State of California
AIR RESOURCES BOARD

**WORKSHOP REPORT:**

# Technical Status and Revisions to Malfunction and Diagnostic System Requirements for 2010 and Subsequent Model Year Heavy-Duty Engines (HD OBD)

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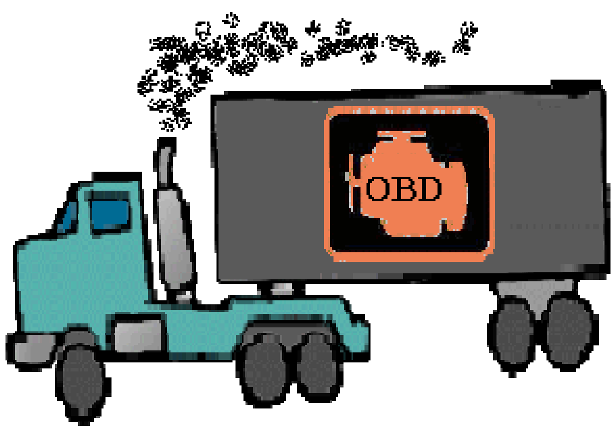


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# I. INTRODUCTION

On-board diagnostic (OBD) 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 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 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 California Air Resources Board (ARB) originally adopted comprehensive OBD regulations in 1989, requiring all 1996 and newer model year passenger cars, light-duty trucks, and medium-duty vehicles and engines to be equipped with OBD systems (referred to as OBD II). In 2004, ARB adopted the Engine Manufacturer Diagnostic system (EMD) regulation (section 1971, title 13, California Code of Regulations (CCR)), which requires manufacturers of heavy-duty engines and vehicles (i.e., vehicles with a gross vehicle weight rating greater than 14,000 pounds) to implement diagnostic systems on all 2007 and subsequent model year on-road heavy-duty Otto-cycle (gasoline) and diesel engines. However, the EMD regulation is much less comprehensive than the OBD II regulation, requiring the monitoring of only a few major emission control technologies and containing no standardized requirements. Essentially, the EMD regulation was developed to require heavy-duty engine manufacturers to achieve a minimum level of diagnostic capability while focusing most of their resources on meeting the new 2007 exhaust emission standards. Subsequently, in 2005, ARB adopted section 1971.1, title 13, CCR, which established comprehensive OBD requirements for 2010 and subsequent model year heavy-duty engines and vehicles.

The OBD requirements for heavy-duty engines are important, especially considering the increasingly stringent heavy-duty emission standards that will be phased in during the 2007-2010 timeframe. As new engines are being designed to meet these stringent standards (which include the application of new emission control technologies), the OBD system will help ensure that the engines are able to meet these standards and maintain low emissions for the life of the engine. It will accomplish this by monitoring the durability and performance of the emission control components and systems and by providing technicians with information that will help in diagnosing and fixing the malfunctions. Currently, the requirements allow manufacturers to implement an OBD system on a single engine family for the 2010 through 2012 model years before implementing it on all engines in the 2013 model year. This phase-in is primarily designed to allow manufacturers to more effectively use their personnel and testing resources (which are already heavily being used to ensure compliance with the 2010 emission standards) and allow them to gain experience on a smaller number of engines prior to widescale implementation.

Since adoption of the heavy-duty OBD regulation in 2005, ARB staff has been meeting with manufacturers to review progress in meeting the regulatory requirements. A number of issues have been identified where staff and industry differ significantly as to the necessity of or the stringency of a monitoring requirement. While staff agrees some modifications are warranted in some cases, staff also disagrees with some of manufacturers' proposed changes. The following section details manufacturers' main concerns and proposed changes as well as ARB staff's conclusions and attendant rationale. Staff is also proposing other amendments to the regulation that are not detailed below, including additions to the required data stream parameters and updates to the latest versions of Society of Automotive Engineers and International Organization of Standards documents. All the proposed amendments to section 1971.1 are included in Attachment A, with proposed additions to the regulation denoted by underline and proposed deletions denoted by ~~strikeout~~.

## II. TECHNICAL STATUS UPDATE AND PROPOSED AMENDMENTS

### A. INFREQUENT REGENERATION ADJUSTMENT FACTORS

Diesel emission control technology has been rapidly evolving in recent years to allow engines to achieve compliance with lower tailpipe standards. However, some of the new emission controls do not work in a traditional manner of continuously reducing emissions. Instead, these components effectively reduce emissions for some amount of time and then temporarily require an alternate mode of operation to renew/regenerate the component before it can resume effectively reducing emissions. Two examples of such emission controls are the particulate matter (PM) filter, which typically requires an active regeneration event every 300 to 500 miles to burn off the accumulated soot, and an oxides of nitrogen (NOx) adsorber, which periodically requires a desulfurization event. When these infrequent, but periodic, events occur, tailpipe emissions can increase dramatically and exceed the allowable tailpipe standards. Accordingly, the tailpipe standards require diesel engine manufacturers to account for these infrequent emission increases and include them as part of their emission measurement when determining compliance with the tailpipe standard. Since these events occur infrequently, the emission test procedures define a method for manufacturers to account for the additional emissions by taking into account the frequency of the events, the magnitude of emission increase of the event, and the duration of the event. For a simple example, take a regeneration event that is active once within every ten emission tests, causes an emission increase of 1.3 grams per brake-horsepower hour (g/bhp-hr) NOx, and takes less than one emission test to complete. The emission test procedures would require one-tenth of the 1.3 g/bhp-hr increase, or 0.13 g/bhp-hr, to be added to emission test results obtained without the event, and this total would be compared to the tailpipe emission standard. This method allows the excess emissions generated during the infrequent event to be spread out across all emission tests between successive events and to provide a representative average emission level from the vehicle. Manufacturers are all aware of these provisions and have been performing such measurements as part of their certification process since they began using emission controls with infrequent regeneration events.

Within OBD, there are several malfunctions that are required to be detected prior to emissions exceeding defined tailpipe levels (e.g., prior to emissions exceeding 2.0 times the standard). Because infrequent regeneration events do affect overall emissions from the vehicle, the OBD regulation also requires diesel engine manufacturers to account for these events when calibrating diagnostics that are tied to defined emission levels. Further, the presence of the malfunction itself can affect the regeneration event (in frequency, duration, or even magnitude of emission increase) so manufacturers are currently required to take those effects into account and calibrate such that the average emission level from the engine, including adjustments for infrequent regeneration events with a malfunction present, is at or below the required OBD malfunction threshold. However, engine manufacturers have requested this requirement to account for impacts on infrequent regeneration adjustment factors when calibrating OBD monitors (section 1968.2(d)(6.2)) be eliminated or changed.

First, manufacturers have argued that the additional testing time and resources to properly determine the adjustment factors are significant and costly. Second, the tailpipe emission certification process already ensures the emission solution is robust and includes the emission impact of the infrequent regeneration processes. Thus, they argue, there is little added benefit in determining unique infrequent regeneration adjustment factors (IRAFs) for each OBD malfunction. Accordingly, they have asked staff to eliminate the requirement to account for changes in IRAFs due to threshold parts and to either ignore IRAFs altogether or to allow the certification IRAFs to be applied instead. ARB, however, does not agree with the manufacturers' position and is not proposing elimination or modification of this requirement.

Manufacturers have indicated it takes substantial test time and resources to establish IRAFs for tailpipe certification and repeating that process for each OBD threshold would be an enormous task. ARB staff, however, believes manufacturers would not need to repeat the entire process to determine what, if any, impact the presence of a malfunctioning component will have on IRAFs. The costs and resources necessary should be very limited, requiring only a small amount of additional resources and emission testing (if needed), and should be nowhere near the level of effort required to generate the baseline factors for tailpipe certification. For this reason, staff’s cost analysis apportioned only a small amount of resources to the specific task of determining unique IRAFs. The engineers that are carrying out calibration of OBD malfunctions (which involves iterative emission testing with a varying degree of a malfunctioning part) must have a detailed understanding of the engine and interactions between various components, especially in cases where a component is malfunctioning. This knowledge is necessary to design a robust diagnostic that will comprehend these interactions and still make correct decisions. This is the very same type of knowledge staff expects manufacturers to use to determine if there is an impact to the adjustment factors that warrants further analysis or testing to identify the magnitude of the change to the baseline factors. Specifically, the baseline factors would only be affected if the implanted malfunction causes significantly higher PM accumulation rates in the PM filter (such that active regeneration would be triggered more frequently) or causes emissions during an actual regeneration event to be significantly different. Staff expects manufacturers to be able to reasonably estimate whether either of those two cases is likely and, for those that are, use existing or additional emission test data to determine the impact. The baseline factors would then be scaled accordingly.

Manufacturers have argued that they conduct lengthy test processes to accurately quantify the interval between regeneration events for tailpipe certification and repeating such tests would be a costly use of resources. However, it is not expected that a manufacturer would have to implant the fault and continue testing until a regeneration event occurs to be able to make that determination. Manufacturers would be able to reasonably extrapolate the impact using shorter test intervals by looking at data captured during the iterative emission testing being done for the OBD threshold calibration. As an example, by gathering data of the PM filter loading (e.g., by looking at engine-out PM emissions or more likely, the rate of accumulation for the various regeneration triggers) during testing with an implanted malfunction and comparing it to baseline testing, manufacturers would be able to determine if the malfunction is likely going to lead to more frequent or less frequent regeneration and by how much. Such data would be sufficient to determine the necessary adjustment to the baseline frequency factor. For those malfunctions that the manufacturer has determined are likely to have an impact on regeneration emissions themselves, manufacturers may have to carry out an additional test with a malfunctioning component present and regeneration active and compare the results to the baseline to determine the magnitude of the adjustment to the baseline factors. However, even this 'additional' test may likely be encountered during the normal calibration of the OBD threshold or could be intrusively triggered by inserting a loaded PM filter or altering the regeneration triggers to force the regeneration to happen while the faulty part is installed. As the manufacturer applies similar strategies and controls across its product line, this process would likely be refined even further to make capturing the necessary data an automatic step during the calibration process and thus, virtually eliminate the need for any additional testing.

Some manufacturers have suggested they would encounter substantial additional testing to develop adjusted IRAFs in spite of staff examples of how the process could be shortened using engineering judgment. Manufacturers claim that they cannot be sure their own engineering judgment is "good enough." They believe that, to ensure emissions are below required IRAF-based OBD thresholds with a faulty component present, nothing short of full-scale testing could be used. This argument seems specious, however, since a great deal of OBD decisions require sound engineering judgment to be applied - from determining what kind of malfunction is most likely to yield the highest emissions for a given threshold-based monitored component to deciding what kind of driving cycle will reveal the highest emission increase to determine whether a component even needs to be functionally monitored. What matters most is that the analysis and data used in arriving at the adjusted IRAF are documented and wellfounded. Should an estimating methodology contain a flaw that isn't easily anticipated, leading to higher than expected regeneration emission impacts during in-use compliance testing or some other reasonably non-anticipated effect takes place, section (m)(4) of the heavy-duty OBD regulation provides relief in that ARB may not consider a system noncompliant if it is caused by something that could not have been reasonably foreseen by the manufacturer.

In OBD, there are several malfunction thresholds that require calibration to ensure malfunctions are detected before they exceed prescribed emission limits. These malfunctions may affect engine-out emission levels or aftertreatment performance (e.g., conversion efficiency of pollutants) which, in turn, can alter the regeneration frequency or emission levels during a regeneration event much more than when all components in the system are operating normally. Therefore, the manufacturers' position that the baseline tailpipe emission certification process already accounts for the emission impact of the infrequent regeneration processes is incorrect. Without re-determining the frequency or measuring the new emission levels, a manufacturer cannot verify that the total emissions from the vehicle, on average, will be at or below the required OBD threshold levels when a fault is detected. For example, if manufacturers were not required to adjust the IRAF for a malfunctioning oxidation catalyst when calibrating the oxidation catalyst monitor, the manufacturer would likely be able to calibrate the system to only detect a fault when an oxidation catalyst was completely missing since the impact of the catalyst on emissions during non-regeneration is generally very small. However, during a regeneration event, where emission levels can be 10 or more times above the emission standard with a properly operating system, a missing catalyst can cause those emissions to be substantially higher still. One manufacturer reported to ARB that emissions were so high during a regeneration event with a malfunctioning catalyst that they were unable to measure the results in their emission test cell. The manufacturers' suggested approaches of applying the baseline IRAFs and/or not taking into account the higher emissions would lead to a much higher emission level in the real world before a malfunctioning catalyst would be detected.

## B. STANDARDIZED METHOD TO MEASURE REAL WORLD MONITORING PERFORMANCE

Currently, the regulation requires manufacturers to track monitor performance by counting the number of monitoring events and the number of driving events. The number of monitoring events is defined as the numerator and the number of driving events is defined as the denominator. The ratio of these two numbers is referred to as the monitoring frequency and provides an indication of how often the monitor is operating relative to vehicle operation. It is important to note that the denominator is a measure of vehicle activity, not a measure of "monitoring opportunities". The regulation requires manufacturers to design monitors that meet a minimum acceptable ratio, currently set at 0.1 for 2013 and subsequent model year engines.

The current requirement for incrementing the general denominator is:

1.) minimum engine run time of 10 minutes;

2.) minimum of 5 minutes, cumulatively, of vehicle operation at vehicle speeds greater than 25 miles-per-hour (mph) for gasoline engines or calculated load greater than 15 percent for diesel engines; and
3.) at least one continuous idle for a minimum of 30 seconds encountered; and the above three conditions met while:
4.) ambient temperature above 20 degrees Fahrenheit and
5.) altitude of </= 8000 feet.

Industry has expressed concerns that some monitors may not execute on the denominator drive cycle defined above and, therefore, some vehicles may exhibit poor in-use ratios. However, industry has erroneously reached the conclusion that the denominator represents a drive cycle during which all monitors must be executed. On the contrary, manufacturers are not required to design monitors to execute during the denominator drive cycle but are required to design robust monitors that perform frequently in-use. Monitors are designed to run when specific engine operating conditions are met—not when a specific drive cycle is met—and the occurrence of those conditions happens independent of whether a denominator drive cycle is met. For example, a case may exist where a monitor never executes on the denominator cycle but the minimum in-use frequency ratio may still be satisfied because the monitor executes frequently on other drive cycles. The purpose of the denominator is not to provide industry with a drive cycle by which to run all monitors but to provide ARB with a measure of vehicle activity.

Additionally, industry has requested changes in the definition of the denominator drive cycle. When the regulation was adopted in 2005, diesel engine manufacturers indicated that they did not always have access to vehicle speed and thus, could not determine when a vehicle had spent five cumulative minutes above 25 mph. As an alternative, they proposed, and ARB accepted, five minutes above 15 percent engine load for diesel engines. At this time, however, diesel engine manufacturers have now indicated that 15 percent engine load is not a consistent indicator from engine to engine, since it could be satisfied at idle on some engines while it is satisfied with operation somewhere above 25 mph on other engines. Diesel engine manufacturers now propose greater than 50 percent calculated load for five cumulative minutes in lieu of greater than 15 percent for five cumulative minutes. Further, for those engines that do have access to vehicle speed, industry has requested permission to alternatively use the gasoline engine parameter of greater than 25 mph for five cumulative minutes on diesel engines in lieu of the greater than 15 percent load.

Regarding the denominator drive cycle, ARB's objective is to provide a common definition because manufacturers will be held to the same minimum in-use frequency ratio based on this definition and the use of different definitions would lead to inequity among manufacturers. Under the current regulation, while gasoline and diesel engines do not use the same definition, all diesels are required to use a consistent definition and all gasoline are required to use a consistent definition. This consistency among similar engines is imperative to ensure equivalent stringency in requirements among manufacturers and must be maintained. However, staff agrees that the 15 percent engine load criterion is inappropriate as a consistent measure of engine work or vehicle activity. To address industry's concern and maintain commonality, staff is proposing to change this definition to exclude the calculated load parameter and instead include five cumulative minutes of engine speed at or above 1150 rpm for diesel engines. Staff believes 1150 revolutions-per-minute (rpm) represents an engine speed above idle in virtually all engines and is a positive indicator that the engine is being used to do work (e.g., move the vehicle, operate a substantial power take-off unit). Many engines have peak torque that occurs at 1200 rpm and above and most manufacturers' engines are subject to the not-to-exceed emission standard at engine speeds above 1150 to 1200 rpm. And, whenever the engine is doing work, it is vital that the emission controls are working properly so basing an in-use monitoring frequency relative to how often the engine is being used to do work is appropriate. Further, all manufacturers have access to engine speed and could accurately determine when this criteria was satisfied. With the 2010 model year production fast approaching, however, staff believes some lead time is necessary and is allowing 2010 through 2012 model year diesel engines to use the calculated load criterion. Additionally, to maintain consistency of the denominator definition and equality among manufacturers, staff does not agree with manufacturers' request to optionally use the vehicle speed criterion in lieu of the engine speed or load criterion.

In addition to the proposed changes to the general denominator definition above, staff is proposing a separate denominator for PM filter monitoring. Currently, the regulation allows manufacturers to submit proposed criteria for incrementing the PM filter monitor denominator for ARB approval. Since the adoption of the requirement, staff has gained enough knowledge from discussions with engine manufacturers to propose specific criteria for the PM filter monitor, which engine manufacturers have indicated will most likely be tied to PM filter regeneration events. Thus, in addition to meeting the general denominator on at least one driving cycle, staff is proposing that the PM filter denominator be incremented after 750 minutes of cumulative engine run time. The basis for 750 minutes is calculated starting from a 300-500 mile interval that industry has indicated is typical of distance between PM filter regenerations and assuming an average vehicle speed of 40 mph (500 miles / 40 mph = 12.5 hours = 750 minutes).

The proposed revised definition for the general rate-based denominator for diesel engines is:

1.) minimum engine run time of 10 minutes;
2.) minimum of 5 minutes, cumulatively, of engine operation with engine speed at or above 1150 rpm; and
3.) at least one continuous idle for a minimum of 30 seconds encountered; and the above three conditions met while:
4.) ambient temperature above 20 degrees Fahrenheit and
5.) altitude of </= 8000 feet.

The proposed definition for the PM filter rate-based denominator is:

1.) minimum of 750 minutes of cumulative engine run time since the last time the PM filter denominator was incremented and
2.) meeting the above requirements for the general denominator on at least one driving cycle.

## C. DIESEL FUEL SYSTEM MONITORING

The regulation currently requires diesel manufacturers to continuously monitor for fuel system pressure control malfunctions. While some manufacturers have implemented common rail fuel systems, which can readily be monitored continuously for pressure malfunctions, others have expressed concerns that fuel pressure monitoring cannot be done continuously for non-common rail systems such as electronically controlled, mechanically actuated, unit injector systems . Based on the current design of the unit injector system, where fuel pressure is generated within each individual injector as opposed to via a high-pressure fuel pump as used in a common-rail system, the only method identified by the manufacturers to continuously monitor the fuel pressure would be to add a pressure sensor in each injector, which may not be a practical solution. Manufacturers contend there are no other viable solutions for continuous fuel pressure monitoring for unit injector systems. Manufacturers indicate, however, that they can monitor for fuel pressure faults by running an intrusive monitor once per trip under constrained conditions. Accordingly, manufacturers have asked ARB to change the regulation to only require monitoring to be conducted once per trip on non-common rail systems.

It is important to achieve proper fuel pressure in a diesel engine to maintain low emission levels. Continuous monitoring of the fuel pressure would ensure that if there was a problem, even it if only affected a portion of the engine operating conditions or if it had a varying impact (e.g., a big impact in some regions and a small impact in other regions), it would reliably get detected as long as operation in impacted regions was encountered. Conversely, with a once-per-trip monitor that only runs under a subset of engine operating conditions, only faults that impact the region where monitoring occurs will be reliably detected.

However, ARB does agree that it would be very difficult, if possible, to continuously monitor the fuel pressure on unit injector systems or fuel systems that achieve injection fuel pressure within the injector or increase pressure within the injector (e.g. in the injector of an amplified common rail system) given their current design, and is thus proposing to not require continuous fuel pressure monitoring for these systems. Proper fuel pressure, however, is still critical for emissions and staff is concerned about different faults that may only impact specific regions of the engine operating conditions. As a compromise, staff is proposing a change that would allow once per trip monitoring of fuel pressure, but manufacturers would be required to demonstrate that the diagnostic (or diagnostics) can detect all failure modes which would lead to a fuel pressure problem within the entire range of engine operating conditions and before emissions exceed the OBD malfunction thresholds. A manufacturer would be required to submit details of their system and a failure analysis, such as a failure mode and effects analysis, identifying all possible failure modes and the effect each has on fuel pressure across the entire range of engine operating conditions. If different faults can cause pressure problems in exclusive regions (e.g., some only affect idle and some only affect off-idle), the manufacturer would be required to implement more than one diagnostic or enable the diagnostic in various operating conditions to cover the regions where faults could occur and use logic to ensure such faults are robustly detected.

In addition to the above proposal, based on discussions with some manufacturers working on their fuel pressure control monitors, ARB has identified an area where further clarification would be beneficial. Specifically, manufacturers have asked questions about whether they should be using a single injector fault or a fault that affects all cylinders equally when calibrating the fuel pressure, quantity, and timing monitors to the OBD thresholds. Staff generally tries to pick a reasonable compromise between calibrating for all possible combinations of failures and a manageable number of combinations. Therefore, staff is proposing that for fuel pressure, quantity, and timing monitoring for systems that have single component failures which could affect a single injector (e.g., systems that build injection pressure within the injector that could have a single component pressure fault caused by the injector itself), manufacturers would be responsible for calibrating for both a single cylinder fault that causes the system to reach the malfunction criterion as well as a fault that equally affects all cylinders such that the malfunction criterion is reached. Staff believes this represents reasonable coverage for failures in use, be it a gradual deterioration or fault that affects all cylinders virtually equally or a more severe degradation or malfunction of a single injector that by itself causes such an emission increase. For systems that achieve injection pressure outside of the injector (e.g., common-rail systems), staff is proposing that for fuel quantity and timing monitoring, manufacturers would be required to calibrate for both a single cylinder fault and a fault that equally affects all cylinders, while for fuel pressure monitoring, manufacturers would only be required to calibrate for a fault that equally affects all cylinders. Staff's rationale for the difference in fuel pressure monitoring is that systems like a common-rail system achieve injection pressure independent of the individual injectors and are unlikely to have a pressure fault affecting a single cylinder (but are still susceptible to quantity or timing faults that would affect a single cylinder or all cylinders equally).

## D. DIESEL NON-METHANE HYDROCARBON (NMHC) CONVERTING CATALYST MONITORING

The regulation currently requires diesel engine manufacturers to design the OBD system to detect an NMHC catalyst malfunction when the catalyst conversion capability decreases to the point that NMHC emissions exceed 2.5 times the applicable standard for 2010 model year engines. However, if a catalyst malfunction does not result in emissions exceeding this threshold, the regulation allows the manufacturer to detect a malfunction when the catalyst has no detectable amount of NMHC conversion capability. Monitoring of NMHC conversion performance is also required for catalyzed PM filters, with monitoring similarly required at 2.5 times the applicable standard or, if emissions cannot exceed that level, for complete failure of the NMHC-catalyzing function.  The regulation also currently requires manufacturers to monitor the NMHC catalyst for its ability to perform other emission-related functions.  Specifically, monitoring is required to ensure that the catalyst performance is sufficient to provide an exotherm necessary for PM filter regeneration and, if applicable, to generate a desired feedgas (e.g., nitrogen dioxide ($NO_2$)) to promote better performance in a downstream aftertreatment component (e.g., for higher NOx conversion efficiency in a selective catalytic reduction (SCR) system).

With respect to NMHC-converting catalyst monitoring, engine manufacturers are concerned that total failure of NMHC catalysts will push emissions over the threshold and force them to implement threshold monitors.  Furthermore, they do not believe that there is any monitoring technology that can robustly detect anything other than a completely failed NMHC catalyst.  Lastly, they believe the current requirement of determining and applying an adjusted IRAF when determining the emission level of a malfunctioning catalyst exacerbates this problem by requiring them to detect a less degraded catalyst.  Accordingly, manufacturers have asked ARB to raise the threshold to 4.0 times the NMHC standard and remove the requirement to develop and apply an adjusted IRAF so that manufacturers would very likely only have to implement functional monitors.

Staff, however, does not agree with the manufacturers' assessment of the current monitoring technology, and is not proposing any changes to the current malfunction thresholds.  Staff believes that there are currently feasible methods to perform threshold monitoring of the NMHC catalyst.  For discerning a good from bad catalyst, manufacturers have primarily focused on whether the catalyst can generate a sufficient exotherm and have concluded that a catalyst is either able to produce a sufficient exotherm (and thus, is perfectly adequate) or it is unable to produce a sufficient exotherm (and thus, is completely failed).  Manufacturers have concluded from such analysis that there is no level of catalyst degradation between perfectly adequate and completely failed and that an exotherm monitor can only discern those two states.  However, in talking with suppliers and individual manufacturers, catalysts do indeed have intermediate levels of deterioration that cause increases in light-off temperature and lower conversion efficiencies.  By looking more closely at the catalyst behavior during active regeneration (e.g., by investigating how much time and/or fuel is needed to generate an exotherm, tracking the actual temperature rise from the exotherm versus the expected, and using better temperature sensors), manufacturers may be able to better determine the characteristics exhibited as an NMHC catalyst degrades (even if it is still capable of eventually getting to a high enough exotherm to achieve regeneration of the PM filter).  As an alternate approach, there are at least two light-duty manufacturers that are planning on monitoring the catalyst during a cold start.  Often combined with an accelerated catalyst light-off strategy similar in concept to what many gasoline manufacturers use, this monitoring approach tracks the light-off and/or temperature rise characteristics to evaluate the catalyst during intrusive actions intended to bring the catalyst up to the desired temperature quickly after a cold start.

Along with improved monitoring approaches, manufacturers have the ability to reduce the emission impact associated with a malfunctioning catalyst.  For example, engine-out NMHC emission levels have a direct impact on the emission levels from a malfunctioning NMHC catalyst.  The lower the engine-out emissions, the lower the tailpipe emissions for a given level of degraded catalyst.  In addition to looking into reducing engine-out emissions, manufacturers can also look into reducing emissions during a regeneration event.  Manufacturers have generally indicated that without an NMHC catalyst, baseline tailpipe NMHC emissions are very close to the NMHC standard (still under in some cases, slightly over in others) and nowhere near the OBD malfunction criteria of 2.5 times the standard.  However, when an active regeneration of the PM filter occurs and the NMHC catalyst is degraded or non-functional, emissions can be very high.  Accordingly, when defining the level of degraded catalyst that reaches the OBD malfunction threshold (e.g., 2.5 times the standard), the emissions during the PM filter regeneration are the primary emission contributors.  Because manufacturers are required to account for changes in regeneration emissions in the form of an adjusted IRAF, the 'threshold' NMHC catalyst is almost exclusively defined by the impact on regeneration emissions.  The more infrequent the regenerations or the smaller the emission increase during regeneration, the more tolerant the system is of a degraded catalyst before the OBD malfunction criterion is reached.  Again, manufacturers have the ability to directly reduce the emission impact associated with a malfunctioning catalyst by minimizing emissions during a PM filter regeneration event. Manufacturers that have less refined control strategies for regeneration (e.g., injecting fixed quantities of fuel regardless of the observed temperature rise/reaction of the catalyst) will have higher associated emissions while those that more closely regulate the regeneration event can take quicker action to terminate or reduce fueling when the expected reaction does not occur.  At least two manufacturers have taken this approach to be able to meet a lower tailpipe emission level with a degraded catalyst that their catalyst monitor is able to identify as a malfunction.

Similar to their argument for NMHC converting catalyst monitoring, manufacturers have also asked for the 2010 model year threshold to be raised from 2.5 to 4.0 times the standard for catalyzed PM filter NMHC conversion monitoring to ensure that only a functional check would be needed.  Staff has been talking with suppliers and individual manufacturers regarding the use and monitoring of catalyzed PM filters.  While there is no consistent trend in industry, many are looking at catalyzed PM filters and acknowledging that the incremental cost of a catalyzed PM filter is not insignificant.  As such, those that are using catalyzed PM filters are doing so because they are realizing actual benefits.  Most have stated that it simply 'helps out' with regeneration without being able to quantify the actual impact.  Discussions with others indicate that the catalyzed coating leads to higher levels of passive regeneration at lower exhaust temperatures, helps convert hydrocarbon (HC) and carbon monoxide created during an active regeneration, and can help generate $NO_2$ feedgas for downstream SCR systems. Again, given the importance of these tasks and manufacturers' acknowledgment that they are spending extra money to have these functions, it is appropriate that monitoring be required.  If the reasoning behind having the catalyzed coating is the impact on passive regeneration, then this function should be able to be monitored by looking at regeneration frequency or rate of soot loading increase under conditions where high levels of passive regeneration are expected. At least one heavy-duty manufacturer believes that there will be a detectable difference in active regeneration frequency between a PM filter with and without the catalyzed coating and is designing their 2010 monitor to detect this. However, staff acknowledges that manufacturers are scrambling to finish their systems for the 2010 model year and many are behind schedule on OBD development because the emission calibrations are not finalized. The success of the monitoring approaches outlined above may be highly dependent on the actual catalyst configuration, significance of the catalyst loading on the PM filter, and regeneration strategy (especially reliance on high levels of passive regeneration). Accordingly, staff is proposing to delay the monitoring requirements of the catalyst function of catalyzed PM filters until the 2013 model year to give manufacturers more time to refine their systems, optimize regeneration strategies, and better investigate the impacts of the catalyzed PM filter.

For monitoring of the NMHC catalyst's ability to generate a desired feedgas used to improve performance of a downstream aftertreatment component, manufacturers have indicated that insufficient knowledge exists about what property of the catalyst causes the desired feedgas and thus have argued that there is no feasible or known method to verify that such function is still properly operating. Further, manufacturers have indicated that the impact of such a failure is decreased efficiency of the downstream aftertreatment component (e.g., SCR system). Accordingly, manufacturers have asked ARB to eliminate the requirement to directly verify the NMHC catalyst generates sufficient feedgas for other components and to instead rely on monitoring of the downstream component (e.g., SCR system) to detect a failure if the impact is large enough to cause emissions to exceed the OBD malfunction criteria.

However, the manufacturer's claim that they have insufficient knowledge about the mechanism of the catalyst that creates the desirable feedgas is not supported. Staff has met with various suppliers to the manufacturers who have indicated that they understand the properties of the catalyst extremely well and alter specific components to achieve the feedgas generation the manufacturers are asking for. In most cases, the catalyst is being used to oxidize nitric oxide (NO) to $NO_2$ to increase the relative $NO_2$ levels, which can help oxidize soot in a PM filter (leading to higher levels of passive regeneration of the PM filter or more effective active regenerations) and, perhaps more importantly, can improve NOx conversion efficiency in an SCR system. Using a catalyst to generate such a feedgas is not that new of a technology as there are even retrofit devices certified by ARB for use on older model year diesel engines that take advantage of these catalyst properties. Further, discussions with suppliers indicate that that this catalyst function is likely to be the first to deteriorate and would not be accompanied with a substantial change in the catalyst's HC conversion efficiency or ability to generate an exotherm. As such, staff believes that being able to determine whether the catalyst is still performing this function is essential and is concerned that a failure of this function will not likely be detected by the NMHC catalyst monitoring strategies mentioned above.

The manufacturers' proposal would require the failure of this function to be detected only if it alone causes the SCR system conversion efficiency to drop so far that it exceeds the OBD thresholds for the SCR system (approximately 2.5 to 3.0 times the standard). Staff does not believe this is an acceptable solution because, while failure of this NMHC catalyst property will lead to decreased SCR NOx conversion efficiency and likely higher tailpipe NOx levels, it is not expected to cause a large enough impact to exceed the SCR catalyst threshold. Under this scenario, this NMHC catalyst property could be completely non-functional, tailpipe emissions will be increased by some amount, and the system will continue to operate without any indication to the operator that a malfunction has occurred. Further, if the SCR system itself eventually degraded enough that the combined impact of the upstream catalyst and the SCR catalyst efficiency exceeded the threshold and illuminated the MIL, technicians would likely only replace the SCR catalyst components to extinguish the MIL. This repair sequence would result in essentially a partial repair—emissions would never be returned to the levels they were at when the upstream catalyst was also properly functioning. At this time, the most promising monitoring technology for verifying this function of the catalyst is some form of an SCR system NOx conversion efficiency evaluation to detect lower than expected conversion efficiencies in the absence of the proper feedgas. One heavy-duty manufacturer has indicated its intent to detect such a malfunction by evaluating the NOx conversion efficiency across the SCR system during specific operating conditions. If successful, this manufacturer would be able to detect a fault when this property of the NMHC catalyst was gone but the SCR system was still operating properly.

If the catalyst's ability to generate NO2 also has a significant impact on PM filter regeneration, another possible monitoring approach would involve evaluation of PM filter regeneration characteristics. In cases where the catalyst is used to promote high levels of passive regeneration, manufacturers may be able to identify a malfunction when backpressure or other soot loading measures indicate much higher loading than expected if passive regeneration was working correctly. Given the importance of proper feedgas generation to PM filter regeneration and/or proper SCR system NOx conversion efficiency and the information from suppliers that this catalyst property will likely deteriorate first, staff is not proposing to adopt the changes suggested by the manufacturers. However, staff acknowledges that the monitoring approach of looking at SCR system conversion efficiency does ultimately rely on SCR system configuration and NOx sensor accuracy and is concerned that the monitor resolution may be insufficient in the 2010 timeframe. Additionally, for monitoring approaches looking at PM filter regeneration, the ability to discern properly operating systems from malfunctioning systems may be highly dependent on the manufacturer's catalyst configuration and regeneration strategy. Accordingly, staff is proposing to delay functional monitoring of proper feedgas generation until the 2013 model year. This additional leadtime should provide manufacturers the ability to better understand the catalyst properties used to generate the feedgas, optimize and refine catalyst configurations and PM filter regeneration strategies, and gain experience with NOx sensors and SCR systems to investigate areas where feedgas generation is expected to be high or have a substantial impact on conversion efficiency and focus on those regions for possible monitoring approaches.

Additionally, to be consistent with the recent OBD II regulation update, staff is proposing to add specific language detailing the requirements for manufacturers to functionally monitor an NMHC-converting catalyst used to prevent ammonia slip downstream of an SCR system. Under the current regulation, all NMHC-converting catalysts have to be monitored but specific details were only provided for the most common types of catalysts such as catalysts used to generate an exotherm for PM filter regeneration or catalyzed PM filters. As has been traditionally done in the OBD regulatory updates, as new emission control technologies become more defined, staff adds more specific language to clarify the requirements that apply to that technology. This often removes the need for manufacturers to submit a monitoring plan (e.g., as is required in the 'other emission controls' section) and gives clear direction to manufacturers as to what is expected.

## E. DIESEL OXIDES OF NITROGEN (NOx) CONVERTING CATALYST MONITORING

The regulation currently requires diesel manufacturers to monitor the NOx catalyst(s) for proper conversion capability and to detect a catalyst malfunction before NOx emissions exceed any of the applicable standards by more than 0.3 g/bhp-hr for the 2010 model year. The regulation also requires engines equipped with SCR systems or other catalyst systems that utilize an active/intrusive reductant injection to monitor these systems for proper performance. Manufacturers have expressed concern that the current NOx sensor technology will not provide the accuracy at low concentration levels necessary for OBD monitoring of the SCR catalyst. According to manufacturers, a fresh production NOx sensor currently has a tolerance of +/- 6 parts-per-million (ppm) while an aged NOx sensor currently has a tolerance of +/- 12 ppm. Further, they indicated that the average NOx emissions over the federal test procedure (FTP) transient cycle would have to be roughly 20 ppm to meet the 0.2 g/bhp-hr NOx tailpipe standards for 2010 while concentrations would be roughly 50 ppm at the OBD threshold of 0.3 g/bhp-hr above the standard. Therefore, using an aged +/- 12 ppm NOx sensor to robustly discern a properly operating system at 20 ppm (that could read as high as 32 ppm) from a malfunctioning system at 50 ppm (that could read as low as 38 ppm) would not provide sufficient separation to be feasible. Based upon a paper assessment of the NOx sensor capability as an SCR monitoring device, manufacturers have indicated that to meet the 2010 model year requirements, an aged NOx sensor's accuracy would need to be about +/- 5 ppm, and that a sensor with such an accuracy will not be available in time to meet the 2010 requirements. Thus, manufacturers have asked staff to relax the OBD malfunction threshold for the 2010 model year to a level of 0.6 g/bhp-hr (or 60 ppm) above the NOx tailpipe standard instead of 0.3 g/bhp-hr (or 30 ppm) above the NOx tailpipe standard.

ARB is not convinced that the current NOx sensor capability necessitates raising the SCR catalyst monitor threshold as high as manufacturers have requested. Manufacturers have not provided engineering test data from actual calibrations to support their assessment of SCR monitoring capability and have based their claims primarily on a paper assessment using ‘average’ concentrations over an entire emission test. ARB does, however, believe that some interim relief is needed to address some remaining uncertainties with NOx sensor durability at high mileage and is proposing to raise the OBD malfunction threshold to 0.4 g/bhp-hr (or 40 ppm) above the NOx tailpipe standard for the 2010 through 2012 model years (concurrently, this same threshold will also apply for 2010 through 2012 model year NOx sensor performance monitoring). Based on the manufacturers’ over-simplified analysis, this would require discerning a 20 ppm system (reading as high as 32 ppm) from a 60 ppm system (reading as low as 48 ppm). As explained below, manufacturers should be able to be more selective when monitoring is conducted to provide even more separation than this.

Despite some manufacturers’ claims that improved NOx sensors are needed to monitor the SCR system, other manufacturers have identified different monitoring strategies that utilize current NOx sensor technology to successfully monitor the SCR catalyst. Most of these strategies rely upon monitoring the SCR catalyst only under normally occurring conditions where NOx concentrations are higher. Staff has been shown data indicating that sustained periods of operation above 20 ppm NOx concentrations are occurring during the FTP transient cycle on engines designed to meet the 2010 NOx standard. At higher NOx concentrations (greater than 60 ppm), the accuracy of the NOx sensor is not as critical (e.g., an accuracy of +/- 12 ppm has less relative influence if you are measuring a concentration of 60 ppm instead of 20 ppm) and can provide sufficient separation between a good catalyst and a threshold catalyst.

Manufacturers could design their SCR monitors to run when these higher NOx concentrations are either occurring naturally or created intrusively. Staff has data from a manufacturer that demonstrates the ability to intrusively increase the NOx output of an engine by decreasing exhaust gas recirculation (EGR) under specific engine operating conditions to run other emission-related diagnostics. Therefore, staff believes it is feasible to use the concept of intrusively increasing engine out NOx emissions and to calibrate an SCR catalyst monitor that will both be able to monitor the catalyst with currently available NOx sensors and be within the proposed OBD thresholds. An example of how this could be done is by defining specific engine operating conditions and intrusively reducing EGR flow to temporarily increase inlet (and outlet) SCR catalyst NOx concentrations. While intrusive diagnostics that increase emissions are generally avoided, the negative emission impact of intentionally increasing NOx to the SCR catalyst could be minimized by appropriately increasing reductant injection dosing to the SCR catalyst such that properly operating systems still result in low SCR outlet NOx concentrations while malfunctioning systems show larger relative outlet levels due to the decreased conversion efficiency and increased inlet levels.

In addition to monitoring only at higher NOx levels, alternative methods of monitoring the SCR catalyst conversion efficiency may be available. Staff believes it is feasible to intrusively perform SCR catalyst monitoring by temporarily disabling or altering reductant injection to optimize conditions for catalyst monitoring. Manufacturers have argued that they cannot afford to perform such intrusive strategies because of the negative emission consequence of reduced/disabled reductant injection. However, staff has data from an SCR system showing reductant injection being completely disabled temporarily with no adverse emission impact due to the reductant storage properties of an SCR catalyst. This data suggests that there may be a possibility to infer SCR catalyst NOx conversion efficiency by measuring reductant storage capability if the two parameters can be correlated. Such a strategy would require disabling the dosing and watching for a reaction in the rear NOx sensor. If the sensor saw an increase in NOx soon after disablement, it would indicate poor reductant storage (and potentially correlate to poor NOx conversion efficiency). If the sensor did not see an increase in NOx after some amount of time, the system could conclude the catalyst was working correctly and resume reductant delivery. This strategy offers the potential to avoid any negative emission consequence during monitoring of the SCR catalyst while the catalyst is good by terminating the monitor before any NOx breakthrough has occurred.

## F. DIESEL PARTICULATE MATTER (PM) FILTER MONITORING

The heavy-duty OBD regulation currently requires the OBD system to identify malfunctions of the PM filter when the filtering capability degrades to a level such that tailpipe emissions exceed a specific threshold. For the 2010 through 2015 model year engines, the threshold is the highest of the following thresholds: 0.05 g/bhp-hr as measured from an applicable emission test cycle (i.e., FTP or supplemental emission test (SET)) or the applicable standard plus 0.04 g/bhp-hr (e.g., 0.05 g/bhp-hr for a standard of 0.01 g/bhp-hr).

Heavy-duty engine manufacturers have expressed concern that the current threshold is too stringent and is not technically feasible for the 2010 model year time frame. They contend that the current status of technology cannot support such a threshold. When ARB originally adopted the current requirement in 2005, staff proposed that improved differential pressure sensors and refined soot-loading models should allow manufacturers to comply with the above thresholds by the 2010 model year. Manufacturers insist that current differential pressure sensors cannot measure pressures with the accuracy necessary to comply with the required thresholds in the given timeframe and that there are a number of uncontrolled variables that affect the accuracy of soot-loading models, such as a “lack of rigid control of fuel specifications” and the increased usage of biodiesel fuels that cannot be accounted for in the models. Additionally, part-to-part variability of PM filters increases the uncertainty of the pressure sensor correlation with the emission threshold. In order to achieve the current emission thresholds for PM filter monitoring, manufacturers believe PM sensors are necessary. However, these sensors are not expected to be available in the 2010 time frame.

ARB staff agrees that some relief is needed for these initial years of PM filter monitoring implementation based on discussions with manufacturers about their progress in meeting the monitoring requirements. Thus, staff is proposing to raise the PM filter threshold for the 2010 through the 2012 model year engines to 0.07 g/bhp-hr as measured from an applicable emission test cycle (i.e., FTP or SET) or the applicable standard plus 0.06 g/bhp-hr (e.g., 0.07 g/bhp-hr for a standard of 0.01 g/bhp-hr). Staff believes the increase of the emission threshold by up to 40 percent will sufficiently address manufacturers' concerns on the technical feasibility of meeting the threshold. Two medium-duty diesel engines are already capable of detecting PM filter malfunctions below 0.07 g/bhp-hr and others are expected to meet these same levels soon. Additionally, two heavy-duty engine manufacturers have indicated that they are on track to detect malfunctions prior to PM emissions exceeding 0.05 g/bhp-hr but do not yet have final calibration data to conclusively demonstrate it.

Additionally, heavy-duty diesel manufacturers will have the added knowledge gained from 3 years of equipping engines with PM filters prior to introducing monitors in 2010 that comply with the 0.07 g/bhp-hr threshold. This is in contrast to medium-duty diesel manufacturers who introduced diagnostics meeting the proposed emission threshold concurrent with the introduction of the PM filters on their engines. It is anticipated that with this additional time, heavy-duty diesel manufacturers would be able to meet the same level of diagnostic performance as their medium-duty diesel counterparts.

Furthermore, staff projects that the additional time should provide manufacturers the opportunity to further refine versions of the technology and components they currently plan to use for the diagnostic such as soot loading models and differential pressure sensors. In general, the diagnostics typically involve a comparison of the expected differential pressure derived from the soot-loading model and the actual measured differential pressure sensor across the PM filter. If the measured differential pressure is too small compared to the modeled differential pressure, a malfunctioning PM filter can be determined. However, if the soot loading model and/or the differential pressure sensor are not accurate, it is difficult to discern a good PM filter from a bad one because the differential pressures for the good and bad filters would overlap. As a result, only higher thresholds can be monitored with a crude soot loading model. With improvements to soot loading models and differential pressure sensors, staff believes that most heavy-duty manufacturers will be able to reliably identify malfunctioning PM filters at the proposed 0.07 g/bhp-hr PM threshold in the 2010 timeframe.

In addition to improving the monitoring stringency, more accurate soot loading models would allow manufacturers to operate their PM filter diagnostic more frequently than is currently possible with crude soot models. Under certain engine operating conditions such as driving with a clean PM filter (i.e., a PM filter clear of soot) or low exhaust flow rates, it may be difficult to discern a good PM filter from a bad PM filter, especially with a crude soot model. To compensate for the shortcomings of their soot models, some manufacturers have proposed monitoring the PM filter only under high speeds and loads and only during a limited manufacturer-specified period following a PM filter regeneration event. As a result, in-use monitoring frequency may be low for such strategies and may have difficulty complying with the in-use monitoring frequency requirements. However, if a more accurate soot loading model is utilized, monitoring can be achieved at lower engine speeds (e.g., lower exhaust gas flow rates encountered during highway cruising) and can occur at a variety of PM soot loads, thereby increasing the monitoring frequency of the diagnostic. Improvements to differential pressure sensors will also have a similar positive effect on PM filter monitoring. Therefore, further refinement of soot-loading models and differential pressure sensors would reduce much of the diagnostic measurement variation manufacturers are concerned about and allow monitoring at the proposed 0.07 g/bhp-hr level under a variety of operating conditions that are encountered frequently during in-use driving.

Other areas for improving the diagnostic's accuracy include reducing the manufacturer tolerances in the engine, reducing the part-to-part variability of the backpressure characteristics of the PM filters, and correcting for the backpressure variations of PM filters caused by manufacturing tolerances. Generally, any improvements to aspects that reduce the variation of PM output of the engine or the backpressure characteristics of the PM filter would reduce diagnostic error. Manufacturers could demand tighter tolerances from their suppliers to reduce the variation in these parts to improve the accuracy of the diagnostic. While deviations in back pressure are probably not critical for the durability or trapping performance of the PM filter, they likely will be critical for diagnostic purposes. Sizing of the PM filter itself also plays a role in the backpressure levels and manufacturers are expected to still be gaining experience from the field to define the optimum characteristics to improve monitoring capability.

Additionally, engine manufacturers could correct for PM filter backpressure variation due to manufacturing tolerances. PM filter suppliers would need to individually flow test each filter to determine its backpressure characteristics at different flow rates. This flow rate characteristic could then be coded to identify its variation from nominal specifications. At the engine manufacturing plant, this flow rate correction factor could then be scanned into the engine control unit to individually correct the backpressure variations caused by manufacturing tolerances. Such a method has been used for several years by some medium-duty diesel engine manufacturers to correct the flow characteristics of individual fuel injectors and fuel pumps. Further refinement could lead to on-board adaptive or learning strategies whereby the basic characteristics of the actual engine, PM filter, and pressure sensor are accounted for with some form of assembly line process. Some manufacturers use processes similar in concept to this to correct for cylinder to cylinder variations and/or improve idle quality or engine balancing during assembly. Such strategies also have the potential to be adapted during real world driving conditions or even triggered intrusively following a repair action that would necessitate re-learning.

Regarding manufacturer's concerns on fuel specification variation and increased usage of biodiesel fuels causing uncertainty in the soot loading models, staff agrees that consistent fuel quality is an important aspect in ensuring accurate modeling of the soot loading. However, diesel fuel quality in the United States is consistent in quality and will deliver consistent performance on diesel vehicles. In order to sell diesel fuel, fuel producers must demonstrate that various constituents of their candidate fuel meet certain specifications, including sulfur content, aromatics, and lubricity, and that tailpipe emissions from using the fuel on a known engine do not exceed emissions of that emitted from a reference fuel on the same engine. Additionally, ARB has a fuel enforcement program where fuel inspectors conduct frequent, unannounced inspections of refineries, service stations, distribution and storage facilities, and other facilities to ensure California diesel fuel is of a consistent quality. Lastly, staff acknowledges that biodiesel fuels have been shown to reduce exhaust PM emissions and thereby affect the accuracy of soot loading models if its usage is unaccounted for. However, staff believes that biodiesel usage is still very small in California (less than 0.1%) and its effect on PM soot loading models is not significant in the more common forms available (i.e., B2 or two percent biodiesel content). If higher blends of biodiesel fuel do affect the robustness of the PM filter diagnostics, manufacturers can continue to do what they do today and limit their usage by specifying limits on biodiesel fuels which may be safely used to avoid voiding the engine warranty on parts that can be damaged by its usage, such as the PM filter, fuel injectors, seals, and rubber gaskets. Further, the uncertainties introduced by fuels would have a larger impact on soot loading models as the soot loading increases towards full. However, most manufacturers constrain monitoring to the period shortly after a regeneration event. Even if manufacturers extend the interval and/or wait until some minimum amount of soot is accumulated to achieve better separation between a good and malfunctioning PM filter, it is expected that manufacturers would still limit the loading to the lowest soot loading levels where they can achieve robust monitoring and where the uncertainties introduced by low levels of fuel variation should have minimal impact.

As for PM sensors, staff agrees with industry that these sensors will not be commercially viable for the 2010 timeframe. However, PM sensor manufacturers are making progress and are continuing their development work towards developing a commercial product capable of meeting the 2013 model year PM filter thresholds. For the 2010 model year, as mentioned above, considering that some medium-diesel engine manufacturers are currently achieving the proposed 0.07 g/bhp-hr PM filter emission threshold without PM sensors for the 2007 model year, staff believes that heavy-duty diesel engine manufacturers should also be capable of meeting this threshold in the 2010 timeframe utilizing conventional technology (i.e., PM filter soot modeling and differential pressure sensors).

In addition to the proposed amendment mentioned above, staff is also proposing changes to the malfunction criteria for PM filter frequent regeneration monitoring. Currently, the regulation requires manufacturers to indicate a frequent regeneration fault before emissions exceed 2.0 times the NMHC emission standards. However, in discussions with manufacturers and review of submitted emission data, NOx emissions have often increased significantly during PM filter regenerations. Depending on the manufacturer’s strategy, some NOx emission controls may be temporarily disabled or otherwise scaled back during regeneration events leading to a substantial NOx increase. In some cases, it appears that NOx emissions may be more affected than NMHC emissions. Thus, staff is proposing to require manufacturers to indicate a fault before emissions exceed 2.0 times the NMHC standards or the applicable NOx standard by more than 0.2 g/bhp-hr, whichever occurs first, starting with the 2013 model year.

Lastly, manufacturers have expressed concern about the current requirements for monitoring the NMHC conversion capability of catalyzed PM filters. Staff addressed this issue in section D (Diesel NMHC Converting Catalyst Monitoring) above.

## G. ENGINE COOLING SYSTEM MONITORING

The heavy-duty OBD regulation requires manufacturers to monitor cooling systems for malfunctions that affect emissions or other diagnostics. Engine manufacturers often modify engine operation strategies based on engine coolant temperature (ECT) and utilize it to enable other OBD diagnostics. Malfunctions resulting in improper engine temperature regulation may disable OBD diagnostics, reduce OBD monitoring frequency, cause changes in engine and emission control operation, and cause an increase in vehicle emissions. Therefore, ARB has required cooling systems to be monitored to detect malfunctions if either of the following occurs: (i) the ECT does not reach the highest temperature required by the OBD system to enable other diagnostics, or (ii) the ECT does not reach a warmed-up temperature within 20 degrees Fahrenheit of the engine manufacturer's nominal thermostat regulating temperature. Since engine manufacturers are responsible for designing their own OBD monitors, they have direct control over the first criteria by limiting how high they specify the enable temperature used for other monitors. Manufacturers that choose to design emission solutions that are less sensitive to temperature (or work effectively earlier in warm-up) and design diagnostics that are robust at lower warm-up temperatures can directly reduce the stringency of this monitor.

Nonetheless, engine manufacturers have expressed difficulty in meeting these requirements primarily because the engine may be used in a variety of vehicles and with various other devices that affect the warm-up of the engine. Other than the assurance that there is sufficient cooling capacity at peak engine loads, historically, few constraints have been placed on vehicle manufacturers (i.e., truck builders) and thus, there is significant variance in the engine warm-up characteristics in individual vehicles. Due to this variety, engine manufacturers have commented that they cannot properly distinguish normal warm-up behavior from malfunctioning warm-up behavior. To address these concerns, manufacturers have proposed several modifications to the regulation they believe would make cooling system monitoring more feasible in the 2010 timeframe. One such request involves a change that would allow cooling system monitors to take longer to make pass or fail decisions, spanning many more trips than the two-trip strategy currently allowed for decision making. Specifically, manufacturers have asked permission to only illuminate the MIL if a fault is detected on six consecutive trips. Engine manufacturers believe a 6-in-a-row monitoring strategy will effectively filter out abnormal drive patterns or anomalies in vehicle operation that may cause the system to occasionally be delayed in warm-up or not warm-up, yet they would still eventually detect a fault for systems with a true fault.

ARB staff disagrees with the engine manufacturers' request to use a longer statistical filter to detect faults because it does not adequately address the issue; these strategies simply allow for more time on less than sufficiently robust monitors hoping that false fails will not occur often enough or that the driver will not frequently or repeatedly engage in what they consider ‘abnormal driving patterns.’ A more appropriate solution is for engine manufacturers to better define enable conditions or the modeled coolant temperature to either account for or disable the monitor during such ‘abnormal’ driving conditions if an accurate pass/fail decision cannot be made. While this can result in less frequent monitoring and must be balanced with maintaining reasonable monitoring frequency under the breadth of conditions encountered in the real world, designing (or allowing) a monitor to run under conditions where it may make an incorrect decision is always inappropriate as it can lead to erroneous decisions in-use and undermine technician and vehicle operator confidence in the OBD system. Accordingly, staff will not be proposing a change to the currently required 2-in-a-row detection strategy.

Engine manufacturers have also requested that cooling system monitoring be disabled/desensitized on engine starts with ambient or starting temperatures below 60 degrees Fahrenheit. They believe this allowance will help reduce calibration burden and constrain monitoring to temperatures where truck cabin heat or other sources would be used minimally and would have less impact on delaying proper warm-up. The heavy-duty OBD regulation currently allows engine manufacturers, with Executive Officer approval, to use alternate malfunction criteria and/or monitoring conditions that are a function of temperature at engine start on engines that do not reach the temperatures specified in the malfunction criteria when the thermostat is functioning properly. Similarly, light- and medium-duty vehicles are given relief for engine starting temperatures below 50 degrees Fahrenheit and several engine manufacturers have used this provision for select vehicles (e.g., primarily vehicles with very large passenger compartments). ARB has recognized vehicle operation in California at temperatures below 50 degrees Fahrenheit is limited and accordingly, most ARB emission standards only apply down to 50 degrees Fahrenheit. However, the amount of vehicle activity in the temperature range from 50 to 60 degrees Fahrenheit is expected to be substantial in California, so monitoring to a less rigorous threshold in this temperature region could affect a substantial fraction of vehicle activity. As stated before, engine manufacturers have some control over the stringency of this monitor, as they have the ability to calibrate their OBD systems to use lower enable temperatures for appropriate monitors and still be robust in detecting faults. Thus, while ARB agrees that engine manufacturers should be allowed to desensitize the thermostat monitor on lower engine start temperatures, ARB is proposing to allow this on engine starts with temperatures below 50 degrees Fahrenheit, not 60 degrees Fahrenheit.

Citing the difficulty in accounting for heat sinks, engine manufacturers have also requested that cooling system monitoring be limited to detection of malfunctions in which the thermostat is fully stuck open, irrespective of what temperature is or is not achieved. Manufacturers feel that simply verifying the thermostat is not fully stuck open would greatly simplify the monitoring process and allow manufacturers to design for a range of applications, ensuring some minimum capability on all applications. ARB, however, disagrees and believes failures that prevent proper warm-up for emissions and diagnostics need to be detected regardless of the failure mode (e.g., fully stuck open, partially stuck open, leaking, opening too early). Engine manufacturers would also be required to monitor for failures which cause the ECT to cool back down below diagnostic enablement temperatures after they have been reached (e.g. monitoring to ensure temperatures stay above thresholds after they are initially reached). In certain situations, an idling vehicle with a malfunctioning thermostat and low airflow across the engine bay can reach warmed-up temperatures and pass thermostat monitoring yet when the vehicle reaches higher speeds, additional cooling is introduced across the radiator and engine block, lowering the ECT below the temperature necessary for other OBD diagnostics. This situation could effectively disable all diagnostics that require off-idle operation without being detected as a cooling system fault. Proposed revisions to the regulation will have this requirement clearly stated.

Engine manufacturers have also expressed interest in allowing vehicle manufacturers some ability to calibrate their own cooling system criteria in order to properly account for appropriate heat/work losses in the final vehicle configuration. In recognizing the difficulty of engine manufacturers to calibrate for every type of vehicle the engine is likely to be used in, ARB believes giving vehicle manufacturers some capability to select between various calibration parameters to best match the specific vehicle configuration would be a workable solution. This would allow the OBD system to be better optimized for the specific truck configuration while still allowing vehicle manufacturers a wide range of authority in what they add to the system and how it impacts vehicle warm-up. While ARB feels this is a reasonable approach, engine manufacturers will need to take appropriate actions to ensure vehicle manufacturers are given proper instruction on how to determine the proper calibration to select and are not allowed to just default to one that would be inappropriate. Further, engine manufacturers are ultimately held responsible for OBD compliance in-use and inappropriate selection by vehicle manufacturers could result in enforcement action against the engine manufacturer.

## H. EMISSION-RELATED COMPONENT FAILURE MODES

The heavy-duty OBD regulation requires manufacturers to monitor “emission-related” components and systems that can either affect emissions or other OBD monitors. For major emission-related components or systems, functional monitors are generally required if a specific failure does not cause emissions to increase above the OBD emission threshold. For other emission-related input or output electronic components like sensors or valves, they are required to be monitored as completely as possible, regardless of the emission impact of individual failure modes of the component. This generally includes monitoring for circuit/out-of-range, rationality high and low, and functional faults.

Manufacturers have expressed concerns with these requirements. Specifically, while the regulation specifies the components and systems that are required to be monitored, it does not distinguish between emission-related and non-emission-related “failure modes” of these components and systems. Manufacturers have indicated they should not have to monitor for specific failure modes of a component or system that do not impact emissions or other OBD monitors and believe the regulation language should be modified to allow manufacturers to be exempt from monitoring of these specific failure modes. For example, if a valve can only affect emissions when stuck closed, manufacturers argue they should not also have to detect stuck open failures.

ARB staff, however, disagrees. Allowing regulation language that would exempt monitoring of specific failure modes would only lead to many more discussions and arguments between manufacturers and ARB staff regarding whether or not a specific failure mode does indeed affect emissions during any reasonable in-use driving condition. One area of contention could be the specific driving conditions or driving cycle under which the emission impact of the specific failure mode should be evaluated. A failure mode that does not cause any emission increase during cruising conditions, for example, may cause a considerable increase in emissions during higher load driving. Manufacturers would have to run many test cycles to determine which driving conditions would indeed impact emissions. Additionally, considering the many applications one engine can be used in, manufacturers would need to determine if the failure mode that does not affect emissions in one application (e.g., a bus that mostly experiences city driving) could affect emissions in another application (e.g., trucks that run mostly on the freeways). Another area of contention could be the actual impact of the specific failure mode on other OBD monitors. For example, a manufacturer may consider a particular failure mode to be non-emission-related because, in addition to not resulting in any emission increase, the failure mode would not directly cause the disablement of any of the OBD monitors. However, this failure mode may indirectly affect another component of the vehicle such that certain enable conditions of other OBD monitors may be harder to meet (e.g., a failure mode of one component could indirectly slow down the increase of the engine coolant temperature, thereby delaying enablement of other monitors tied to engine coolant temperature). This would require a lot of analysis and testing on the part of the manufacturer and ARB staff to rule out all these indirect consequences and to consider which other OBD monitors may be affected. For the few failure modes that may fall under such an exemption, the amount of workload required to determine if these failure modes are indeed exempt would be huge. It should also be noted that, under the current policy, manufacturers are not required to add any additional hardware just to accomplish monitoring of all failures—monitoring of all failures is limited to monitoring that is technically feasible.

Thus, ARB is maintaining its current policy to require the complete monitoring of emission-related components and systems. A component that is experiencing a failure mode that does not have an emission impact or affect other OBD monitors is still clearly a malfunctioning component. If a repair technician sees an emission-related component experiencing this failure mode but with no MIL illuminated, this may cause confusion with the technician, which would undermine the confidence of the OBD system in the field. With the heavy-duty OBD regulation requiring the complete monitoring of these components, the extra workload to distinguish emission-related failure modes from non-emission-related failure modes will not be necessary and the confidence in OBD in the field will be sustained

## I. SERVICE INFORMATION REQUIREMENTS

The heavy-duty OBD regulation currently contains requirements for service information that heavy-duty manufacturers are required to make available to the repair industry, which were not included in the stand-alone service information regulation, section 1969 of title 13, CCR, at the time the heavy-duty OBD regulation was adopted in 2005. Thus, the heavy-duty OBD regulation currently details requirements for heavy-duty manufacturers to provide basic information including OBD monitor descriptions, information necessary to execute each monitor (e.g., enable conditions), and information on how to interpret the test data accessed from the on-board computer. Additionally, it requires manufacturers to make available repair procedures for OBD faults that either only require the use of a generic scan tool or require the use of a non-generic scan tool as long as they make information available to the aftermarket scan tool industry to manufacture their own tools to perform the same functions. Furthermore, it includes language that clarifies that the stand-alone service information regulation, to the extent it is effective and operative, supersedes any redundant service information requirement in the heavy-duty OBD regulation. In 2006, section 1969 was updated to include OBD information manufacturers are required to make available for heavy-duty vehicles, including requirements to make available to independent service facilities service tools to access the OBD information. Thus, the heavy-duty industry has requested that the service information requirements in the heavy-duty OBD regulation be deleted.

However, the updated detailed requirements in section 1969 only apply to 2013 and subsequent model year heavy-duty engines, while enhanced OBD systems are required on some 2010 through 2012 model year heavy-duty engines under the heavy-duty OBD regulation. For model years prior to 2013, section 1969 only requires heavy-duty manufacturers to make available information and tools they already currently provide to dealers and independent facilities. Thus, since heavy-duty manufacturers currently do not provide information regarding manufacturing of scan tools to perform the same functions as the non-generic scan tools, they are not obligated to provide this information for the 2010 through 2012 model year engines under section 1969. Accordingly, section 1969 is not redundant to the service information requirements of the heavy-duty OBD regulation and does not automatically supersede it. Further, with such a position, manufacturers could provide access only for their authorized dealers to the heavy-duty OBD fault information and deny access to all independent repair facilities. Given the intent of the heavy-duty OBD system is to achieve early identification of the presence of a malfunction and prompt repair, it would be inappropriate to allow manufacturers to restrict access only to authorized dealer facilities. Therefore, ARB staff is not deleting the current service information requirements in the regulation as manufacturers suggested to prevent this problem for 2010 through 2012 model year heavy-duty engines with OBD systems. These requirements are important to prevent the heavy-duty OBD program from getting off to a bad start. If repairs of OBD-related malfunctions can only be done by dealers (and not independent service facilities) during these first few years of heavy-duty OBD implementation, the overall intent of the program will be undermined and it could jeopardize the future acceptance of the system by the repair industry.

## J. CERTIFICATION DEMONSTRATION TESTING REQUIREMENTS

Manufacturers are required to design and calibrate the OBD system to detect some malfunctions before specific emission thresholds are exceeded at any time within the full useful life of the engine. Depending on the size of the heavy-duty vehicle, the useful life can be 110,000 miles, 185,000 miles, or 435,000 miles. The current regulation requires manufacturers to conduct emission demonstration testing prior to certification to ensure that the systems are indeed able to detect faults before the thresholds are exceeded. And, to ensure the emission thresholds are not exceeded for the full useful life, ideally, the manufacturers would age the whole system (i.e., the engine and all emission controls) to full useful life and then verify the calibration for each fault is correct. However, ARB recognizes that manufacturers have limited experience, resources, and time to age the engine, engine emission controls, and aftertreatment to full useful life, especially for engines subject to a 435,000 mile useful life. Additionally, manufacturers have traditionally claimed that engines and engine components deteriorate very little based on past experience, and that this trend is expected to continue. ARB, therefore, compromised in 2005 by allowing manufacturers to simply 'break-in' the engine and engine components by aging for 125 hours while requiring aging of only the aftertreatment to full useful life for demonstration tests. Further, since aging to accumulate the full mileage is time consuming, ARB also allows manufacturers to develop and use accelerated aging processes to simulate full useful life aging. Manufacturers would ideally develop and validate these processes with actual aged parts and are required to have these processes approved by ARB after a thorough review.

Even with ARB's compromise on the aging requirements, the manufacturers assert that they will not be able to create full useful life aged aftertreatment components or develop an accelerated aging process for the aftertreatment in time for the 2010 model year. Manufacturers cite the lack of time and experience in developing such a process and validating it with real data and the lack of experience with the new aftertreatment components in the field. Therefore, the manufacturers instead proposed a phase-in schedule that would allow for less rigorous aging to lower mileage goals in the initial years of implementation. Specifically, for the 2010 through 2012 model years, an engine manufacturer would age the aftertreatment to the level used to satisfy ARB certification requirements for determining the deterioration factor, whatever that intermediate mileage level for each manufacturer may be. For the 2013 through 2015 model years, an engine manufacturer would age the aftertreatment up to 185,000 miles. And finally, for the 2016 and subsequent model years, an engine manufacturer would age the aftertreatment to the current requirement of full useful life. Additionally, the manufacturers proposed that the scope of the aftertreatment aging be limited to 'key components' only, specifically the diesel oxidation catalyst, diesel particulate filter, NOx aftertreatment catalyst, oxygen sensors, and NOx sensors.

After discussing with engine manufacturers their progress towards meeting the 2010 emission standards and OBD implementation, ARB recognized that manufacturers are further behind than anticipated. Thus, ARB agrees that interim relief is appropriate to allow manufacturers to build up the knowledge and field experience with these new components to understand the extent of deterioration during useful life. However, staff does not believe the schedule or scope of the manufacturers' proposal really provides the necessary incremental steps towards a long term solution. The changes proposed by staff below are intended to focus on a successful long term solution and require manufacturers to meet interim requirements that are logical steps in the process.

While this discussion is specific to the allowed aging during demonstration testing, it is important to remember that manufacturers are liable in-use for proper detection of faults before the OBD emission thresholds are exceeded at any time during the useful life. If manufacturers do not properly account for all the synergistic effects and total system deterioration that occurs during useful life, they risk non-compliance and recall, fines, or other remedial action. Thus, from ARB's perspective, even for OBD monitor calibration purposes (not just demonstration testing), manufacturers need to (and are required and expected to) account for full useful life deterioration and base their calibration efforts on that. As is commonly done within the light-duty vehicle community, manufacturers are expected to develop engineering shortcuts and procedures to account for this full useful life performance. However, to be successful, these procedures have to accurately represent in-use deterioration and overall system performance. The only way a manufacturer can be sure that its procedure accurately represents in-use performance is to validate the systems (engine, engine component, and aftertreatment) created by their engineering procedures against actual full useful life (e.g., high mileage) systems.

Based on discussions with manufacturers and suppliers as they are progressing towards finalizing 2010 model year system designs, ARB is especially concerned about engine (and component) deterioration and its synergetic effects with the aftertreatment. Despite manufacturers' previous assertions that diesel engines and components deteriorate very little, ARB has seen fairly dramatic changes in diesel engines with control strategies and new components (including new EGR systems, EGR coolers, fuel injection system changes, turbo component changes, etc.) that operate in much more varied control points (e.g. near partial homogeneous charge compression ignition type operation with heavy EGR, tight air-fuel ratio control in specific regions). In light of such complicated system architecture and control strategies, previous conventions and knowledge about diesel engine and component deterioration no longer seem applicable. Until experience is gained with high mileage evaluations and real world experience, it would be inappropriate to assume past deterioration characteristics will continue on these new systems. With this perspective, an engine aged for 125 hours (which is currently required by the OBD regulation) would not likely be representative of one at full useful life, so calibration or demonstration testing with such an engine would not provide assurance of OBD compliance throughout useful life. Additionally, manufacturers appear to have insufficient experience and knowledge to be able to accurately account for or predict the cumulative aging effects of the total system by simply aging a few "key" components of the aftertreatment (as manufacturers have proposed). ARB believes the only long term solution to get compliance assurance is to require manufacturers to generate high mileage systems and/or to collect and use data from real world high mileage systems to develop and validate accelerated aging procedures for the entire system (i.e., the engine, engine components, and aftertreatment system).

Thus, while agreeing that interim relief with lower aging mileage goals is appropriate, ARB is proposing to revise the requirements with a phase-in schedule containing higher interim goals than those proposed by the manufacturers. Additionally, for the reasons stated above, ARB believes that total system aging (engine plus the aftertreatment system) must be considered and is revising the requirements to achieve that in the long term.

For the 2010 to 2012 model years, the proposed changes would continue to allow the use of an engine aged for 125 hours. However, in lieu of requiring the aftertreatment system to be aged and validated as representative of full useful life, the changes would allow manufacturers to only age the individual aftertreatment components (e.g., PM filter, oxidation catalyst) and exhaust gas sensors (e.g., NOx, lambda sensors) to the manufacturer's best estimates of useful life without the rigors of validation that would normally be required for ARB to approve the system as representative of full useful life. In discussions with manufacturers and suppliers, it appears fairly straightforward for manufacturers, in consultation with their suppliers, to identify the key aging mechanism (e.g., time at or above specific temperatures), to calculate expected operation over useful life in those key conditions, and to develop an accelerated aging process to condense that aging into a reasonable timeframe. Where these approaches fall short is in validation to real world operation that the estimates of expected operation were correct and/or whether other component deterioration altered the outcome. However, the manufacturer's responsibility to validate the accelerated aging process would be waived for these model years.

In exchange for the relaxed requirements, a manufacturer would be required to collect and report in-use data from 2010 or later model year engines operated in the real world. The data collected would be from engines and systems operated for approximately 18 months or longer and with mileages equal to the full useful life for engines subject to 110,000 or 185,000 mile useful life and at least 185,000 miles for engines subject to 435,000 mile useful life. Such data collection by manufacturers would require removing real world aged systems (engine and aftertreatment) from vehicles, installing the systems on engine dynamometers, running various emission tests to quantify the system deterioration, and reporting the data to ARB late in the 2011 calendar year. For 2013 to 2015 model year engines subject to 110,000 or 185,000 mile useful life, a manufacturer would be required to use the knowledge gained from the collected data to modify (if needed) and validate its accelerated aging processes for ARB's approval. For 2013 to 2015 model year engines subject to 435,000 mile useful life, a manufacturer would also be required to use the collected data to validate and/or modify the accelerated aging procedure used in 2010 to better equate to real world deterioration, however, the manufacturer would still be allowed to use its best estimates for full useful life aging as the collected data would only allow validation up to 185,000 miles and not to the full useful life of 435,000 miles.

For engines subject to 435,000 mile useful life, manufacturers would additionally be required to collect data from 2010 or newer model year real world aged systems with mileage equal to 435,000 miles and report the data to ARB in the 2014 calendar year. Identical to the data collected at 185,000 miles, the manufacturer would be required to obtain high mileage systems, perform various emission tests to quantify and understand the deterioration, and incorporate that knowledge to refine and validate its accelerated aging procedures to be representative of full useful life and used for certification of 2016 and subsequent model year systems.

The following table summarizes the proposed requirements.

Table I: Phase-in aging data requirement schedule for engine and aftertreatment

| Year | Aging data required at certification for accelerated aging | |
|---|---|---|
| | Engine | Aftertreatment |
| 2010-2012 model year | 125 hours aging | Accelerated aged to best estimates of full useful life on aftertreatment components |
| Report in-use data in 2011 | ~18 months (for light and medium HDDE, full useful life, for heavy HDDE, 185,000+ miles) real world aging data on 2010 model year engines | ~18 months (for light and medium HDDE, full useful life, for heavy HDDE, 185,000+ miles) real world aging data on 2010 model year engines |
| 2013-2015 model year | For light and medium HDDE: accelerated aging to full useful life validated with real world aging data<br><br>For heavy HDDE: Best estimates for accelerated aging to full useful life incorporating 185,000 real world aging data | For light and medium HDDE: accelerated aging to full useful life validated with real world aging data<br><br>For heavy HDDE: Best estimates for accelerated aging to full useful life incorporating 185,000 real world aging data |
| Report in-use data in 2014 | 435,000 mile full useful life real world aging data on a 2010 or later model year engines | 435,000 mile full useful life real world aging data on a 2010 or later model year engines |
| 2016 model year and after | Accelerated aging to full useful life validated with real world aging data | Accelerated aging to full useful life validated with real world aging data |

## K. EMISSION-INCREASING AUXILIARY EMISSION CONTROL DEVICE (EI-AECD) TRACKING

An additional important item relative to the effectiveness of diesel emission controls in-use is the usage of auxiliary emission control devices (AECDs). Typically, AECDs consist of alternate control strategies or actions taken by the engine controller for purposes of engine, engine component, or emission control component protection or durability. In some cases, activation of an AECD has been justified by the manufacturer as needed to protect the engine and it can result in substantial emission increases while the AECD is activated. AECDs have been an essential part of the certification process and the subject of numerous mail-outs and guidance by U.S. EPA and ARB to help ensure consistent interpretation and equity in usage among all manufacturers. Approval usually involves lengthy review and considerable scrutiny by ARB staff to try and understand the complex algorithms and strategies used by various manufacturers and additionally relies on data supplied by manufacturers as to the expected occurrence/operation of these items in-use. However, such data are often based on the operation of one or two trucks for a few hours of operation and are not likely to be representative of the extreme variances in engine duty cycles and vehicle operator habits that the diesel engines are exposed to in the real world. Further, the complicated algorithms and calculations used by manufacturers to activate such strategies are not easily decipherable nor comparable from one manufacturer to another, making consistent policy decisions and equity among all manufacturers extremely difficult, if not impossible, to achieve.

To help alleviate this issue, staff is proposing requirements for the vehicle's on-board computer to keep track of cumulative time that a subset of these AECDs is active. Specifically, the proposed language only requires tracking of AECDs that cause an emission increase (i.e., emission increasing AECDs or EI-AECDs). Further, the language only requires tracking of EI-AECDs that are justified by the manufacturer as needed for engine protection and are not related to engine starting or operated substantially during the emission test cycles. Additionally, there is a provision for some AECDs to be approved as not-to-exceed deficiencies and any such AECDs are automatically excluded from being considered an EI-AECD. In the rare instance (if any) that there is an EI-AECD that is justified as needed for engine protection but it actually is comprised of no sensed, calculated, or measured value and no corresponding commanded action by the on-board computer to act differently as a result, it would also be excluded from being tracked as an EI-AECD. Lastly, AECDs that are only invoked solely due to any of the following conditions would be excluded from being considered and EI-AECD: (1) operation of the vehicle above 8000 feet in elevation; (2) ambient temperature; (3) while the engine is warming up and cannot be reactivated once the engine has warmed up in the same driving cycle; (4) failure detection (storage of a fault code) by the OBD system; (5) execution of an OBD monitor; or (6) execution of an infrequent regeneration event.

For those strategies that meet all the requirements above to be considered an EI-AECD, the on-board computer would be required to log cumulative time each one is active and update the stored counter at the end of each driving cycle with the total cumulative time during the driving cycle. Further, each EI-AECD would be counted and reported separately (EI-AECD #1, etc.). ARB staff would be able to use this data to confirm or refute previous assumptions about expected frequency of occurrence in-use and use the data to support modifications to future model year applications and better ensure equity among all manufacturers. This data will also help ARB staff identify “frail” engine designs that are under-designed relative to their competitors and inappropriately relying on EI-AECD activation to protect the under-designed system.

Manufacturers have raised several concerns regarding this required tracking including technical concerns, confidentiality concerns, and the inappropriateness of including such a requirement in the OBD regulations. Regarding technical concerns, manufacturers have argued that determination of which AECDs are emission-increasing will require additional emission testing time. However, as was done with the same requirements in the OBD II regulation, staff has defined emission-increasing as reducing the emission control system effectiveness and thus, made the determination based on engineering analysis, not any emission test data. Industry has also argued that many EI-AECDs have varied levels of emission increase and they are not simple on/off switches, thereby complicating the counting process and making no distinction between items with a large emission impact and those with only a minor emission impact. To address this, staff split tracking of each EI-AECD that is not a simple on-off decision into two separate counters to separately track time spent with “mild” EI-AECD activation (defined as action taken up to 75 percent of the maximum action that particular EI-AECD can take) and “severe” EI-AECD activation (defined as action taken from 75 to 100 percent of the maximum action that particular EI-AECD can take). As an example, an EI-AECD that progressively derates and eventually shuts off EGR when the engine overheats would be tracked in the “mild” counter for time spent commanding EGR derating of 1 to 75 percent and tracked in the “severe” counter for time spent commanding EGR derating of 75 to 100 percent (fully closed). Manufacturers have also expressed concern about the complexity of tracking two EI-AECDs that may be overlapping and both commanding action. After further discussion with individual manufacturers about how their strategies were structured, staff modified the proposal to require independent tracking of the EI-AECDs and not require the software to decipher which of the overlapping EI-AECDs was actually having the bigger impact and only accumulate time in that counter.

Regarding confidentiality, manufacturers have indicated that their algorithms and strategies that comprise their EI-AECDs are extremely confidential and do not want their competitors to know the details. Manufacturers have indicated that they believe staff’s proposal would provide competitors with more detail of their EI-AECDs and make reverse-engineering easier. Staff’s proposal, however, does not provide any additional information to make it easier to reverse-engineer a competitor’s strategies nor does it provide any detail about the strategies or algorithms used. The only data staff’s proposal would make available is cumulative time an engine is operated with a specific numbered EI-AECD active (e.g., EI-AECD #6). Only the certifying manufacturer and ARB would know for any particular engine what strategy or algorithm a particular EI-

AECD corresponded to. Further, since the cumulative time data is only updated at the end of a drive cycle, a competitor could only ascertain that, at some previous time in the operation of this engine, a particular EI-AECD was activated a cumulative amount of time. The data would not indicate at what time during any previous drive cycles the EI-AECD was active, whether it was active for one long period or many short bursts of time, or the severity of the action (or even what action) was taken during the EI-AECD activation. As can be done today, a manufacturer would be better served emission testing the engine, identifying real time spikes in emissions, and analyzing the engine operating conditions where the spikes actually occurred to reverse engineer his competitor's products rather than looking at data that does not tell him when the actual activation may have occurred. Lastly, given that the only items of discussion here are EI-AECDs justified by the need to protect the engine, a manufacturer's desire for confidentiality can be motivated by only one concern—that it is currently activating an EI-AECD (and thus, protecting its engine) during conditions that its competitors are not (and thus, not equally protecting their engine) thereby giving the manufacturer a competitive advantage in engine durability. By definition, this means that the manufacturer is activating its EI-AECDs more often (in conditions where its competitors are not). But this is also some of the very same inequity that ARB staff struggle to eliminate in certification in cases where a manufacturer is overly conservative in concluding engine "protection" is necessary and/or staff use to distinguish a "frail" engine design relative to competitors' engines.

## L. OTHER PROPOSED AMENDMENTS TO THE HEAVY-DUTY OBD REGULATION

Staff is proposing modifications to better define "continuous" monitoring for several monitors. Currently, the regulation defines "continuously" in the context of monitoring conditions for comprehensive component circuit and out-of-range monitors. Accordingly, this definition doesn't apply for monitors such as diesel fuel pressure control monitoring and EGR system feedback control monitoring, which are also required to be monitored "continuously." Staff intended "continuously" in this case to mean that these monitors have to run virtually all the time except during conditions where false detections could occur. Thus, staff modified the monitoring conditions requirement for these monitors to clarify that.

Staff refers to "idle" operation in some sections of the heavy-duty OBD including the permanent fault code erasure requirements, in-use performance ratio requirements, and the standardization tracking requirements. "Idle" operation is currently defined as conditions where vehicle speed is less than or equal to one mph, among other criteria. Some manufacturers have indicated that their engines do not utilize vehicle speed information and thus, cannot sense vehicle speed. They further indicated that engine speed is an acceptable surrogate to use to determine idle operation. Thus, ARB is proposing to define idle operation as conditions where, among other criteria, either the vehicle speed is less than or equal to one mph or engine speed is less than or equal to 200 rpm above the normal warmed-up idle speed.

Staff is also proposing amendments to the monitoring requirements that would attempt to clarify the requirements for various types of EGR and boost pressure control systems.  Currently, the monitoring requirements for these two systems were written with the premise that they would both have direct feedback-control of EGR flow and/or boost pressure, as staff had believed that almost all manufacturers would use such systems.  However, based on discussions with manufacturers as they review their plans for 2010 and later engines, the monitoring requirements needed to be modified to account for a broader range of systems.  Examples include open loop boost pressure systems or control systems that technically use closed-loop control of other parameters such as fresh air flow or cylinder intake air concentration and modify EGR flow and/or boost pressure to achieve the desired target instead of direct closed loop control of EGR flow and/or boost pressure.  As detection of emission-related faults of these systems is important, regardless of whether or not they are directly feedback controlled, staff proposed amendments to the malfunction criteria for these monitors to indicate a fault tied to the "expected" EGR flow or boost pressure, rather than solely referring to the "commanded" EGR flow or boost pressure.

Similarly related, the EGR and boost pressure monitoring requirements include malfunction criteria tied to the system being unable to achieve proper closed loop control (e.g., not entering closed-loop control when it was expected to, reaching control limits when it should not have).  These requirements only apply if the system has feedback control of EGR flow or boost pressure.  However, as mentioned above, some manufacturers are using feedback control systems of slightly different parameters in lieu of EGR flow or boost pressure as staff originally anticipated (e.g., modify or control EGR flow not to achieve a target EGR flow rate but to achieve a target air-fuel ratio). Accordingly, these alternate systems should be similarly monitored for failures that affect proper closed loop operation.  Staff is thus proposing to require manufacturers to submit a monitoring plan for ARB's review and approval.  This would allow manufacturers and ARB staff to evaluate the technology and determine an appropriate level of monitoring that is both feasible and consistent with the closed-loop monitoring requirements for the EGR and boost pressure control systems.

For diesel boost pressure control systems, staff is proposing changes to account for systems that are not equipped with variable geometry turbochargers (VGT) systems. Currently, only VGT systems are additionally monitored for slow response failures (e.g., malfunctions that cause the system to take longer than expected to achieve the target boost pressures.).  Discussions with manufacturers have identified that malfunctions that cause the system to take longer to achieve desired boost levels can affect emissions, regardless of the boost hardware architecture.  Accordingly, staff is broadening the slow response malfunction criteria to apply to all boost systems, regardless of whether the system uses a VGT.  It should be noted that most manufacturers have indicated that slow response boost failures rarely could get bad enough that they would cause emissions to exceed the OBD threshold and thus, are subject only to a functional monitor.  Further, most manufacturers are able to demonstrate that the under and over boost monitors meet the definition of a functional check for slow response by demonstrating they detect induced response failures with such diagnostics before emissions are too high. This proposed requirement, however, will ensure that any manufacturer who has a larger sensitivity to slow response boost malfunctions will be required to detect faults before emissions exceed the prescribed threshold levels.

Manufacturers have expressed concerns about the specific requirement to monitor both the MIL and the wait-to-start lamp for circuit continuity malfunctions (e.g., burned out bulbs). Specifically, manufacturers have argued that, as engine builders/suppliers, they do not have control over the instrument panels and driver displays selected by truck builders in the final vehicle. In many of those systems, the warning lights are directly wired and controlled by the instrument panel itself, not the engine control unit (ECU), and it would require instrument panel changes and/or added hardware or software in the instrument panel to diagnose the lights and send that information back to the engine ECU. As another option, manufacturers would need to provide for and require that these warning lamps be directly hardwired to the engine ECU to ensure enough information is available to diagnose the circuits. Further, manufacturers have indicated a strong trend in industry to change from incandescent bulbs to light emitting diode (LED) technology for the warning lamps. Manufacturers have argued that LEDs are much less susceptible to burned out bulb failures, leaving only circuit faults to the LED as a likely failure mode. In some cases, the LEDs are directly attached to circuit boards, virtually eliminating any hardwiring. Lastly, one manufacturer has indicated that given the nature of an LED and its extremely low current draw levels, certain failure modes within the LED itself are not technically feasible to detect.

Staff’s original intent for monitoring the wait-to-start lamp was different from the rationale for monitoring the MIL. For the wait-to-start lamp, monitoring has always been required in light-duty from the start of OBD II implementation. If this lamp does not function properly, a vehicle operator may crank the engine too soon, causing increased emissions from extended cranking or failed crank attempts before the engine is finally started. Further, if the lamp malfunctioned, the MIL would be illuminated to indicate the need for repair. Based on the potential for direct emission impact, staff is not proposing any changes to the requirements for wait-to-start lamp monitoring. For MIL monitoring, however, the rationale for monitoring was to simplify roadside or other inspections of heavy-duty vehicles. Rather than requiring an inspector to shut off the engine and enter the vehicle cab to visually look for the proper function of the MIL (and record that observation somehow), the intent was the entire inspection could be automated and all necessary information could be downloaded electronically via a scan tool. However, the presence of a non-functional MIL does not necessarily need to be considered in a roadside type inspection. Unlike the wait-to-start lamp, a malfunction of the MIL by itself does not lead to a direct emission impact. And, unlike other malfunctions that result in MIL illumination, a malfunction of the MIL itself prevents the MIL from illuminating, thereby largely eliminating the chance for the driver to be alerted and take appropriate action. If other emission-related faults are present, the data downloaded at inspection will properly indicate the fault data and lead to correct pass/fail decisions. Given the minimal additional benefit for roadside inspection and the reduced opportunity for a driver to voluntarily notice and take corrective action for a failed MIL, staff is proposing to eliminate the requirement to monitor the MIL for circuit malfunctions.

Lastly, staff is proposing some amendments to the heavy-duty OBD regulation to be consistent with recently updated requirements in the OBD II regulation. These include changes to the erasure protocol of permanent fault codes (section 1971.1(d)(2.3)), addition of monitoring requirements for diesel cold start emission reduction strategies (proposed section 1971.1(e)(11)), and changes to the monitoring requirements for gasoline cold start emission reduction strategies (section 1971.1(f)(4)) and crankcase ventilation systems (section 1971.1(g)(2)).

## M. ENFORCEMENT REGULATION

During the 2005 heavy-duty OBD rulemaking process, staff also indicated its intent to adopt a separate enforcement regulation for heavy-duty OBD similar to that currently used for OBD II (section 1968.5). Thus, ARB staff is also proposing adoption of section 1971.5, which would establish enforcement procedures and requirements for heavy-duty vehicles and engines with OBD systems.

Under the OBD II requirements for light- and medium-duty vehicles, ARB adopted a separate, stand-alone enforcement regulation for OBD II systems (title 13, CCR section 1968.5). Though there is currently no stand-alone enforcement regulation that applies to heavy-duty OBD systems, the heavy-duty OBD regulation contains some items related to enforcement. Specifically, the regulation includes higher interim in-use compliance standards for the OBD monitors that are calibrated to specific emission thresholds. For the 2010 through 2015 model year engines, an OBD monitor will not be considered non-compliant (or subject to enforcement action) unless emissions exceeded twice the OBD threshold without detection of a fault. Additionally, the number of engines that would be liable in-use for compliance with the OBD emission thresholds would be limited. Manufacturers will only be liable in-use for the highest sales volume engine rating (e.g., a specific rated power variant) within the one engine family that has OBD in the 2010 through 2012 model years, while other engine ratings in that engine family will have no liability in-use for detecting a fault at the specified emission threshold. For 2013 through 2015 model years, all engine ratings within this original OBD engine family will be liable for meeting the emission thresholds. Additionally, a limited additional number of engine ratings in other engine families would become in-use liable in the 2013 model year. Emission threshold liability for all engines in-use will not take effect until the 2016 model year. These provisions allow manufacturers to gain experience in-use without an excessive level of risk for mistakes and allow them to fine-tune their calibration techniques over a six year period. Additionally, given that the vast majority of the heavy-duty OBD requirements apply directly to the engine or its associated emission controls, the engine manufacturer has the responsibility for ensuring the requirements are met. Thus, the party certifying the engine and OBD system (typically, the engine manufacturer) is also the responsible party for in-use compliance and enforcement actions. In this role, the certifying party would be ARB's sole point of contact for noncompliances identified during in-use or enforcement testing.

In cases where remedial action will be required (e.g., recall), the certifying party will take on the responsibility of arranging to bring the vehicles back into compliance. To protect themselves, it is expected that engine manufacturers will require engine purchasers to sign indemnity clauses or other agreements to abide by the build specifications applicable to the engine and to bear ultimate financial responsibility for noncompliances caused by the engine purchaser.

During the 2005 rulemaking process for the heavy-duty regulation, staff indicated its intent to adopt enforcement requirements for heavy-duty OBD systems that are similar in comprehensiveness to those currently required for light-duty and medium-duty OBD II systems, with the goal being to adopt such a regulation prior to implementation of heavy-duty OBD systems in the 2010 model year. Thus, staff is proposing the adoption of section 1971.5, title 13, CCR, which would establish enforcement procedures and requirements for heavy-duty OBD systems. Staff intends for most of these proposed enforcement requirements to be structured very similarly to those currently required for light- and medium-duty OBD II vehicles. For example, the proposed enforcement criteria and testing procedures for non-compliances concerning in-use performance monitoring ratios and other non-emission-threshold-related issues are intended to be very similar to what is required in the OBD II enforcement regulation. The main differences would be related to non-compliances related to exceeding the OBD emission malfunction thresholds, including the criteria that would need to be met for ARB to assume there is a non-compliance and to initiate further enforcement testing, and the specific testing procedures that would need to be carried out. In the light-duty area, the OBD enforcement regulation relied heavily on well established vehicle procurement, screening, and testing procedures used for tailpipe emission compliance testing. In the heavy-duty area, however, ARB has very limited tailpipe emission compliance testing experience and it is not easily referenced or mimicked for heavy-duty OBD purposes. Staff is currently discussing the proposed requirements with other ARB and U.S. EPA staff involved with heavy-duty engine testing, but have not yet gathered enough information to put forth a specific proposal documenting how engines from heavy-duty vehicles will be selected for procurement, how they will be screened to verify they are valid engines for testing, and how many engines will need to be tested. Thus, there is no proposed HD OBD enforcement regulatory language available at this time. Nonetheless, staff is seeking industry input on suggestions for procedures to be used to determine compliance with heavy-duty OBD emission threshold monitors (e.g., those required to detect a fault before FTP or SET emissions exceed 2.0 time the applicable standards) specifically in regards to procuring appropriate engines, options for testing at various facilities including at ARB, at the manufacturer's laboratory, or an outside laboratory, and distributing a reasonable testing burden on the ARB and the manufacturer in cases of suspected non-compliance.