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TO: ALL INTERESTED PARTIES

SUBJECT: INTERIM PROCEDURE FOR TECHNICAL REVIEW AND FOR VERIFICATION OF EMISSION REDUCTION CLAIMS FOR PM AND NOx RETROFIT DEVICES OF EXISTING ON-ROAD AND OFF-ROAD HEAVY-DUTY DIESEL VEHICLES AND EQUIPMENT

In recent years, engine and aftertreatment technology for heavy-duty diesel vehicles has shown promising results (in both the laboratory and the field) to reduce particulate matter (PM) and oxides of nitrogen (NO_x) emissions. This is of significance due to the fact that, in August 1998, PM exhaust from diesel-fueled engines was identified by the Air Resources Board (ARB) as a toxic air contaminant. As presented in the draft Proposed Risk Reduction Plan for Diesel-Fueled Engines and Vehicles, released July 13, 2000, substantial diesel PM reductions can be achieved with retrofits of in-use diesel engines. Consequently, there is interest by manufacturers and the general public, in investigating and evaluating emission control devices to reduce the toxic emissions from in-use heavy-duty diesel vehicles (HDDV). In addition, retrofits of in-use diesel engines to reduce NO_x emissions may also be necessary if the major population centers in California are to reach their clean air goals. Recently, $50 million has been authorized in the 2000/01 fiscal year for the continuation of the Carl Moyer Program. This program provides incentives for cleaner heavy-duty engines in public and private fleets. An additional $75 million has been authorized in the Sacramento and San Joaquin Valleys for the same fiscal period to implement low-emission strategies for their heavy-duty vehicles. These strategies include retrofitting existing engines to lower emission levels.

There are also regulations being developed that would require the retrofit of HDDVs to obtain lower emissions from these vehicles. One such regulation is the Regulations for a Public Transit Bus Fleet Rule and Emission Standards for New Urban Buses (Transit Bus Fleet Rule). This regulation, although not yet finalized, was approved by the ARB on February 24, 2000. The Transit Bus Fleet Rule targets PM and NO_x emissions from new transit buses and requires diesel particulate filter retrofits to reduce PM emissions from existing diesel-fueled buses. As a result of this regulation, other anticipated regulations in development, and public interest, manufacturers are developing emission control systems (ECS) to reduce PM and NO_x emissions from heavy-duty diesel vehicles. Additionally, manufacturers have asked the ARB to review and verify the emission reduction capabilities of their various ECSs.

In recognition of the major role that PM and NO_x retrofit technologies must play to improve California's overall air quality, the ARB has developed the following interim procedures to provide maximum flexibility while guaranteeing real and durable emission reductions. These procedures will enable verification of the emission reduction claims of retrofit technologies and speed their commercial introduction. An engine or retrofit technology manufacturer with a PM or NO_x reduction strategy or technology should contact ARB staff to discuss how to participate in this verification program.

Upon meeting the minimum requirements of the review process, the ARB will provide the manufacturer with verification of emission reduction claims. The manufacturer should also request a Vehicle Code 27156 exemption, that may be transmitted with the verification process[1], to permit sales and installation of the reviewed ECS in the State of California. The emission reductions determined as part of this process may be used for incentive programs (such as the Carl Moyer Program) and for emission reductions to be claimed as part of local air quality attainment plans.

Subsequent to finalization of the Transit Bus Fleet Rule, a Manufacturers Advisory Correspondence will be issued and mailed to advise manufacturers whether additional information is required to certify an ECS that has been verified by this interim review to the requirements in the Transit Bus Fleet Rule regulation. The requirements of this process may be as simple as a written request for certification to the Transit Bus Fleet Rule.

Each ECS will be categorized as either: 1) systems expected to reduce PM emissions by at least 85 percent, or to achieve PM levels of 0.01 grams per brake-horsepower-hour or less, or 2) systems expected to achieve reductions primarily in NO_x emissions, with possible PM emission reductions. Regardless of the category, the ECS and support information will be reviewed in the same manner, as described below. The focus of the first category is to demonstrate compliance with the Transit Bus Fleet Rule and any voluntary PM emission reduction programs. ECSs capable of achieving at least an 85 percent PM reduction are required as part of the Transit Bus Fleet Rule. The purpose of the second category is to demonstrate compliance with voluntary emission reduction programs, which are primarily aimed at NO_x emissions.

For certain engines in specific applications, PM reductions of 85 percent or PM emissions of 0.01 grams per brake-horsepower-hour or less, may not be feasible. For example, this primarily, although not always, occurs with regenerative ECSs which require high exhaust temperatures to operate more effectively. In certain applications

[1] The Vehicle Code 27156 exemption process is for on-road vehicles only and may be expedited upon request so that the manufacturer can sell their product, without emission reduction claims, prior to receiving the verification letter, if they so choose.

which experience long periods of idling and low exhaust temperatures, regeneration occurs less frequently (or not at all), producing lower PM reductions compared to applications with higher exhaust temperatures. In these applications, manufacturers should demonstrate the highest control efficiency (or lowest emission rate) possible and should provide sufficient application information to support any claims that a PM reduction of 85 percent or PM emission level of 0.01 grams per brake-horsepower-hour or less cannot be achieved for the specific application and/or engine family.

In addition to equipment modifications, manufacturers may propose fuel modifications to achieve emission reductions. While the process described in this procedure outlines information necessary to verify reductions from equipment-based ECSs, an equivalent procedure is being developed for fuel-based modifications. If you are interested in having ARB review and verify fuel modifications to reduce emissions, please contact Mr. Steve Brisby, Manager, Fuels Section at (916) 322-6019.

In general, to participate in the emission reduction verification process, the manufacturer should submit to the ARB sufficient information to determine each of the following:

1. Claimed emission reductions and/or emission levels,
2. System durability,
3. System compatibility with the engine and vehicle operating conditions,
4. Fuel sulfur requirements, and
5. System labeling.

Each criterion is described in detail below. In addition, in-use inspection and testing will be required for the ECSs. These requirements will be described in a supplemental letter and will be sent out in the near future. The ARB staff will be available to discuss these, and the requirements described below, to provide feedback on a test plan to ensure that the necessary data for the verification process are obtained. Additionally, ARB staff may be available to assist manufacturers in the testing and data collection process.

1. Claimed Emission Reductions and/or Emission Levels

The manufacturer of an ECS should specify a percent reduction and/or brake specific emission limit (grams per brake-horsepower-hour) which the system is expected to achieve for the duration of its emission durability lifetime (described in Section 2, below). Any expected brake specific emissions should not be greater than current emission standards authorized by law. Additionally, any

increase above baseline emissions should not exceed the test-to-test variability[2]. Claimed emission reductions/limits should be supported by the manufacturer's emission test data. Test data to verify percent reductions should include baseline tests and modified-with-ECS tests.

The manufacturer should also identify the specific engine and vehicle applications (e.g., engine make, model, model year, and vehicle application) with the emission claims. Emission reductions may be engine and/or application specific due to varying engine and application characteristics.

Prior to testing, each ECS should be aged. The manufacturer should propose an aging period, which allows for stabilization of ECS. Along with the proposed stabilization period, the manufacturer should include any associated data and justification to support the proposed aging period. After the stabilization process, the ECS should be tested on an engine family basis (as described in the Code of Federal Regulations 40 Part 86). Engine families could be aggregated if it is demonstrated to the satisfaction of the ARB that ECS performance and emissions do not vary significantly between engine families. At least one engine from each engine family, or approved aggregated engine families, should be used in the emission testing process. The manufacturer may tune-up or rebuild the engine only prior to baseline testing. Any tests conducted immediately subsequent to a tune-up or rebuild will be considered a baseline test.

If the manufacturer is claiming a percent emission reduction, the engine with the lowest applicable emissions in the engine family, or aggregate engine families, should be used for testing. If the manufacturer is claiming emission reductions to specified levels, the engine with the highest applicable emissions in the engine family, or aggregate engine families, should be used for testing. Note that verifying an ECS to a specific emission level may have less applicability to other engine families than verifying to a specific emission reduction. For example, verifying a particulate filter to an urban bus PM level of 0.01 grams per brakehorsepower-hour is not likely to have carryover to school buses or refuse trucks, while carryover is more likely with a verification to an 85 percent PM reduction level.

Since ECS design (i.e., catalyst formulation and regeneration) is often based on fuel sulfur content, engines should be tested with diesel fuel similar to the required fuel as discussed later in Section 4 - Fuel Sulfur Requirements.

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[2] If the manufacturer expects any increase in emissions due to use of the ECS, it should consult with the ARB.

Each engine should be tested on the applicable California test procedure. A chassis test may be used in lieu of an engine test, with Executive Officer approval. Chassis testing should utilize the heavy-duty Urban Dynamometer Driving Schedule test cycle or another test cycle approved in advance by the Executive Officer. Chassis testing can only be used to verify a percent emission reduction. The test cycle utilized in the emission testing should represent the driving conditions of the vehicle applications submitted by the manufacturer. For ECSs requiring regeneration events, the test cycle should be repeated as many times as needed for regeneration to occur. The average of all valid test cycle repetitions between regeneration events would be used for ECS verification.

The manufacturer should complete at least two emission tests of one ECS on the same engine, or chassis. The duplication of emission tests on the same engine, or chassis, will show any test-to-test variability in emissions. Test-to-test variability should be no greater than 10 percent and should not be significant compared to the percent emission reduction. Additional emission tests on the same engine, or chassis, and the same ECS should be conducted if the test-to-test variability exceeds 10 percent or is significant compared to the percent emission reduction. Test results should show baseline and post-control emissions of total PM, non-methane hydrocarbons or total hydrocarbons (whichever is used for engine or vehicle certification), NO_x, and carbon monoxide. Emissions data for pollutants that the system does not target are necessary to verify no adverse effects on overall emissions due to adding the ECS. The verification of ECS emission claims from the ARB will reflect the average of the test results.

Should the ARB have reason to believe that there may be an increase in toxic air contaminants as a result of the ECS installation, the manufacturer may be required to perform an analysis of the exhaust. In some cases, this may only include an analysis of PM, benzene, 1,3-butadiene, formaldehyde, and acetaldehyde. Since many components of uncontrolled diesel exhaust are classified as toxic air contaminants, the associated risk should not increase as a result of the ECS.

2. System Durability

The manufacturer should demonstrate the system's emission durability through actual field or bench testing. Manufacturers may carry-across emission durability data to other engine families with prior ARB approval if the manufacturer demonstrates that the emission durability demonstration conditions are similar to or worse than those expected from any carry-across engine family. Note that the

worst-case durability vehicles tested may not be the same as the emission-data vehicles discussed in the previous section. For example, a worst-case emission demonstration of percent reduction may require testing the engine family with the lowest emissions, whereas the emission durability demonstration may require data from the engine or application with the lowest exhaust temperature and/or highest emissions.

The minimum duration of the durability testing should represent the periods of time or activity as shown in Table 1. For each engine type and size, the durability testing period should be that which occurs first. For example, the durability testing for an on-road 300 horsepower engine should be 5 years or 150,000 miles (or equivalent time in hours), whichever occurs first. A manufacturer may propose to shorten the durability testing with ARB approval if other data or information is available to demonstrate ECS emission durability to at least the applicable duration identified below.

Engine Type	Engine Size	Minimum Durability Testing Period	
		Years	Activity
On-Road	Light heavy-duty, generally 70 to 170 hp, Gross Vehicle Weight Rating (GVWR) normally less than 19,500 lbs.	5 years	60,000 miles (or equivalent time in hours)
	Medium heavy-duty, generally 170 to 250 hp, GVWR normally from 19,500 lbs. to 33,000 lbs.	5 years	100,000 miles (or equivalent time in hours)
	Heavy heavy-duty, generally exceeds 250 hp, GVWR normally exceeds 33,000 lbs.	5 years	150,000 miles (or equivalent time in hours)
Off-Road	Under 25 hp, and for constant speed engines rated under 50 hp with rated speeds greater than or equal to 3,000 rpm	3 years	1,600 hours
	At or above 25 hp and under 50 hp	4 years	2,600 hours
	At or above 50 hp	5 years	4,200 hours

Table 1 - Minimum Durability Testing Periods

Only normal maintenance may be conducted on the ECS during demonstration of the emission durability period. If normal maintenance includes a change of any component of the ECS, approximate time (miles, years, or hours) between component change should be included with the results of the demonstration, and submitted to the ARB. Additionally, these maintenance components should

either be included with the original ECS or included free of charge to the customer at the maintenance intervals.

If the manufacturer has not yet sufficiently demonstrated the durability requirements or needs additional time to confirm the impacts of the warranty requirements, the manufacturer may choose to develop durability data using an experimental permit, which can be granted by the ARB. The review and verification process cannot be completed until durability is fully demonstrated. During the emissions durability period, the ECS needs to meet the following criteria:

a. Emission reductions from the vehicle and the ECS should not be less than the claimed emission reductions,
b. Emissions from the vehicle and the ECS should not exceed the claimed emissions,
c. The ECS should not result in any damage to the engine, and
d. Maintenance of the ECS/engine beyond that specified in the owner's manual will only be allowed with ARB approval.

The minimum duration of the defects warranty period should represent the periods of time or activity as shown in Table 2. For each engine type and size, the defects warranty period should be that which occurs first. For example, the defects warranty period for an on-road 300 horsepower engine should be 4 years or 100,000 miles, whichever occurs first.

Engine Type	Engine Size	Minimum Defects Warranty Period	
		Years	Activity
On-Road	Light heavy-duty, generally 70 to 170 hp, GVWR normally less than 19,500 lbs.	4 years	40,000 miles
	Medium heavy-duty, generally 170 to 250 hp, GVWR normally from 19,500 lbs. to 33,000 lbs.	4 years	65,000 miles
	Heavy heavy-duty, generally exceeds 250 hp, GVWR normally exceeds 33,000 lbs.	4 years	100,000 miles
Off-Road	Under 25 hp, and for constant speed engines rated under 50 hp with rated speeds greater than or equal to 3,000 rpm	2 years	1,100 hours
	At or above 25 hp and under 50 hp	3 years	1,800 hours
	At or above 50 hp	4 years	2,800 hours

Table 2 - Minimum Defects Warranty Periods

During the defects warranty period, the manufacturer will be liable for any defects in the ECS caused as a result of normal operation.

3. System Compatibility with the Engine and Vehicle Operating Conditions

Additional information is required to verify that an ECS is compatible with the engine and operating conditions, including the following: a) Engine backpressure, b) Regenerative system requirements, c) Non-regenerative system requirements, d) Effects on engine performance, e) Application compatibility, and f) Fuel sulfur requirements (see Section 4 below). Manufacturers who are not certain what additional information is necessary to demonstrate system compatibility should consult with the ARB for guidance.

a. Engine Backpressure

Retrofitting a vehicle often involves the installation of emission control equipment to the exhaust system of the vehicle. In some cases, this may result in added backpressure which, in turn, could cause excessive load on the turbocharger and engine, and increased fuel consumption. The manufacturer should demonstrate that the resulting backpressure is within the engine manufacturer's specified limits, or will not result in any damage to the engine.

b. Regenerative System Requirements

Many ECSs require regeneration of their media. Two methods of regeneration are active and passive. An active regeneration system requires an external source (electrical or mechanical), outside of normal operation, to regenerate the ECS. Some examples of active regeneration are the use of exhaust fuel injection or the use of heating mechanisms on particulate filters to initiate combustion of collected particulate matter. A passive regeneration system does not require another source, other than normal operation, to regenerate the ECS. An example of passive regeneration is a catalytically coated particulate filter that has a regeneration cycle initiated based on exhaust temperature. The examples listed above are primarily used for the control of PM emissions. There are various other ECSs available, which require regeneration, including NO_x adsorbers. If an active regeneration system is proposed, information regarding the regeneration method should be included. This information includes, but is not limited to, performance data that are monitored, thresholds and control logic that are integrated into the system to activate the regeneration process, and whether the control logic requires any changes from engine to engine and/or application to application.

c. Non-Regenerative System Requirements

Catalyst-based systems have different formulations of catalysts depending upon various engine attributes and engine applications. The manufacturer is required to identify engine and application uses for each catalyst formulation. Proprietary information should be identified as such when submitted.

Other systems, such as selective catalytic reduction, require an additional supply of reducing reagent to assist the emission reduction process. The manufacturer should indicate the consumption rates of the reagent and intervals at which the supply will need to be replenished. Consumption should be based on the engine and/or application. Additionally, information regarding the reduction process should be included. This information includes, but is not limited to, performance data that are monitored, thresholds and control logic that are required to operate the system, and whether the control logic requires any changes from engine to engine and/or application to application.

d. Effects on Engine Performance

Since the method of regeneration can vary from system to system, the manufacturer should submit information on the method of regeneration. For active regeneration systems, this supplemental information includes, but is not limited to, the effects on engine performance and the effects on fuel consumption. For passive regeneration systems, this supplemental information includes, but is not limited to, the effects of engine performance due to backpressure.

e. Application Compatibility

The manufacturer should provide typical temperature profiles, average duty cycles, and/or other parameters necessary to verify proper application compatibility of the proposed applications from field-collected data of specific applications. Sufficient data should be taken from the worst case vehicle and the worst case route, per application, to determine worst case driving conditions[3]. These data should be compared with operational requirements of the ECS to ensure proper design.

[3] The “worst case” is determined by the requirements of the ECS and may be the highest emitting vehicle, operating under the lightest load, with minimal torque demand.

4. Fuel Sulfur Requirements

There are various grades of diesel fuel available for sale, with respect to fuel sulfur content. The test fuel should meet the specifications contained in the California Code of Regulations (Subsections 2280 through 2283 of Title 13), with the exception of the sulfur content. Since performance/durability of an ECS often depends on diesel fuel sulfur, the manufacturer should specify the maximum sulfur level the ECS is designed for. Several common diesel sulfur contents include 15 ppm, 30 ppm, 50 ppm, and 500 ppm, all by weight. The maximum sulfur content may be one listed above or another fuel sulfur content. Testing of transit buses for PM reduction should use ultra-low sulfur diesel fuel with a sulfur content no greater than 15 ppm by weight.

The sulfur content of the test fuel should be no less than 66 percent of the stated maximum sulfur content. For example, if a manufacturer is verifying the ECS to a maximum of 500 ppm sulfur diesel fuel, the test fuel should not be less than 330 ppm sulfur by weight (500 ppm x 66% = 330 ppm). However, manufacturers may use a test fuel with a sulfur content greater than the stated maximum fuel sulfur content. Additionally, any expected consequences due to misfueling should be noted, as well as methods for reversing any negative effects from misfueling.

5. System Labeling

The manufacturer should provide a label on the ECS, which identifies the manufacturer, model number, and the month and year of manufacture. The manufacturer should include a scale drawing of a sample label with the submittal to the ARB.

The procedure described above is a general process, which will apply to a wide range of ECSs, engines, and applications/duty cycles. To ensure proper design and performance of ECSs, manufacturers have additional responsibilities prior to selling their ECS to a consumer. In addition to ensuring that the system is compatible with the application and sufficient regeneration (if required) will occur, the manufacturer should provide the following information in the ECS owner's manual (the owners manual should be submitted to the ARB during the review and verification process):

- Specify the durability period which the ECS is expected to perform as claimed and to not damage the engine,
- Specify the warranty period of the ECS in which the manufacturer is liable for any defects,
- Specify installation and maintenance requirements for the ECS,
- Specify fuel consumption penalty, if any, and
- Specify fuel sulfur content limitations, if any, to the purchaser.

Attached are a sample letter (Attachment 1) and checklist of supplemental information (Attachment 2). The sample letter is an example of a verification letter the ARB would provide after successful submittal of all necessary information. It states that ARB has reviewed, and verified the claims of emission reductions based on data provided regarding the ECS. The checklist consists of information and data required for the ARB to complete a review of the ECS. The ARB may request additional information if deemed necessary.

Applications for the emission reduction verification process should be mailed to:

Air Resources Board
Attn: Mr. Robert H. Cross
Chief, Mobile Source Control Division
9528 Telstar Avenue
El Monte, California 91731

Should you have any questions or comments regarding this review and verification process, please contact Mr. Michael Carter, Chief, Emission Research and Regulatory Development Branch, at (626) 575-6632.

Sincerely,

Robert H. Cross, Chief
Mobile Source Control Division

Attachments