

Summary Guide of the Draft Proposed Regulation:

A Guide To Understanding California Air Resources Board's (CARB) Heavy-Duty On-Board Diagnostic (OBD) Regulation

This document is intended to provide a brief description of the various elements of the proposed heavy-duty OBD regulation and some background information, rationale, and examples to better understand the regulation. It is organized in the same order as the proposed regulation and includes the relevant regulation section numbers for reference.

(a) Purpose- self explanatory.

(b) Applicability- self explanatory.

(c) Definitions- self explanatory.

(d) General Requirements

This section describes the general rules for the malfunction indicator light (MIL) and fault code storage/erasure.

(d)(2) The basic concept is to require MIL illumination after a fault has been detected on two consecutive driving cycles (the “two-in-a-row” strategy). Pending fault codes are stored on the first detection and matured to “active” or “confirmed” codes once the MIL comes on. This section also details other rules for the MIL (visibility, symbol, etc.).

(d)(3) This section provides guidelines to manufacturers on defining operating conditions for how often monitors should run and what type of limitations manufacturers can put on the diagnostics (“monitoring conditions”). In general, monitoring can be constrained whenever technically necessary to get reliable and robust results but must also still be designed to run frequently on vehicles in the real world. To ensure everyone is on the same page as to what “frequently” means, the OBD system has to log data on how often the vehicle has been driven and how often the major monitors have had a chance to run (“rate-based” tracking of monitors).

(d)(4)-(5) These sections provide very detailed specifications about exactly how this “rate-based” data should be formatted, incremented, and reported to make sure everybody is doing it the same way. In general, the major monitors (~8 of them) have to be “tracked” by the OBD system. For each of these monitors, the software needs to count how many times the vehicle has been driven (the “denominator”) and it also has to count how many times the monitor ran (the “numerator”). Dividing the numerator by the denominator, a ratio is calculated that gives a measure of how often a monitor runs relative to how often the vehicle has been operated. As stated in section (d)(3) of the proposed regulation, for the first few years, there is no minimum ratio that manufacturers will have to meet in-use. However, starting in the 2013 model year,

manufacturers will have to meet a ratio of 0.100. Monitors should meet at least this minimum frequency in order to be useful in detecting malfunctions during normal driving.

(d)(6) This section describes the process diesel engine manufacturers should use to calibrate an emission threshold monitor. Since manufacturers are required to certify to both the transient Federal Test Procedure (FTP) test and the steady-state European Stationary Cycle (ESC) test, OBD emission thresholds apply to both standards. The manufacturer is required to use the cycle that reaches the emission thresholds first. For example, if an exhaust gas recirculation (EGR) system fault is required to be calibrated to 1.5 times the standards and an 80% clogged EGR system on the FTP results in 1.2 times the standards and on the ESC it results in 1.4 times the standards, the ESC is the correct cycle to use for calibration. Manufacturers are allowed to use engineering analysis and/or test data to determine which cycle is the correct one.

(e) Monitoring Requirements for Diesel Engines

This section details the major monitors required for diesel engines. For each monitor, it describes the purpose (the “requirement”), what has to be detected (the “malfunction criteria”), when the diagnostics have to run (the “monitoring conditions”), and any allowed deviations from the normal MIL and fault code storage strategies.

For each of the following component/system monitors, manufacturers are required to calibrate the monitor so that it is designed to detect a malfunction when a component has deteriorated to the malfunction criteria. It is important to note that the proposed OBD regulation only requires the system to be designed and calibrated to detect a *single component* failure at the required malfunction criteria rather than having to detect every combination of multiple component degradations that can cause emissions to exceed the malfunction threshold (e.g., 1.5 times the standards). In other words, OBD is not required to take into account synergistic effects of multiple component failures. For example, when calibrating an EGR low flow fault that would exceed the threshold, manufacturers would implant only a low flow fault in the EGR system and leave other emission control components/systems (catalysts, particulate matter (PM) filter, etc.) in a nominal, properly-operating condition. The OBD system would not be required to detect an EGR fault if a lesser degree of EGR flow restriction combined with partial deterioration of other components (aftertreatment, fuel system, etc.) causes emissions to exceed the malfunction criteria.

(e)(1) Fuel system. Manufacturers are required to detect fuel system faults that cause emissions to increase. The faults are built around the fuel system pressure control (e.g., common rail fuel pressure control or hydraulic pressure control) and focus on detecting faults when the feedback system can no longer deliver the desired pressure. Given the sophistication of the feedback system and the years of design and field experience with these systems by 2010, faults would be required to

be detected when emissions reach 1.5 times the standard. By design, a feedback system should be able to maintain emissions below the standards up to the point that the feedback system can no longer achieve the desired pressure. Thus, the fault threshold should reflect a control system that is near or at its control limits.

Given the critical emission importance of proper fueling, monitoring for proper injected fuel quantity and injection timing are also required. By performing essentially a cylinder balance type strategy (at idle or during overrun conditions), the system can look at the relative magnitude and timing of a small pilot-like injection (based on crankshaft acceleration and angle) and compare it with what was expected.

Lastly, in all cases where a feedback system is employed, manufacturers are required to monitor for faults that delay/disable the start of feedback, cause the system to default out of feedback, or, where applicable, cause the system to adapt out to control limits such that no further feedback correction can be made.

(e)(2) Misfire monitoring. For the 2010-2012 model year, manufacturers would be required to detect malfunctions that cause a complete single cylinder misfire (e.g., one cylinder completely dead). Monitoring is only required to be done once per driving cycle and only at idle. Manufacturers typically perform a cylinder balance like strategy to identify a cylinder that is misfiring.

For the 2013 and subsequent years, however, misfire monitoring will be required to be done continuously (under all engine speeds and loads) and to look for lower levels of misfire (a cylinder or combination of cylinders that are intermittently misfiring) rather than just monitoring for a complete dead cylinder only at idle. With the increased use of EGR (and to varying degrees at different speeds and loads) as well as with emerging technologies such as homogeneous charge compression ignition, the conventional wisdom regarding diesel engines and misfires no longer holds true. These newer technologies can indeed result in misfires that are intermittent, spread out among various cylinders, and only happen at certain speeds and loads.

(e)(3) EGR. The EGR system would be required to be monitored for three primary failure modes: too little flow, too much flow, and slow response to achieve the desired flow. EGR is one of the primary oxides of nitrogen (NOx) emission controls for the majority of manufacturers, and it is critical that the desired flow rate is being delivered. Accordingly, most manufacturers actually use feedback control systems that modulate the EGR valve (and sometimes intake or exhaust pressures) to achieve a desired flow rate. The system is usually a feedback system based on a mass air flow sensor, and the system compensates for small errors to get to the desired flow rate. As long as the system is able to achieve the desired flow rate, emissions stay relatively low. However, when the system is no longer able to get to the flow it needs or takes too long to get there, emissions can increase dramatically. Based on the precision with which the EGR control systems work and the

experience manufacturers will have with EGR by 2010, a fault would be required to be detected when emissions reach 1.5 times the standard. For a system that is feedback controlled to an actual flow rate, this emission increase should not occur until the system is at or near its control limits (e.g., no longer able to compensate and deliver the desired flow rate). The performance of the EGR cooler (if used) would also be required to be monitored to make sure it has sufficient cooling capacity. It is expected that it will take near complete failure of the cooler (no cooling of the exhaust gas) before it would cause emissions to exceed 1.5 times the standards and that manufacturers would be able to use a temperature sensor (after the cooler) for monitoring.

(e)(4) Boost pressure. Again, like the fuel system and EGR, by 2010, manufacturers should have significant experience with boost systems. Most manufacturers use some form of feedback control involving the manifold pressure/boost sensor as well as increasing use of variable geometry turbos with vane position and/or turbine speed. While boost pressure control problems may not have as much of an emission impact as EGR or fuel system problems (partially because the pressure sensor always tells you what pressure you are actually at), operating at incorrect boost levels (e.g., the “smoke limit” fueling rate) can indeed increase emissions over time. Again, 1.5 times the standard is appropriate for this feedback controlled system, and it is expected, based on how the systems typically work, that a manufacturer would have to calibrate this diagnostic to indicate a fault when the feedback system over a period of time cannot compensate the system (or takes too long) to deliver the desired boost.

Along with boost pressure, intercooler performance would also be required to be monitored to make sure it is still providing sufficient cooling of the charge air. Manufacturers are expected to use existing charge air temperature sensors to perform this monitoring. Given that the control systems compensate for the charge air temperature, it is expected that the cooler will have to have a severe reduction in cooling performance before emissions start to increase.

(e)(5) Hydrocarbon (HC) catalyst monitoring. This section primarily targets monitoring for oxidation catalysts that are located upstream of the PM filter to aid in regeneration. The requirement would also cover monitoring of other HC converting catalysts such as “guard” or “clean-up” catalysts located after PM filters, NOx adsorbers, or selective catalyst reduction (SCR) catalysts. Monitoring of the catalyzed portion of a catalyzed PM filter is covered under the PM-filter monitoring requirements, not this section.

For 2010-2012 model year engines, monitoring would be required to verify that the HC catalyst still has sufficient conversion efficiency to maintain emissions at or below 2.0 times the HC standards. If, as expected, complete failure of the catalyst would not cause emissions to exceed 2.0 times the standard, manufacturers would only be required to verify that there is some detectable level of conversion efficiency still present (e.g., a “functional” check). Manufacturers are expected to use

temperature sensors to measure the exotherm during an active PM filter regeneration event and correlate the observed temperature increase with the conversion efficiency of the catalyst.

In 2013, the threshold for detecting a malfunction would drop to 1.5 times the HC standards. This would provide manufacturers with an additional three years of experience with monitoring of oxidation catalysts and their failure/deterioration modes. With this experience manufacturers' should be better able to correlate measured exotherm temperature rise and conversion efficiency.

Given that the primary role of the oxidation catalyst is to assist other aftertreatment (e.g., to provide an exotherm to increase exhaust temperature and achieve an active PM filter regeneration), the catalyst would also be required to be functionally monitored to make sure that it is still "good enough" to reach the necessary PM-filter regeneration temperatures. With manufacturers closely controlling regeneration and often feedback strategies based on catalyst outlet/PM filter inlet temperatures, the feedback system itself should be able to identify when the necessary regeneration temperatures cannot be reached during a commanded active regeneration event. Given the consequences of not achieving PM-filter regeneration when desired, most manufacturers already have such a monitoring strategy in place, and it should not require much further refinement.

Lastly, if there is more than one oxidation catalyst in the aftertreatment system, the regulation would allow manufacturers to monitor and calibrate the different catalysts either separately or in combination with each other. If a manufacturer chooses to monitor various catalysts in combination with each other, an aging plan would be required to be submitted to CARB for review. The plan would be required to explain how the manufacturer is going to appropriately age the combination of catalysts to represent what would likely happen in-use.

(e)(6) NO_x catalyst monitoring. This section details requirements for monitoring NO_x catalysts including lean-NO_x catalysts and SCR catalyst systems. In general, the catalyst itself would be monitored to make sure it has sufficient NO_x conversion to keep emissions below a threshold while additional components such as the SCR reductant injection system components are monitored for proper function.

For 2010-2012 model years, the catalysts would be required to be monitored and a fault detected when emissions exceed the standards by an additional 0.3 g/bhp-hr. For example, for engines certified to a 0.2 standard, a fault would need to be detected when emissions reach $0.2 + 0.3 = 0.5$ g/bhp-hr. In 2013, the threshold would drop down to the standard plus 0.2 g/bhp-hr (instead of 0.3 g/bhp-hr). In the case of feedback based SCR systems, manufacturers would be expected to use the same NO_x sensor that is used for feedback control for monitoring. With the control strategy designed to keep emissions below the standard, the control strategy would likely need to be at or near its control limits before emissions exceed 2 to 2.5 times the emission standards. As such, a diagnostic would likely be structured around

identifying a control strategy that is at or near its limits. The additional three years before the thresholds are lowered should give manufacturers enough experience to better refine their control strategies, which should result in improved diagnostic capability.

For non-feedback SCR systems or passive lean-NO_x catalysts, manufacturers are expected to be getting lower conversion efficiencies out of the components. Accordingly, complete failure would not likely cause a manufacturer to exceed the monitoring emission threshold and only a functional check would be required.

For the rest of the SCR system (e.g., reductant tank, delivery, and injection system), manufacturers would be required to perform functional monitoring and comprehensive component monitoring (e.g., circuit checks). This would include verifying reductant is actually being injected into the exhaust and that the proper reductant is being used. Manufacturers would be expected to identify the majority of these items by using a NO_x sensor in the exhaust and monitoring the response of the sensor to increases or decreases in reductant injection. In conjunction with the feedback control of the SCR system, manufacturers would also be required to monitor for faults that delay/disable the start of feedback, cause the system to default out of feedback, or where applicable, cause the system to adapt out to control limits such that no further feedback correction can be made.

(e)(7) NO_x adsorber monitoring. This section details the monitoring requirements for NO_x adsorbers. In general, the adsorber would be identified as malfunctioning when it can not keep emissions below a monitoring threshold. This threshold would be the identical threshold that is used for SCR catalyst systems. That is, for 2010-2012 model years, the adsorber must be monitored and a fault detected when emissions exceed the standards by an additional 0.3 g/bhp-hr. For engines certified to a 0.2 standard, a fault would need to be detected when emissions reach $0.2 + 0.3 = 0.5$ g/bhp-hr. In 2013, the threshold would drop down to the standard plus 0.2 g/bhp-hr (instead of 0.3 g/bhp-hr).

Manufacturers are expected to use the same two wide-range oxygen sensors (sometimes referred to as air-fuel ratio sensors) for monitoring that are used for control of the system. Again, given that the control strategy is designed to keep emissions at or below the standards, a control strategy would likely need to be at or near its limits before emissions would reach the monitoring threshold of 2 to 2.5 times the standards. In combination with the control strategy, monitoring of the oxygen storage capacity of the adsorber can be used to correlate to NO_x adsorption capability and thus, to emission levels. Monitoring may also need to be linked to a desulfation event and the oxygen storage capacity could be measured shortly after the event to distinguish a malfunction from a temporary sulfur poisoning. Knowledge and experience gained from the first three years could be used to refine the control strategy, correlation, and monitoring strategy as necessary to meet the lower monitoring thresholds. A NO_x sensor could also be potentially used downstream of the adsorber for further control optimization or monitoring refinement.

The reduction injection system used for desorption of the adsorber (in-cylinder or in-exhaust) would also need to be monitored. In the case of the in-cylinder system, it is expected that the fuel injection system monitors would be sufficient to verify that the in-cylinder injection was functioning. However, for in-exhaust systems, manufacturers would need to perform a separate functional check to verify that the reductant is actually being injected into the exhaust. Again, the same two control sensors would likely be used to determine that the system was able to deliver reductant (e.g., to achieve a rich exhaust gas composition necessary for desorption) and would suffice as a functional monitor.

(e)(8) PM filter monitoring. This section details the monitoring requirements for the PM filter including monitoring PM-filtering performance, regeneration performance, feedback control of regeneration, and catalyst performance (for catalyzed PM filters).

The first requirement for 2010-2012 model year engines would be for the filtering performance itself and is intended to identify cracks or other leakage that allows PM-emission levels to exceed 0.05 g/bhp-hr. This represents an emission level that is roughly halfway between engines without a PM filter (~0.1 g/bhp-hr) and those that are operating as designed with a PM filter (~0.01 g/bhp-hr). To identify such leaks, manufacturers would need to look at a combination of items including a soot-loading model (to estimate current PM filter-loading levels) as well as delta-pressure measurements (to correlate backpressure to estimated PM filter-loading levels). Strategies could include looking at identifying when PM loading, as estimated by delta pressure measurements, is at a lower level (or accumulating at a lower rate) than the PM loading estimated by the soot loading model. Other strategies could look at delta-pressure levels immediately after a thorough regeneration event to identify backpressures that are below normal. Still other strategies could identify abnormal or unexpected decreases in backpressure to indicate possible leaks that have suddenly occurred.

As manufacturers gather experience with PM filters over the six years from 2007 through 2012, it is expected that a considerable amount of optimization and refinement will go into the control strategy to minimize unnecessary fuel usage and still safely protect the PM filter from excessive loading or overtemperature conditions. A big part of that refinement will likely come from improvements to the soot-loading model to better estimate soot loading (as well as unloading during regeneration and ash accumulation). As model precision increases, model-based monitoring capability should also improve. Accordingly, the monitoring threshold would be lowered in 2013 to 0.025 g/bhp-hr (instead of 0.05 g/bhp-hr) (which still represents an absolute emission level that is 2.5 times the emission standard). It is expected that refinements to the same monitoring techniques will be sufficient to reach these levels but other approaches may also emerge including the use of soot sensors to more directly identify increased PM levels in the exhaust.

Regeneration is an essential element of PM-filter performance and must be carefully controlled and carried out. Most manufacturers will have multiple layers of feedback systems to ensure the regeneration process is carefully done to minimize the risk of runaway regeneration or overheating. Failure to achieve regeneration or properly regenerate can typically lead to increased risk of damage or catastrophic failure of the PM filter. Working off of the feedback control systems, manufacturers would need to identify malfunctions that cause the system to be unable to achieve regeneration when commanding such an event to occur. To the extent feasible, manufacturers would need to separately identify malfunctions that cause the system to be unable to achieve regeneration. For instance, by monitoring oxidation inlet catalyst temperature, oxidation outlet catalyst temperature, and PM outlet temperature, manufacturers may be able to distinguish faults such as intake throttle faults (insufficient catalyst inlet temperature) from oxidation catalyst faults (insufficient catalyst outlet temperature) from intrusive fuel injection (in-cylinder or in-exhaust) faults (insufficient PM outlet temperature). Other strategies would include monitoring the delta pressure across the PM filter before and after (or even during) regeneration to ensure regeneration occurred.

Closely related to insufficient regeneration would be a situation where regeneration is being commanded to occur too frequently. This could be a result of partial regeneration, excessive ash accumulation, or even reduced PM filter capacity. These items may indeed show a drop in delta pressure from before to after (or during) regeneration but would trigger the need for a regeneration more frequently than normal. In addition to the increased fuel usage from frequent regeneration, HC emissions are likely higher during a regeneration event. Thus, more frequent active regeneration (e.g., every 20 miles instead of every 300 miles) leads to higher HC emissions. Manufacturers would be required to detect a fault if regeneration is occurring so frequently that HC emissions would exceed 2.0 times the standard or whenever the regeneration frequency exceeds the manufacturer's design limits/specifications for normal operation.

(e)(9) Variable valve timing (VVT) system monitoring. This section would require monitoring of all VVT and/or lift systems. Manufacturers would be required to monitor the system for faults that cause a target error (actual position doesn't match commanded position) and slow response (actual position takes too long to get to the commanded position). Based on the precision with which valves must be controlled for proper engine operation, this monitor would be required to detect a malfunction when emissions reach 1.5 times the standards. It is expected that most manufacturers will be able to implement a single diagnostic that identifies both slow response and target errors and will likely be calibrated when the system has reached its control limits and can no longer achieve the desired valve timing or lift.

(e)(10) Exhaust gas sensors. This section identifies the monitoring requirements for both wide-range oxygen ("air-fuel") sensors and NOx sensors. Monitoring requirements for the two are separately identified and there is a further distinction

between sensors located upstream (closer to engine) of aftertreatment and those that are located downstream of one or more aftertreatment components.

Wide-range oxygen sensors located upstream of any aftertreatment are typically used for EGR control (i.e., to “trim” EGR flow rates under specific operating conditions). Again, given the accurate control manufacturers will have with EGR flow feedback control systems, this sensor will be used to fine-tune the EGR flow and, as such, will need to be very accurate. Offsets, biases, or slow response of this sensor will drive the system to incorrect EGR flow rates and could have a large emission impact. Given its presence upstream of any aftertreatment, however, manufacturers should have multiple monitoring options available to verify the sensor is working correctly including overrun events with fuel cut, idle, and even rich fueling during active PM filter regeneration. Accordingly, manufacturers will be required to detect a malfunction before emissions exceed 1.5 times the standards.

For NO_x sensors and wide-range sensors located downstream of one or more aftertreatment components, monitoring is complicated by the presence of the aftertreatment component and its variable effect on the exhaust gas. Accordingly, the monitoring thresholds are much higher for both PM and NO_x emissions (where the aftertreatment can have the largest unknown impact). These sensors will need to be monitored for faults that cause: (1) HC emissions to exceed 1.5 times the standard; (2) NO_x emissions to exceed the standards by an additional 0.3 g/bhp-hr; or (3) PM emissions to exceed 0.05 g/bhp-hr. These NO_x and PM thresholds are identical to those used for the PM and NO_x aftertreatment devices and are appropriate because these sensors will be used in the control of those devices. Like the PM and NO_x aftertreatment components, the NO_x and PM thresholds for these sensors drop to more stringent levels in 2013 (NO_x additive of 0.2 g/bhp-hr over the standard and PM emission level of 0.025 g/bhp-hr).

These sensors will also need to be monitored for circuit faults (e.g., shorts and opens) as well as faults that delay the start of feedback operation or cause disablement of feedback operation. Lastly, if the sensors are used to monitor other components, the sensors would need to be monitored to ensure that they are still performing “well enough” to be used as a monitoring device. For example, if a NO_x sensor is used to monitor an SCR catalyst and detect when the catalyst is malfunctioning, the NO_x sensor will need to be monitored to make sure that it is still performing well enough (accuracy, response, etc.) to be able to identify a malfunctioning SCR catalyst.

- (f) Gasoline engine monitoring. These requirements are essentially identical to those required for medium-duty gasoline engines under the OBD II program with the notable exception that the evaporative system would only be required to monitor for 0.030” diameter leaks, not of 0.020” leaks.

(f)(10) Alternate fuel engines. By the definition in this regulation ((c)(21)), all alternate fuel engines would be considered gasoline engines, regardless of whether

they are derived from diesel engines or gasoline engines. Alternate fuel engines are typically spark-ignited and have more similar emission control strategies and components to gasoline engines than diesel engines. Accordingly, alternate fuel engines are subject to the monitoring requirements of gasoline engines. However, given the limited market segment and the uncertain role that alternate fuel engines will play in the market, manufacturers would be allowed to request relief from any OBD requirement through the 2016 model year. Relief will be granted in any case where the use of the alternate fuel may cause a monitoring strategy to be unreliable.

(g) Monitoring requirements for both diesel and gasoline engines. This section details monitoring requirements for components that are common to both gasoline and diesel engines.

(g)(1) Engine cooling system. Proper warm-up of an engine can be crucial to emission controls and many other component control strategies are linked to the engine warm-up. This includes items like EGR control or fuel injection quantities or timing restrictions to reduce white smoke, and may also be used for aftertreatment control strategies (e.g., only enabling active regeneration after the engine is warmed up). Manufacturers also often use coolant temperature as an enable condition for other monitors (e.g., to improve monitor robustness by only monitoring items when the engine is warmed-up). Delays in warm-up or failure to reach certain levels can cause increased emissions or disablement of other control strategies or their monitors. Accordingly, the engine cooling system is monitored for thermostat malfunctions (e.g., too slow to warm up) and coolant temperature sensor malfunctions (e.g., irrational, biased, offset, or stuck sensors and circuit faults). Manufacturers would be required to define appropriate enable conditions (e.g., where warm-up is expected to occur in a predictable manner) and identify a fault if the system fails to reach normal warmed-up temperatures within time or fails to reach whatever temperature is need to enable other OBD monitors.

(g)(2) Positive crankcase ventilation (PCV) system. This section identifies the monitoring requirements for PCV systems. In general, manufacturers would be required to identify a fault if part of the system becomes disconnected or otherwise starts venting crankcase emissions directly to the atmosphere. Unlike other monitors, however, much of the PCV monitoring requirements can be satisfied by meeting design criteria regarding the types of materials, connectors, hose-routing, and repair procedures rather than diagnostics that sense when disconnections occur.

(g)(3) Comprehensive components. This section identifies the monitoring requirements for the rest of the emission-related electronic input and output components (e.g., sensors, valves, and actuators). Manufacturers would be required to monitor input and output components that are used for other OBD monitors (e.g., pressure sensors used to monitor the PM filter). Manufacturers would also be required to monitor input and output components that, by themselves, increase emissions when they malfunction.

As stated previously under section (e), manufacturers are required to detect OBD malfunctions if a single component is bad enough that, by itself, it causes emissions to exceed the OBD threshold of 1.5 times the standards, not when combinations of partially deteriorated or malfunctioning components cumulatively cause high emissions. To somewhat mitigate the loophole that exists because the OBD system is “blind” to the synergistic effects of multiple component failures (and consequently, potentially high in-use emissions), manufacturers are required to monitor individual comprehensive components for failures that cause any emission increase, not just an increase that is large enough to make an engine fail the tailpipe standards.

For comprehensive components, there would be no emission thresholds—monitoring consists solely of circuit checks (opens/shorts), rationality checks (does the sensor reading make sense), and functional checks (does the valve open and close when commanded to do so). Input components are required to be monitored for circuit faults and “rationality” faults. Rationality faults are those where the sensor is reading within the sensor’s operating range but is indicating a value that doesn’t make sense based on other available information. An example could be an intake manifold pressure/boost sensor that indicates a high boost condition while other sensors indicate the engine is operating at an idle speed and load. Output components such as valves or actuators are monitored for circuit faults and functional faults. A functional fault is defined as a component that does not properly respond to computer commands. For example, monitoring the current draw of a glow plug when it is commanded on could verify the component is functionally working.

(g)(4) Other emission component monitoring. This section is a catch all for new emission control technologies that emerge in the future. Because the regulation cannot define specific requirements for technologies that do not yet exist, this section would require manufacturers using new technologies to submit a monitoring proposal for review and approval prior to introducing a new technology. Generally, manufacturers would be expected to come to the CARB to discuss such a plan many years in advance of introduction to ensure that adequate monitoring will be in place at the time of certification.

(g)(5) Exceptions to monitoring requirements. This section provides further guidance to manufacturers on conditions where monitoring relief generally is, or can be, granted. This includes items like disablement of monitors at high altitude, low fuel level, low/high battery/system voltage levels, and while power take-off (PTO) components are active.

(h) Standardization. This section describes the details of how information must be standardized and transmitted between vehicles and scan tools as well as exactly what information must be transmitted.

(h)(2) Specifies where the diagnostic connector would be required to be located (i.e., to make it easier for technicians and inspectors to locate it with minimal interruption to the vehicle operator).

(h)(3) Identifies the specific Society of Automotive Engineers (SAE) and International Standards Organization (ISO) communication protocols that can be used.

(h)(4) Specifies data and functions that need to be supported and available for scan tools, including readiness (used for inspection purposes), data parameters (used for diagnosis, repair, and inspections), freeze frame data (for diagnosis and repair), fault codes (pending, confirmed/active, previously active, and permanent), monitor test results (for diagnosis), software calibration (for inspections), and vehicle identification number (for inspections).

(h)(4.2) Specifies which engine data parameters would need to be supported and transmitted to a scan tool such as engine speed, torque, engine coolant temperature, etc. The required data stream parameters also include “Not-To-Exceed (NTE) status,” which would be used to ensure valid data are collected during in-use enforcement testing (e.g., NTE testing with a portable emission measurement system). The real-time status of the engine would be reflected as one of four states: within the NTE control area (NTE sampling is valid); outside the NTE control area (NTE sampling is not valid); within a manufacturer-specific 5% “limited testing” carve-out area (NTE sampling is valid as long as it is less than or equal to 5% of the sampled data); or within a manufacturer-specific NTE deficiency area (NTE sampling is not valid). This parameter will be used to protect the engine manufacturer from being erroneously subjected to NTE testing in regions where CARB has already granted relief to the manufacturer as well as to simplify the data processing that will be necessary to perform valid in-use enforcement testing. Definitions for “NTE deficiencies” and the “5% limited testing” region are in the definitions section of the regulation (section (c)(28)).

(h)(5) Sets forth requirements for formatting (resolution, bytes, etc.) of “rate-based” data as well as logged engine run time data (e.g., total engine hours, idle hours, PTO active hours).

(h)(5.2.2) This section includes specifications for logged NTE run time information (e.g., NTE area hours, NTE deficiency active hours, NTE 5% carve-out hours). When an engine manufacturer gets an NTE deficiency or 5% limited testing carve-out region approved, much of the approval is based on the expected frequency that in-use vehicles will operate in those regions. However, this is generally based on very limited test data and may not always be representative of actual in-use operation. While the logged NTE data will not be used for enforcement testing or to trigger enforcement or other retro-active actions, tracking this information will provide both engine manufacturers and CARB assurance that the criteria used at the time of certification are truly representative as well as allow both engine manufacturers and CARB to identify areas for improvement on future model year engines. This provision would also

assure uniform treatment of NTE decisions among manufacturers by certification staff.

This section also identifies specifications for logging a subset of auxiliary emission control device (AECD) run time information. In a similar manner as the logged NTE data, the OBD system is required to log run time while specific AECDs are active. The only AECDs that would be required to be logged are those that: (a) have been approved by Environmental Protection Agency (EPA)/CARB; (b) have not been granted an NTE deficiency; (c) are not limited to use for engine starting; and (d) cause emissions to exceed the numeric NTE emission limits (regardless of whether it happens within or outside of the official NTE control area limits). The definition for this subset of AECDs is included in the definition section of the regulation (section (c)(12)). An example of an AECD that would need to be tracked could be an extended idle engine protection strategy that alters emission control and causes emissions at idle to exceed the numeric NTE emission limits. Others could include engine protection strategies that occur at high ambient temperatures and result in an emission level that is above the numeric NTE emission limits. Analogous to the logged NTE data, these logged AECD data will not be used for enforcement testing or to trigger an enforcement action, but they will be used to identify areas for improvement on future model year applications, where appropriate.

(i) Monitoring Demonstration Testing. This section describes the demonstration testing that must be done for certification. In general terms, for monitors that are calibrated to an emission threshold, manufacturers would be required to calibrate the diagnostics specifically for each engine family. However, for certification purposes, CARB only spot-checks one to three engines a year. On the selected engines, manufacturers have to run an emission test for each diagnostic calibrated to an emission threshold and show that a malfunction is properly detected before emissions exceed the OBD threshold (i.e., demonstrate the monitors were calibrated correctly).

Depending on the number of engine families certified by the manufacturer, CARB would select one (for manufacturers with 5 or fewer engine families) to three (for manufacturers with 11 or more engine families) engines per year for testing. On each of the three engines, manufacturers would be required to individually run emission tests with a threshold component (a component deteriorated right to the OBD malfunction criteria) and show that a fault is detected and emissions are at or below the required OBD threshold. This is only done for monitors that are calibrated to an emission threshold (~8-12 emission tests per engine for a typical 2010 diesel engine).

Test results would be required to be submitted with the certification application. However, for the 2010-2012 model years, manufacturers would be allowed to submit the data within six months after certification instead of before certification.

(j) Certification Application. This section provides a detailed list of the items that would be required to be included in a certification application so that CARB may properly

understand and review the system to verify compliance with the requirements. In general, manufacturers would be required to submit descriptions of each diagnostic identifying the monitored component, the malfunction criteria used, the monitoring conditions, and the fault code that will be stored. For the majority of the documentation, manufacturers are allowed to submit the documentation in any existing format they already have to minimize the need to create specific documentation just for the OBD application.

(k) Deficiencies. This provision in the regulation details the policy that will be used by CARB to certify manufacturers even though they might not meet all of the OBD requirements. For items that don't meet the requirements, manufacturers are assigned deficiencies. In general, a manufacturer is only eligible for deficiencies in cases where it has made a good faith effort to meet the requirements and has a plan to come into compliance as soon as possible. On a case by case basis, manufacturers can be granted the same deficiency for up to three years depending on the severity of the deficiency, the progress being made by the manufacturer to eliminate the deficiency, and the leadtime necessary to make hardware and/or software changes to correct the deficiency. For the 2010 through 2012 model years, there would be no limitation on the number of deficiencies a manufacturer may receive nor are there any monetary penalties. Starting with the 2013 model year, there would continue to be no limitation on the number of deficiencies that may be received but manufacturers are subject to fines of \$25 or \$50 per engine for each deficiency above and beyond two deficiencies.

(l) Production Vehicle Evaluation testing. This section is divided into three parts and details test requirements manufacturers would be required to conduct on actual production vehicles to verify compliance with the regulations. The three basic sections are: (1) compliance with the standardized communication protocols (e.g., SAE J1939); (2) spot-checking that each and every diagnostic can detect a fault; and (3) collection of "rate-based" tracking data from a small sample of in-use vehicles.

(l)(1) Standardized requirements. This section would require a manufacturer to use engineering test tools/equipment to verify that its engines, when installed in production vehicles that are introduced into commerce, actually comply with the standardized communication protocol requirements. The engineering test equipment essentially acts like a scan tool, queries the engine for all of the required information such as fault codes, MIL status, and live engine data, and identifies a problem if the information is not within specification. For instance, items like message timing, message format, and the content of the message data are all checked versus SAE J1939 (or ISO 15765-4) specifications. Testing usually takes about 15-20 minutes to conduct per vehicle.

A manufacturer (or its designee) would be required to test one vehicle for each unique engine family and vehicle variant offered for sale with the manufacturer's engines (up to a maximum of 10 vehicles per engine family in cases where there are more than 10 variants available for an engine family). The regulation would allow manufacturers flexibility to group similar variants together (e.g., those that use the same

communication protocol software and are expected to perform identically in regards to communication of information) and test only one vehicle per grouping. It is expected that most manufacturers would elect to use this flexibility and would be testing much fewer than 10 vehicles per engine family. Testing is required to be done within three months after the start of engine production or within one month after the start of vehicle production, whichever occurs later.

(l)(2) Monitoring requirements. This section would require manufacturers to verify, on a very limited number of actual production engines and vehicles, that each and every OBD diagnostic works as designed and is able to detect a malfunction, store a fault code, and illuminate the MIL. Manufacturers would be required to do this on the same number of engines subjected to certification demonstration testing (see description of section (i)) and on an equal number of vehicles for a total of one to three engines and one to three vehicles (depending on the number of engine families certified by the manufacturer). For each engine/vehicle, a manufacturer (or its designee) must implant or simulate a fault—one at a time—for every OBD diagnostic and verify the fault is detected and illuminates the MIL. After a fault is implanted, the engine would be required to run until the fault is detected, the fault code and MIL status is recorded. Then the code would be required to be cleared and the next diagnostic tested. This testing can typically take two to four weeks per engine. No emission testing is required and the tests can be done in a service bay, on the road, on a test track, on a chassis dynamometer (or an engine dynamometer for the engine tests), or in or any other way the manufacturer can implant the fault and exercise the diagnostic. This testing would be required to be done within the first six months after the start of engine production and the results submitted to CARB.

(l)(3) In-use monitoring performance. The last of the three sections would require a manufacturer to collect “rate-based” data (see description of sections (d)(3)-(5)) from a small number of in-use vehicles. This data identifies how often the major monitors have had a chance to run relative to how much the vehicle has been driven. Manufacturers (or their designees) would be required to group engine and vehicle variants that they expect would likely have similar in-use monitoring frequency. They would be required to gather data from 10-15 vehicles per grouping. The data would be required to be collected and submitted to CARB within six months after vehicles within the grouping were introduced into commerce. Manufacturers are allowed flexibility in how they collect the data but a common method would likely be to retrieve the data via a scan tool on vehicles brought in for service or repair during the first six months.