Mach & equipment	0.00	0.00	0.00
	Assembly plant changes	0.00	0.00	0.00
	Vehicle development	0.00	0.00	0.00
Capitol recovery		2.79	10.10	11.56
Dealership costs	Operating costs	1.48	5.38	6.13
	Capitol recovery	0.77	2.77	3.17
Total incremental cost to consumer		\$51.58	\$186.56	\$213.50

MDV (8500-1000 GVW): Incremental Consumer Cost of a ULEV II Compared to a ULEV I

		8-cylinder (in dollars)
Variable costs	Component	109.17
	Assembly	1.00
	Warranty	0.08
	Shipping	0.13
Support costs	Research	10.59
	Legal	0.00
	Administrative	0.00
Investment recovery costs	Mach & equipment	0.00
	Assembly plant changes	0.00
	Vehicle development	0.00
Capitol recovery		7.26
Dealership costs	Operating costs	3.85
	Capitol recovery	1.99
Total incremental cost to consumer		\$134.06

Table II-37

Light-Duty Truck (0-8500 lbs. GVWR): Incremental Consumer Cost of a SULEV Compared to a ULEV I

		4-cylinder (in dollars)	6-cylinder (in dollars)
Variable costs	Component	75.98	158.53
	Assembly	0.50	2.00
	Warranty	0.00	0.08
	Shipping	0.00	0.13
Support costs	Research	10.59	10.59
	Legal	0.00	0.00
	Administrative	0.00	0.00
Investment recovery costs	Mach & equipment	0.00	0.00
	Assembly plant changes	0.00	0.00
	Vehicle development	0.00	0.00
Capitol recovery		5.22	10.28
Dealership costs	Operating costs	2.77	5.45
	Capitol recovery	1.43	2.82
Total incremental cost to consumer		\$96.50	\$189.87

Light-Duty Truck (0-8500 lbs. GVWR): Incremental Consumer Cost of a SULEV Compared to a ULEV I

		4-cylinder (in dollars)	6-cylinder (in dollars)
Variable costs	Component	124.97	245.38
	Assembly	1.50	2.00
	Warranty	0.08	0.08
	Shipping	0.13	0.13
Support costs	Research	10.59	10.59
	Legal	0.00	0.00
	Administrative	0.00	0.00
Investment recovery costs	Mach & equipment	0.00	0.00
	Assembly plant changes	0.00	0.00
	Vehicle development	0.00	0.00
Capitol recovery		8.24	15.49
Dealership costs	Operating costs	4.36	8.21
	Capitol recovery	2.26	4.25
Total incremental cost to consumer		\$152.12	\$286.13

**Table II-38
Incremental Cost of a LEV II Vehicle Compared to a LEV I Vehicle**

Emission Category	LEV I Vehicle Category	New Vehicle Fleet Composition 4-cyl/6-cyl/8-cyl			Composite Incremental Cost (dollars)
		4-cyl	6-cyl	8-cyl	
ULEV	PC	58%	33%	9%	71.46
	LDT1	91%	9%	0%	46.18
	LDT2	4%	85%	11%	184.13
	MDV2	0%	21%	79%	207.85
	MDV3	0%	17%	83%	208.92
	MDV4	0%	0%	100%	134.06
SULEV	PC	63%	37%	0%	131.05
	LDT1	91%	9%	0%	104.90
	LDT2	5%	95%	0%	279.43

Cost-Effectiveness of LEV II Vehicle Compared to ULEV I Vehicles

Emission Category	LEV I Veh Category	Incremental cost to consumer (dollars)	Emission Reduction 120K miles			Cost-effectiveness		Inc. Cost-effectiveness	
			ROG (lbs.)	CO (lbs.)	Nox (lbs.)	ROG+NOx (\$/lb.)	ROG+CO/7+NOx (\$/lb.)	ROG+NOx (\$/lb.)	ROG+CO/7+NOx (lbs.)
ULEV	PC	71.46	0.0	48.4	67.3	1.06	0.96		
	LDT1	46.18	0.0	51.5	69.3	0.67	0.60		
	LDT2	184.13	2.3	171.2	159.7	1.14	1.10		
	MDV2	207.85	10.6	662.4	156.1	1.25	1.14		
	MDV3	208.92	13.3	796.8	244.0	0.81	0.56		
	MDV4	134.06	11.0	78.4	94.3	1.27	1.15		
SULEV	PC	131.05	5.8	205.5	81.6	1.50	1.12	2.96	1.40
	LDT1	104.90	5.9	216.0	83.9	1.17	0.87	2.85	1.33
	LDT2	279.43	7.7	335.7	174.4	1.53	1.32	4.76	2.19

APPENDIX III

Cost-Effectiveness Analysis

Methodology

In reexamining the cost-effectiveness of the Low Emission Vehicle II program to include the impact of the proposed OBD II requirements, the staff bifurcated the lifetime of Low Emission Vehicle II applications into two mileage intervals. The first interval, 0 to 120,000 miles, represents the durability period for Low Emission Vehicle II full useful life emission standards. The second interval, beyond 120,000 miles, represents the period in a vehicle's life when OBD II is expected to have a major impact on the program's emission benefits and costs (the staff extended vehicle lifetime to 230,000 miles when EMFAC2001 assumes only 33 percent of a model year remains in service). Cost-effectiveness was calculated in dollars per pound of reactive organic gas (ROG) and oxides of nitrogen (NOx) reduced relative to a Low Emission Vehicle I application for each mileage interval and then summed to determine the cost-effectiveness for vehicles in each Low Emission Vehicle II emission category (LEV II, ULEV II, Tier 2 Bin 4, Tier 2 Bin 3, and PZEV) and vehicle class (passenger cars, LDT1, LDT2 less than 6,000 lbs. GVW, and LDT2 between 6,000 lbs. and 8,500 lbs. GVW). The resulting cost-effectiveness for each vehicle class was then weighted by its percent fraction of the Low Emission Vehicle II fleet in order to determine the average cost-effectiveness of vehicles meeting Low Emission Vehicle II requirements.

Costs

The incremental costs to the consumer for Low Emission Vehicle II applications compared to Low Emission Vehicle I applications were retained from the original analysis for the Low Emission Vehicle II rulemaking and used for the mileage interval from 0-120,000 miles. The methodology used to determine these costs is described in detail in Appendix II above. Costs considered in that analysis included the manufacturers' hardware costs, variable costs (costs of assembly, shipping, and warranty), support costs (research, legal and administrative), investment recovery (machinery and equipment to manufacturer the parts, assembly plant changes, vehicle development, and costs of capital recovery), and dealer costs (operating costs and costs of capital recovery).

However, the original Low Emission Vehicle II analysis did not include the incremental costs for the cleaner federal Tier 2 vehicles that manufacturers are now required to certify in California. Therefore, the staff used the incremental costs for ULEV II vehicles for Tier 2 Bin 4 vehicles and the incremental costs for SULEV vehicles for Tier 2 Bin 3 vehicles. The staff believes this to be a reasonable approximation, since the emission standards are similar. Furthermore, incremental costs for PZEVs were not included in the original cost analysis for Low Emission Vehicle II, since this emission category was provided as an option to the ZEV requirements. It has since become apparent that manufacturers will choose to certify a significant number of PZEVs in order to meet their ZEV obligations. Therefore, the staff has included an incremental cost for PZEVs of \$200, revised downward from the \$500 estimate cited in the Staff

Report for the 1999 review of the ZEV program. The revised cost reflects a reevaluation of the likely technology to be used by PZEVs. Confidential data from several manufacturers suggest that PZEVs will use essentially the same technology as SULEVs that are required to meet the same exhaust emission standards. The original warranty costs for PZEVs have also been reduced to reflect the more cost-effective approach manufacturers will likely use to prevent component failures in the 150,000-mile operating interval rather than build less robust components that might fail and whose repair would result in payment of warranty costs. In the Low Emission Vehicle II rulemaking, the staff estimated the incremental cost for SULEVs at \$131. The revised cost of \$200 for PZEVs also includes costs to the manufacturer for building increased component durability into the emission control components in order to avoid excessive repair costs during the 150,000 mile emission warranty period.

Costs for the vehicle beyond 120,000 miles depend on the repair frequency assumed for each vehicle. For this analysis, the staff assumed that each vehicle (non-PZEV) would undergo two repairs at an average of \$260 per repair⁵⁹ resulting from component malfunctions detected by the OBD system at the proposed MIL illumination thresholds. For PZEVs, the staff assumed one repair at \$275 per repair after the 150,000-mile emission durability and warranty period. Staff developed these average repair costs based on analysis of repair cost data reported from the Smog Check program in California (for OBD II-equipped and non OBD II-equipped vehicles), the Oregon I/M program (OBD II-equipped vehicles only), and a U.S. EPA study on the use of OBD II in I/M programs. A slightly higher repair cost was assumed for PZEVs to reflect the cost for increased durability of the replacement emission control components utilized on PZEVs. For the repair rates, staff analyzed failure rate data from the California Smog Check program and the Oregon I/M program to determine the cumulative number of emission-related repairs the average vehicle would undergo between 120,000 and 230,000 miles. The failure rates were then adjusted to account for the improved durability (and thus, lower failure rate) of vehicles in the Low Emission Vehicle II program. For non-PZEVs, an average failure rate of two emission-related repairs per vehicle was projected between 120,000 and 230,000 miles. For PZEVs (subject to warranty for 150,000 miles), an average rate of a one emission-related repair per vehicle was projected between the 150,000 and 230,000 mile interval.

Emission benefits

Emission benefits for the useful life (120,000 miles) were recalculated using EMFAC2001 for each emission category and vehicle class. The benefits were calculated by summing the pounds per year emissions reduced relative to a Low Emission Vehicle I application for the first nine years of a vehicle's life (according to EMFAC2001, a vehicle travels approximately 125,000 miles in the first nine years).

⁵⁹ Staff estimate for repair costs derived from Oregon I/M program data provided by Gary Beyer, U.S. EPA paper "Evaluation of Onboard Diagnostics for Use in Detecting Malfunctioning and High Emitting Vehicles" (August 2000), and presentation "Smog Operations Applications Unit" (July 2001) and personal communication with Dean Saito, Bureau of Automotive Repair (BAR).

Similarly, emission benefits were calculated for vehicle age ten to nineteen years to account for vehicle mileage between 120,000 miles and 230,000 miles. Emission benefits were determined for both the proposed MIL thresholds and at the higher threshold suggested by industry using EMFAC2001.

To determine emission benefits at the proposed thresholds, vehicle emissions were calculated using EMFAC2001 assuming an effective I/M program. For OBD II-equipped vehicles, the model assumes that OBD II will identify 95 percent of the failures for vehicles in the high to super emission regimes. In EMFAC2001, vehicles remain in the normal and moderate regimes for the useful life (120,000 miles), and then begin to migrate into the high to super regimes. Furthermore, after repair, these vehicles will move evenly to the normal and moderate emission regimes.⁶⁰ This is a reasonable assumption, since the MIL will not deactivate unless the vehicle has been properly repaired. The model assumes the MIL thresholds are set at 1.5 times the tailpipe emission standard for all categories (staff is proposing a threshold of 2.5 times the tailpipe emission standard for SULEVs, but this difference has little effect on the overall analysis).

To simulate emission benefits at the higher thresholds suggested by industry, the emission benefits were determined using EMFAC2001 assuming no effective I/M program in place. In this scenario, vehicles migrate into the high to super regimes and remain there. While no vehicle repairs occur in this scenario, it does simulate vehicles remaining in the higher regimes for a longer period of time. Since an effective repair is determined by MIL deactivation (see discussion below on the impact of OBD II on I/M for Low Emission Vehicle applications), setting the threshold at higher levels would cause the MIL to deactivate at the higher emissions thresholds. Accordingly, there would be no assurance of any emission benefits below the emission level where the MIL deactivates (i.e., there is no assurance that vehicles would migrate to the normal and moderate emission regimes). Accordingly, the staff believes this provides a reasonable approximation of the emission benefits of setting the thresholds at the higher levels.

Since the primary improvement in emissions for Low Emission Vehicle I and Low Emission Vehicle II applications is achieved by reducing cold-start emissions, catalyst efficiencies for these vehicles remain high under I/M test conditions when the catalyst is fully warmed up. Therefore, even when failing the emission standard by a factor of two or three, vehicle emissions under I/M test conditions will remain low. To evaluate the potential effectiveness of the current I/M program without OBD II for low-emission vehicles, the staff conducted I/M tests on a limited number of vehicles meeting Low

⁶⁰ In EMFAC2001, vehicles in each technology group are categorized into five regimes; normals, moderates, highs, very highs, and supers. As vehicles age (or accumulate mileage), their emissions increase as a result of deterioration; hence, they migrate from normal emitting regimes to higher emitting regimes.

Emission Vehicle I and Low Emission Vehicle II emission standards. The vehicles were also tested over the federal test procedure (FTP), the test procedure used to determine compliance with the certification emission standard. Table A below illustrates the results of this test program.

Table A - I/M and FTP Emission Test Results

Vehicle	Test	HC Meas.	NOx Meas.
LEV I	15 mph	11 ppm	37 ppm
	25 mph	7 ppm	5 ppm
	FTP	0.059 g/mi	0.093 g/mi
ULEV I	15 mph	10 ppm	46 ppm
	25 mph	6 ppm	19 ppm
	FTP	0.031 g/mi	0.049 g/mi
SULEV II	15 mph	2 ppm	0
	25 mph	1 ppm	1 ppm
	FTP	0.008 g/mi	0.012 g/mi
PZEV	15 mph	0	0
	25 mph	0	0
	FTP	0.007 g/mi	0.006 g/mi

While the table represents a limited data set, it illustrates the potential problem for current I/M instrumentation to determine small increases in vehicle emissions at low levels. For example, the LEV I FTP hydrocarbon (HC) emissions are approximately double the FTP HC emissions of the ULEV I vehicle. However, the I/M test indicates only a one-ppm difference in vehicle emissions, well outside the resolution of test instrumentation used in the I/M program. In addition, the FTP NOx emissions of the LEV I vehicle are significantly higher than those of the ULEV I vehicle, while the I/M test measured lower emissions for the LEV I vehicle, directionally opposite to the FTP test results. Since the FTP emissions for the LEV I and ULEV I vehicles are 3 to 6 times the HC emission standard and 2.5 to 5 times the NOx emission standard for SULEVs and PZEVs, the data suggest that, if significant improvements in instrumentation accuracy and/or test methods are not made, without OBD II, the I/M program will have difficulty in identifying these vehicles when they exceed the emission standard by a substantial margin. The staff, therefore, believes it is reasonable to assume that an I/M program without OBD would not be effective in maintaining Low Emission Vehicle I and Low Emission Vehicle II applications close to their certification levels. Accordingly, it is appropriate to attribute the emission benefits of the I/M program beyond 120,000 miles solely to OBD II.

Cost-Effectiveness

Cost-effectiveness was calculated for model years 2003-2020. The emission benefit in pounds year of emissions reduced of a vehicle meeting each of the LEV II emission categories (i.e., LEV II, ULEV II, PZEV) was held constant for all model years.

Therefore, the only variable in the analysis was the percent of vehicles meeting each of the LEV II emission categories for each model year as determined by the fleet implementation schedule in EMFAC2001. The cost-effectiveness for each emission category within the vehicle classes (PC/LDT1, LDT2) was then weighted according to its percentage contribution to the fleet. For example, in model year 2007, EMFAC2001 assumes that 25% of new PCs and LDT1s will meet LEV II emission standards, 15% will meet ULEV II emission standards, 19% will meet Tier 2 Bin 4 emission standards, and 37% will meet the PZEV emission standards (ZEVs were not included in the analysis). The weighted cost-effectiveness for the emission categories were then summed within each vehicle class to determine cost-effectiveness for that vehicle class. In addition, since the model assumes that the PC/LDT1 class will constitute 51% of the light-duty vehicle fleet, the cost-effectiveness of the PC/LDT1 vehicle class was further adjusted by that amount. Summing the weighted cost-effectiveness across the vehicle classes then resulted in the cost-effectiveness for the fleet for each model year. The final cost-effectiveness of \$4.57 for staff's proposal was then determined by averaging over model years 2003-2020. The cost-effectiveness of industry's proposal was similarly derived.

APPENDIX IV

Tri-City Database Analysis

The Tri-City database was used as a representative collection of driver habits for the purpose of defining a minimum in-use performance, or monitoring frequency, ratio for OBD II monitoring. The U.S. EPA initiated the Tri-City studies, which involved the random selection of 252 vehicles that were being tested at vehicle Inspection and Maintenance (I/M) facilities in three cities: Baltimore, Atlanta, and Spokane. The vehicles were equipped with data-recording instrumentation that logged time, engine rpm, and vehicle speed. The instrumentation remained on the sampled vehicles and recorded data on a second-by-second basis for 3 to 16 days. However, the database used for the analysis had been condensed into vehicle trip records with relevant parameters needed to determine whether the filtered trip (“f-trip”) criteria had been met. Incidentally, eight of the 252 vehicles’ records were in a different format and therefore not included in the actual database sent to the ARB, which consisted of driving data for the remaining 244 vehicles.

Using this database, analysis was carried out to derive a ratio of tests per f-trip to represent a frequency that achieved monitoring for 90 percent of vehicle drivers in two-weeks time. The data were investigated and filtered to improve the accuracy of the data analysis. First, driving data from the first and last days of driving for a given test vehicle were excluded from the analysis. These data were viewed as unrepresentative of actual driver data on a per day basis due to the fact that the monitoring equipment for the vehicle was not installed for the full day. Specifically, during the first day, vehicles typically had monitoring equipment installed some time between 10 and 11 AM, thus, vehicle trips occurring on the day of installation but before the equipment was installed were not recorded. Likewise, vehicle trips occurring on the last day of sampling but after the equipment was removed were not recorded nor were they included in the database. For these reasons, it was apparent that including these days would bias the vehicle data in the direction of fewer trips per day. Accordingly, two days were subtracted from the total number of days of data for each vehicle (Figure 1).

Second, if data for a given vehicle did not include at least six days of driving after the first and last days were excluded, this vehicle was excluded from the analysis. Driver habits are generally established on a weekly basis. Specifically, weekday driving establishes commuting driver habits while weekend driving establishes errand and excursion driver habits. If a specific vehicle recorded less than six days of driving data, it is not certain that both weekday and weekend driving habits were established in the database. Therefore, all data used in the analysis were taken from vehicles that recorded at least six valid days of driving. This reduced the number of test vehicles in the analysis from 244 to 186.

To calculate the ratio that corresponded to a two-week time period, the vehicle data were analyzed to determine the number of trips per day that met the “filtered trip”, or f-trip, definition (e.g., 10 minutes long, 5 minutes above 25 mph, 30 seconds of idle, etc.)

and, subsequently, determine the average f-trips/day for each vehicle (Figure 2). The mean and standard deviation of this distribution of f-trips/day were found to be 1.79 and 1.11, respectively. Since this distribution was clearly not symmetrical about the mean and tailed to the right (i.e., in the direction of more f-trips/day), a gamma distribution was determined to be the best fit (Figure 3). With the help of a statistician and an iterative process (see Appendix V), the estimated mean and standard deviation of the gamma distribution were calculated to match the distribution of data in the Tri-City database. This yielded an estimated mean of 1.79 and a standard deviation of 0.96.

After the distribution of f-trips/day was determined, the ratio was then derived by determining how often an OBD II monitor would have to operate to ensure that 90 percent of the vehicle population could detect a malfunction within two weeks. Generally, to detect a malfunction and illuminate the MIL, an OBD II monitor has to operate twice. Therefore, if a vehicle is required to illuminate the MIL within two weeks, the OBD II monitor must operate twice within two weeks. To calculate the ratio, it was necessary to estimate the distribution of how often monitors would execute. By then multiplying values from this distribution with values from the distribution of f-trips/day, the minimum ratio that ensures 90 percent of the population will get two decisions in two weeks can be calculated.

To determine the distribution of monitoring frequency, an iterative process was used to model possible distributions. Since vehicle populations that are at or near the minimum frequency would likely have nearly all values between zero and one, a beta distribution was chosen to model the monitoring frequency (Figure 4). Various combinations of assumed means and standard deviations of monitoring frequency were then run through simulations to determine the minimum ratio. For purposes of these simulations, the standard deviations of the monitoring frequency were assumed to be 50 percent of the mean. While both smaller and larger standard deviations were studied, the assumption of 50 percent was selected based on similar standard deviations observed for trips/day and f-trips/day.

For each assumed mean and standard deviation of monitoring frequency, a sample distribution of 100,000 points was generated. Similarly, for the mean and standard deviation of f-trips/day calculated previously, a sample distribution of 100,000 points was also generated. Single values from each distribution were then randomly selected and multiplied together to determine the number of OBD II monitoring events per day for a sample vehicle. If the calculated value was greater than two monitoring events in a 14-day period (i.e., two-weeks), the vehicle was assumed to meet the required monitoring frequency. After doing this for 100,000 simulated “vehicles”, the percentage of cars that met the required frequency was determined. This entire process was repeated with various assumed means for the monitoring frequency until a number was generated that yielded 90 percent of the cars as achieving two decisions in two weeks.

From this method, it was calculated that a mean ratio of 0.336 was the minimum ratio necessary to assure 90 percent of the vehicle population would detect a malfunction

within two weeks. That is, vehicle populations that have a mean (or average) ratio of 0.336 or higher should result in 90 percent of the vehicles from that population detecting malfunctions within two weeks.

Following similar methodology, a separate ratio was developed for a few monitors (notably, the secondary air system and evaporative system leak detection monitors) that typically operate under more constrained monitoring conditions than other monitors and are much more sensitive to ambient temperature fluctuations. For these monitors, a more heavily filtered trip (“fE-trip”) is used for the denominator of the ratio, which would eliminate trips that occur outside of ambient temperatures between 40-95° Fahrenheit and are not “cold-starts”. Further, the increased reliance on cold-starts and ambient temperatures places additional uncertainty in the representativeness of the Tri-City data for vehicles operated in California. Accordingly, the ratio was calculated with a more conservative approach by finding the minimum ratio necessary for 50 percent (instead of 90 percent) of the population to detect a malfunction within two weeks. This additional filtering necessitated a separate calculation of the ratio. With these modifications, the minimum mean ratio was calculated to be 0.260.

Sampling

For enforcement testing done by the Executive Officer to determine if vehicles comply with the minimum ratio, a specific test procedure is proposed in the enforcement regulation (section 1968.5). Specifically, the ARB would collect data from a minimum of 30 vehicles to determine if the minimum ratio was met. However, whenever a sample of vehicles is taken from the total population of vehicles, there is some uncertainty as to how accurately the sample vehicles represent the true population of vehicles. Much of this problem is addressed by using very specific procedures to solicit vehicles for inclusion into the sample. However, since the entire vehicle population cannot be sampled, averaged, and compared to the required minimum ratio, the sample of 30 vehicles will be averaged and compared to a “critical” ratio. The critical ratio is a value slightly less than the required minimum ratio and is calculated such that sample means that are lower than the critical ratio provide evidence that the population mean is lower than the required minimum ratio with 90 percent confidence.

For example, for the required minimum ratio of 0.336, a critical ratio of 0.297 was calculated. Thus, a sample of 30 or more vehicles that had an average ratio of less than 0.297 would indicate, with 90 percent confidence, that the actual population of vehicles had an average ratio of less than 0.336. By establishing these critical ratios and using these values for the “trigger” points in enforcement testing, manufacturers would only be found to be noncompliant if there is very strong evidence to support the finding. This process would, however, allow some manufacturers that are actually noncompliant to falsely be determined to be compliant, but overall should provide sufficient separation to identify the majority of OBD II systems that do not comply with the minimum requirements.

To address one other possible scenario, a second failure criterion based on the median

ratio of the sampled vehicles is also proposed. This is necessary to avoid a potential situation where the vast majority of a population of vehicles have in-use ratios below the required minimum ratio but a few vehicles have extremely high ratios. In this possible scenario, the few high ratios may cause the average ratio of the sample to exceed the minimum ratio despite the vast majority of vehicles actually monitoring at a frequency below the minimum required ratio. To this end, if a sample of 30 or more vehicles had two-thirds or more of the vehicles with ratios below the minimum required ratio, the population would be determined to be non-compliant. This criterion was also developed such that a sample of 30 or more vehicles that fail this criterion provides evidence that the population mean is lower than the minimum required ratio with 90 percent confidence. Following the example cited above where the required minimum ratio is 0.336, a sample of 30 vehicles where 20 or more of the vehicles had ratios below 0.336 would indicate, with 90 percent confidence, that the actual population of vehicles had an average ratio of less than 0.336.

Figure 1: Tri-City Data: Days of Data per Vehicle
(244 vehicles)

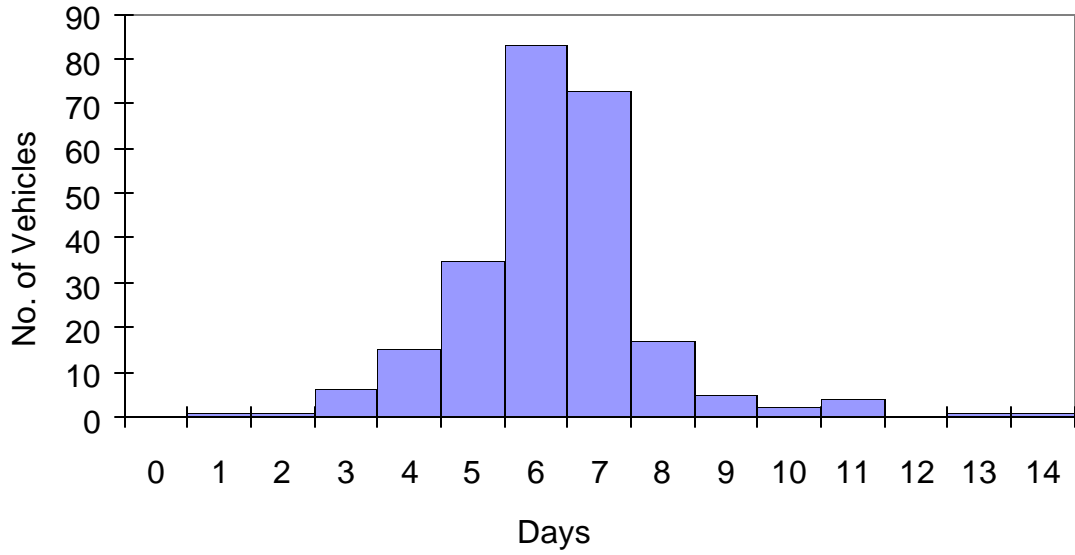


Figure 2: Tri-City Data: f-trips/day
(186 vehicles)

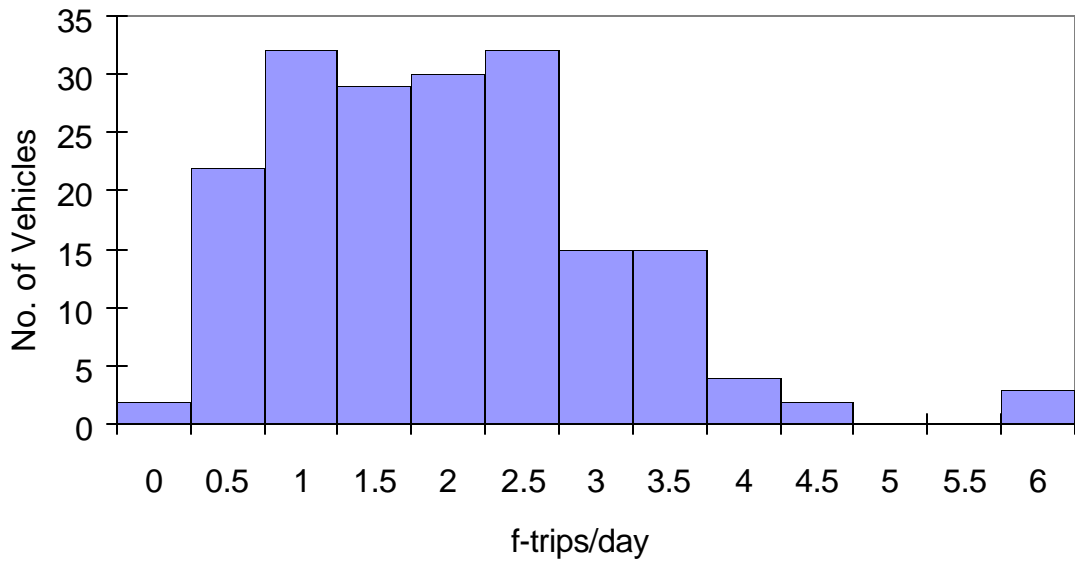


Figure 3: Simulation: Gamma Distribution

(mean = 1.79, SD = 0.96)

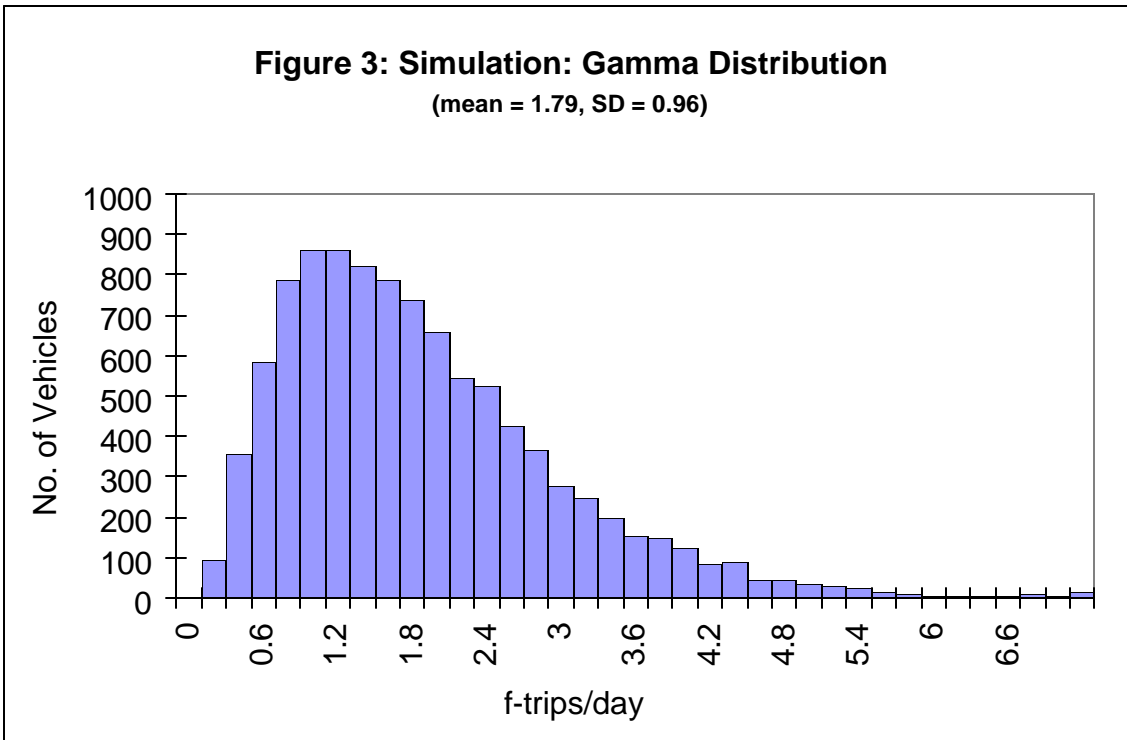
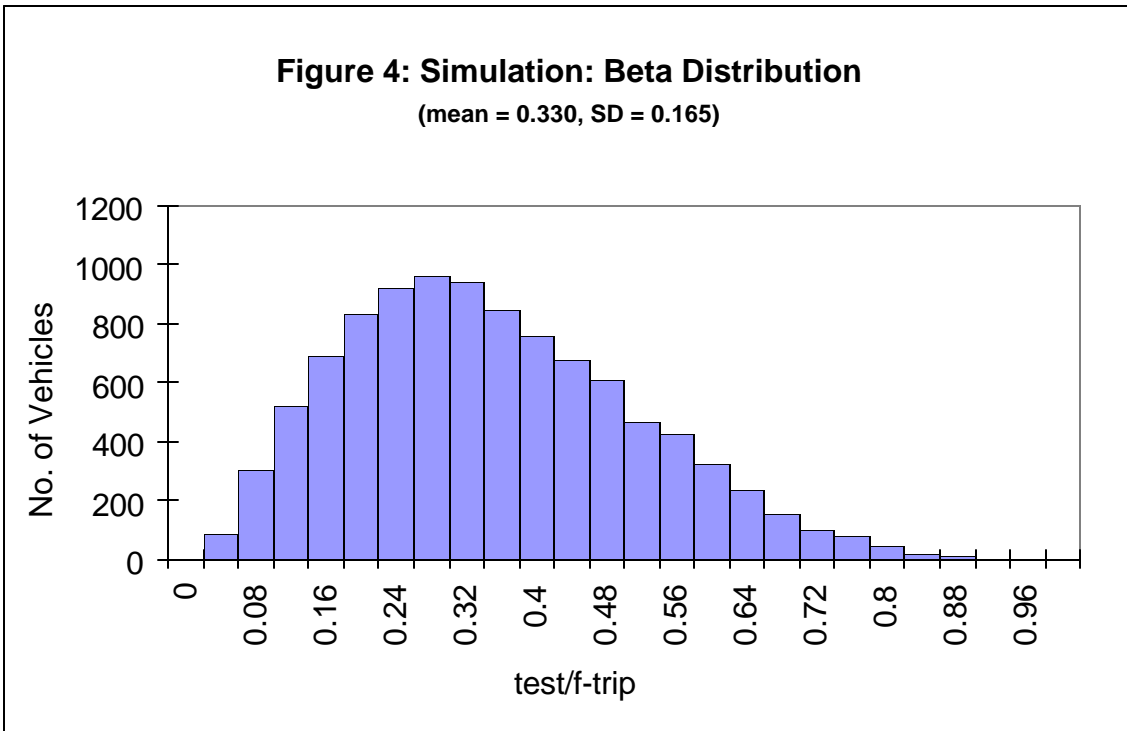


Figure 4: Simulation: Beta Distribution

(mean = 0.330, SD = 0.165)



APPENDIX V

Modeling Vehicle Use and Monitoring Ratios of On-Board Diagnostic Equipment to
Assess Adequate Monitoring Frequency

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1. Introduction

The purpose of the proposed regulation is to insure that a specified fraction of automobiles on the road have on-board monitoring (OBM) equipment that will signal each particular type of defect within two (or three in some cases) weeks of its occurrence. Since it may require two runs of the OBM to detect a defect, this means that it is required that the specified fraction automobiles in service should have the OBM check for a given defect at least once per week on the average (0.67 times per week in some cases).

This requirement in turn depends on two characteristics of a particular vehicle in use. The first is the number of trips taken per week. This may be total trips, or filtered trips in which the “filter” is designed to count only trips on which the OBM is likely to function (for example, greater running time than 10 minutes). The second is the fraction of trips on which the OBM functions. In this report, I discuss a method of modeling each of these two factors, and then using the constructed models to estimate the fraction of a given sub-fleet of automobiles that will meet the monitoring requirement. In order to make the modeling at all feasible, I will assume that the monitoring ratio and the number of trips taken are statistically independent.

The average monitoring frequency (per week) of a vehicle in use is the product of the average number of trips per week and the monitoring ratio. Since both of these vary from vehicle-in-use to vehicle-in-use, both factors must be considered simultaneously to estimate the fraction of vehicle whose average monitoring frequency is at least once per week.

2. The Distribution of Number of Trips

Inspection of Figures 2, 5a, and 5b and Table 1, in material provide to me by CARB staff, along with an analysis of the data provided to me, show that the normal distribution is not a good model for these data. Two connected attributes of the data confirm this. First, there is a pronounced right-skewness to the data. Second, by definition, no value of the number of trips per day can be negative. Consider, for example, the f-trips/day/vehicle data. The average and the standard deviation given in Table 1 are 1.79 and 1.11, respectively. If the distribution were normal, the probability that (on a randomly selected vehicle) the f-trips per day was less than zero would be more than 5%. Although the 10th percentile is still positive, the 5th percentile is not, and this casts doubt on the use of the normal distribution.

The normal distribution can be used to model data that are inherently positive, so long as 1) the distribution is sufficiently bounded away from zero, and 2) the distribution is symmetric. The trips/day data fail test 2 in all cases, and fail test 1 more strongly for f-trips/day than for trips/day (for which the normal-theory chance of that the variable is negative is just over 1%). In both cases, the preponderance of evidence is that the normal distribution is not an adequate model.

As an alternative, I propose the gamma distribution. Like the normal distribution, there is a gamma distribution for every combination of (positive) mean and variance. Unlike the normal, it can model right-skew data, and all values generated from a gamma distribution, as well as all percentage points, are non-negative. In the Appendix, some basic facts about the gamma distribution are displayed. We can thus fit a gamma distribution to the mean and standard deviation of the trip data, and use this to determine the monitoring ratio distribution in order to meet the required monitoring frequency.

There is one additional complication to be dealt with. The data from the Tri-City database do not record the true average number of trips per day. Instead, they record the number of trips during a sample of days. If we assume that each vehicle i has an unobserved, true number of trips per day ξ_i , then if the vehicle is observed for d_i days, the actual number x_i of trips is also a random variable. As a first approximation, we can model this as Poisson with parameter $\theta = d_i \xi_i$. The trips per day estimate for vehicle i is then x_i / d_i . Although the length of observation d_i is random, it is formally ancillary to the estimation of the mean, and does not affect the mean trips per day. This two-stage process does, however, affect the variance. The variance of x_i / d_i is larger than the variance of ξ_i , and the variance of x_i / d_i depends on d_i . All of this means that we cannot estimate the parameters of the gamma model for the trips-per-day distribution directly from the mean and variance of the individual vehicle trips-per-day. Note that this conceptual model can be used for subsets of the data set in which inadequately observed vehicles are removed or for modified data sets in which trips are filtered.

To investigate this issue, I wrote a simulation program that repeated the following steps for each conceptual vehicle:

1. On input, specify the mean and standard deviation of the gamma distribution, and the mean and variance of the days distribution. Also specify the number of days of observation needed for the sample vehicle to be used.
2. For each vehicle
 - (a) Generate the theoretical trips per day x for the vehicle from a gamma distribution with the specified mean and standard deviation.
 - (b) Generate a random days under observation d from a normal distribution with specified mean and variance. Use the observation only if the number of days meets the threshold.
 - (c) Generate an observed number of trips x from a Poisson distribution with parameter dx .
 - (d) Calculate the trips per day $t = x/d$.

3. Compute the mean and standard deviation of the observed trips per day variable t .

For the distribution of days, I used a mean of 6.3 and a standard deviation of 1.57, corresponding to the full data set of the Tri-City data base. I used a threshold of 6 days to correspond to the analysis of the Tri-City data base. I then varied the input parameters of the gamma distribution until the simulated mean and variance over 100,000 trials matched the mean and variance of the actual data as given in Table 1 of the Draft Staff Report. This is then an indirect method-of-moments estimate of the gamma parameters. Table 1 of this document gives the estimated gamma parameters to match the two distributions in Table 1 of the Draft Staff Report.

Table 1: Gamma Parameter Estimates by the Indirect Method of Moments

Variable	Observed		Gamma Estimated		10 th %ile
	Mean	SD	Mean	SD	
TPD	6.95	3.11	6.95	2.95	3.54
f-TPD	1.79	1.11	1.79	0.99	0.70
fE-TPD	0.68	0.47	0.68	0.35	0.29

3. Modeling Monitoring Frequency

The remaining factor that determines monitoring frequency is the monitoring ratio: the fraction of trips, f-trips, or fE-trips during which the monitor executes. In this section, I describe how the monitoring ratio and the trips-per-day parameter interact to produce monitoring frequency. Briefly, the average monitoring frequency (executions per week) of a vehicle in use is the product of the monitoring ratio and the average number of trips per week.

We model the distribution across a category of vehicles of the monitoring ratio by a beta distribution (appendix). This is a more appropriate distribution than the normal, because of the fact that the ratio is bounded below by 0 and above by 1, unlike the normal distribution.¹

To determine the distribution of the monitoring frequency, I ran simulations of 100,000 trials each in which each vehicle in use is assigned a number of trips per day (or f-trips or fE-trips per day) randomly chosen from the appropriate gamma distribution as in the previous section. Then a ratio is chosen from a beta distribution with a mean and standard deviation specified on input. Given a threshold on input (such as one

¹ If the trips are filtered and the total executions of the OBM are recorded, ratios greater than one are possible. Since the concern is with small ratios, and there will be little controversy if the monitoring ratio is near 1, we treat only the case where all ratios are between 0 and 1.

execution per week), the simulation determines the fraction of vehicles in use in which the monitoring frequency exceeds the threshold.

By variation of the beta distribution parameters, we can choose cases in which the predicted mean monitoring frequency matches a pre-specified fraction. In this case, we have varied the beta distribution mean, and assumed that the coefficient of variation is 50%, matching some previous experience. Table 2 shows the results for the four cases we are considering.

Table 2: Monitoring Frequency

Vehicle Activity	Monitoring Frequency	Fraction in Compliance	Beta Mean
Trips/Day	MIL/2 weeks	0.90	0.064
f-Trips/Day	MIL/2 weeks	0.90	0.336
fE-Trips/Day	MIL/2 weeks	0.50	0.260
fE-Trips/Day	MIL/3 weeks	0.50	0.175

4. Vehicle Sampling

Given a sample of vehicles, say 30 in number, a procedure needs to be defined to determine whether the sample of vehicles reasonably corresponds to a population with the desired characteristics. In one plausible method, the manufacturer would be declared out of compliance only if the sampling data were inconsistent with parameter values that would indicate compliance. When we perform this type of hypothesis test with normal assumptions, we usually take the observed variance as if it were the true variance, and then determine whether the mean is too small by comparison. For the beta distributions, we will perform the calculations for the required mean, and for a 50% CV.

The minimum value for the observed mean monitoring ratio from a sample of 30 vehicles, and requiring 90% confidence, is the 10th percentile of the sampling distribution of the mean from a sample of 30 from a beta distribution with mean as given in the fourth column of Table 2, and with a standard deviation half as large. We determined these percentage points by simulation with 100,000 trials. The column in Table 3 labeled "Critical Mesa Ratio" is the minimum mean ratio of a sample of 30 vehicles that is consistent (with 90% confidence) with the true mean ratio being as required in Table 2.

Table 3: Critical Ratios

Vehicle Activity	Monitoring Frequency	Fraction in Compliance	Critical Mean Ratio
Trips/Day	MIL/2 weeks	0.90	0.057
f-Trips/Day	MIL/2 weeks	0.90	0.297
fE-Trips/Day	MIL/2 weeks	0.50	0.230
fE-Trips/Day	MIL/3 weeks	0.50	0.155

In order to avoid an anomalous situation in which the mean ratio criterion is reached by a few large ratios, rather than by the general level, we can also require that the median ratio not be significantly below the required population mean ratio in Table 2. This is achieved (at about the 90% significance level), by requiring that no more than 19 in the 30 vehicles have ratios below the required mean ratio in Table 2. This is a sign test for the median.²

² If the true median was the number listed in Table 2, then there is a 50% chance that each ratio is below the required number. In a binomial sample with $n = 30$ and $p = 0.5$, the chance of 19 or more in 30 being below is 0.1002

Appendix

A. Properties of the Beta Distribution

The beta distribution with parameters (α, β) , denoted $\text{Beta}(\alpha, \beta)$ has density

$$f(x) = [B(a, b)]^{-1} x^{a-1} (1-x)^{b-1}, \quad (\text{A.1})$$

where $B(a, b)$ is the beta function. The mean and the variance of such a beta variable X are given by

$$E(X) = \frac{a}{a+b} \quad (\text{A.2})$$

$$V(X) = \frac{ab}{(a+b)^2(a+b+1)} \quad (\text{A.3})$$

Beta distributions form a natural and flexible class of distributions on $[0,1]$. All values generated from a beta distribution are positive and less than 1, and the parameters α and b can be chosen to match any possible mean m and variance σ^2 as follows:

$$b = \frac{m(1-m)^2 - s^2(1-m)}{s^2} \quad (\text{A.4})$$

$$a = \frac{bm}{1-m} \quad (\text{A.5})$$

Since both α and β must be positive, the requirement on a given mean m and variance σ^2 to be legal values for a beta distribution are

$$s^2 < m(1-m), \quad (\text{A.6})$$

which can be rewritten in terms of the CV as

$$CV < \sqrt{\frac{1-m}{m}} \quad (\text{A.7})$$

For example, if the mean is 0.25, the CV must be less than 3. This mathematical constraint should cause no modeling problems. See Johnson, Katz, and Balakrishnan (1995) for further details.

B. Properties of the Gamma Distribution

The gamma distribution with parameters (α, β) , denoted Gamma (α, β) has density

$$f(c) = [\Gamma(\alpha)]^{-1} c^{\alpha-1} e^{-cb}, \quad (B.1)$$

where $\Gamma(\alpha)$ is the gamma function. The mean and the variance of such a beta variable X are given by

$$E(X) = \alpha\beta \quad (B.2)$$

$$V(X) = \alpha\beta^2 \quad (B.3)$$

Gamma distributions form a natural and flexible class of distributions on $[0, \infty]$. All values generated from a gamma distribution are positive, and the parameters α and β can be chosen to match any mean μ and variance σ^2 as follows:

$$\alpha = \frac{\mu^2}{\sigma^2} \quad (B.4)$$

$$\beta = \frac{\mu}{\alpha} \quad (B.5)$$

See Johnson, Kotz, and Balakrishnan (1994) for further details.

C. Properties of the Poisson Distribution

The Poisson distribution with parameter θ , denoted Poisson(θ) has probability function

$$p(x) = \frac{e^{-\theta} \theta^x}{x!} \quad (C.1)$$

The mean and the variance of such a Poisson variable X are given by

$$E(X) = \theta \quad (C.2)$$

$$V(X) = \theta \quad (C.3)$$

The Poisson distribution is the simplest model for the occurrence of discrete events in time. See Johnson, Kotz, and Kemp (1992) for further details.

References

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