HEAVY-DUTY ON-ROAD VEHICLE INSPECTION AND MAINTENANCE PROGRAM

I. OBJECTIVE

The objective of this study is to develop, evaluate, and assess the cost-effectiveness and economic impacts of alternatives for more comprehensive heavy-duty (HD) vehicle inspection and maintenance (I/M) program prototypes, and provide recommendations for the implementation of a full-scale program. The study results will inform the design of an improved HD I/M program expected for the Air Resources Board's (ARB or Board) consideration in 2017 or 2018, and support the ARB's State Implementation Plan development to achieve national ambient air quality targets in California.

II. BACKGROUND

Over the past twenty years, ARB has reduced on-road HD emissions standards for oxides of nitrogen (NO_X) and diesel particulate matter (PM) by about 97 percent. Despite these significant improvements, HD vehicles over 8,500 pounds are still responsible for approximately a third of California's total NO_X emissions and over a quarter of the diesel PM. While new engines employ improved engine designs and exhaust aftertreatment to certify to more stringent emissions standards, California still needs a more comprehensive HD I/M program to ensure that in-use engines continue to meet emissions performance requirements, as these engines are used in HD vehicles that operate for 20 or more years and travel nearly a million miles.

ARB's existing HD I/M program subjects all HD vehicles operating in California to some element of in-use inspection to control excessive smoke and tampering. Elements of the existing program include:

1) the Heavy-Duty Vehicle Inspection Program (HDVIP), which requires HD trucks and buses to be inspected for excessive smoke and tampering, and engine certification label compliance. Any HD vehicle traveling in California, including vehicles registered out-of-state and in foreign countries, may be tested. Tests are performed by ARB inspection teams at border crossings, California Highway Patrol (CHP) weigh stations, fleet facilities, and randomly selected roadside locations;
2) the Periodic Smoke Inspection Program (PSIP), which requires California HD truck and bus fleet owners to conduct their own annual smoke opacity inspections, and repair those vehicles with excessive smoke emissions to ensure compliance. The ARB randomly audits these fleets, including their maintenance and inspection records, and tests a representative sample of vehicles; and
3) the Emissions Control Label Inspection Program, which is designed to ensure that all HD commercial vehicles operating in California are equipped with engines that meet U.S. or California emissions standards.

However, the existing program does not adequately address the issues of controlling NO_X and PM emissions from the in-use fleet, including both old and new engines.

III. SCOPE OF WORK

In order to achieve the objectives of this proposed study, the investigators will work in consultation with ARB staff during all Tasks. This includes the literature review, I/M test methods development, emissions testing, and data analyses.

This project has two main elements that overlap, but are nevertheless distinct elements:

1) a broad technical and economic analysis of I/M programs looking at the large programmatic picture including national and international programs, and light-duty vehicle programs (Tasks 1 and 2); and
2) the development of an actual prototype HD I/M program, which will focus on development of actual test procedures, vehicle diagnosis and repairs, and vehicle emissions testing (Tasks 2 and 3).

These two elements will be combined in the final data analysis task (Task 4), where results from the vehicle emissions testing and engine repairs evaluation task can be extrapolated and analyzed at the statewide level, to produce estimates of total HD I/M program costs, and cost-effectiveness in reducing pollutant emissions.

Task 1. Perform a literature review of HD I/M programs and previous research regarding such programs, diagnosing high emissions, and performing vehicle repairs, with an emphasis on HD diesel engines

The investigators should identify features of light-duty (LD) vehicle I/M programs that may be transferable to a HD program and identify HD I/M programs in the U.S. and worldwide to assess applicability to an improved HD I/M program in California. This assessment should address: program elements (successful and unsuccessful), program pitfalls, legislative barriers, pollutants measured, scope of physical vehicle inspections and maintenance and records inspections, implementation costs to administering agencies (e.g., staffing needs, enforcement costs, auditing costs, etc.), costs to testing station owners (if applicable), costs to truck owners and operators, and emission benefits.

There has been a fair amount of previous research on the subject of HD engine emissions diagnostic tests, and identifying and repairing high pollutant emitting engines (1-11), although this research was generally focused on diesel engines without aftertreatment. Hence, the selected contractor will be expected to both summarize previous research, and describe how this research will be built upon (or not) to deal with lower-emitting modern engines with NO_X and PM aftertreatment and electronic engine controls.

Ideally, the test method will be able to measure all HD engine pollutant emissions, including NO_X, PM, total hydrocarbons (THCs), carbon dioxide (CO_2), and carbon monoxide (CO). Instrumentation for measuring pollutant emissions shall be investigated, and the relative cost and effectiveness of various types of instrumentation shall be discussed (e.g., 'laboratory grade' versus 'repair grade' pollutant measurement instruments).

This literature review should also include a study of different methods of exercising the engine/vehicle for the purposes of conducting an I/M test, including fixed or transportable chassis dynamometers, remote sensing of vehicle emissions as in-use vehicles pass by the remote sensor (using infrared or other methods), 'free' (unloaded) acceleration tests, or some other method(s). And finally, if needed, the test cycle (e.g., for chassis dynamometer testing), or test conditions (e.g., for remote sensing) shall be investigated to determine the best test cycle or test conditions, depending on the specific test method.

So, the literature review will study all aspects of developing HD I/M programs, including in-use fleet characterization, pollutants to be measured and by what method(s), diagnosis and repairs, test methods and test cycles,

The investigators shall provide a written interim report of their review, making recommendations for I/M test methods to develop in Task 2, and to test and evaluate in Task 3. This report shall be reviewed and approved by ARB staff before beginning Task 2.

Task 2. Based on the Task 1 literature review, develop possible program alternatives for an improved HD I/M program

This task will involve the development of potential improved HD I/M program designs. ARB's existing HD I/M program does not include measurement of in-use NO_X or greenhouse gas (GHG) emissions. Possible program designs could include the use of On-Board Diagnostic (OBD) data, potential use of OBD-based transponders; remote sensing and similar non-invasive vehicle sampling methods to identify high emitters; and/or periodic inspections of HD vehicles operated in California. An improved HD I/M program could require annual or biennial inspections for all vehicles operating in California (those registered in- and out-of-state), and test to measure both for smoke ($PM_{2.5}$) and NO_X emission levels, THCs, CO, and potentially GHG emission levels.

Bidders are encouraged to not confine themselves to a single approach, assuming that there is technical justification for considering and proposing multiple approaches.

The investigators should identify possible program designs for a HD I/M program, including:

- Identification of the engine model years/vehicle classes subject to the program, including vehicles with and without an OBD system;
- Recommendations for testing methodologies, including equipment, to measure emissions for $PM_{2.5}$, NO_X, THCs, CO, and potentially GHGs, and expected accuracy, convenience, cost, etc., including the following:

  Test method. The contractor shall specify the proposed method(s) to exercise the engine so that emissions can be measured, such as a fixed or transportable dynamometer, vehicle acceleration from a rest, vehicle passing a remote sensor, snap idle test, use of OBD data, etc.

Pollutants and instrumentation. Pollutants proposed for measurement as part of a HD I/M program shall be specified, as well as cost-effective instrumentation for making such measurements. Accurate and consistently repeatable NO_X and PM measurements are essential, while THCs and CO_2 are desirable, and CO, if it comes as part of a package (e.g., multiple-gas analyzer).

Test cycle. The proposed test cycle (e.g., AC 50/80 short test) or defined mode of operation (e.g., accelerating from an idle, or cruising at some fixed or varying speed).

High and normal emissions measurement. Implicit in any I/M short test, is the idea that the short test can both correctly identify high emitters, as well as verify that normal emitters are indeed normal, and not high emitters. One means of doing this is to compare short test cycle results against certification cycle test results. This is straightforward if both the certification test cycle and the short test cycle utilize the same test protocols (e.g., chassis dynamometer testing), but is more complicated for HD engines since only the engine is certified, but the entire vehicle will be tested in an I/M short test. So, the contractor will specify how emissions will be determined to be 'normal' and 'high' emitting.

Pass/fail cutpoints. Depending on the test method chosen, different pass/fail cutpoints will have to be developed. For example, for chassis dynamometer testing, cutpoints could be defined in units of grams/mile or grams per horsepower-hour, while for remote sensing, some sort of fuel-based method would be needed.

High emissions diagnosis and repairs. Detecting high emissions is only part of the goal of an I/M program - accurate diagnosis/identification of bad engine components or engine settings, and effective repairs, is equally critical. Hence, bidders should demonstrate knowledge of diesel and gasoline engine technologies, components likely to fail, and emissions impacts for all pollutants.

Overall test method and protocol. All of the above elements should be packaged into an integrated program that specifies protocols and procedures, including instrument and engine/vehicle warmup, engine/vehicle inspection, test protocol and sequence, data collection and data handling, instrument and data QA/QC procedures, etc.

- A discussion of potential exemption criteria, considering such factors such as vehicle age, captive fleets in attainment areas, etc.

For each identified possible program design, the investigators should describe pros/cons and potential costs to administering agencies, contractors/testing station owners (if applicable), and truck owners and operators. All of this information shall be included in the Task 2 Interim report. This report shall be reviewed and approved by ARB staff before beginning Task 3.

Task 3. Based on the results of Task 2, and, in consultation with ARB staff, demonstrate and evaluate the proposed test method(s) for a HD I/M program prototype

This task has three main subtasks: 1) preparation of the test plan, 2) emissions testing and vehicle repairs, and 3) analysis of Task 3 emissions, repair and cost data. The emissions test plan shall describe the emissions testing that will be done to evaluate the proposed I/M program and procedures developed in Task 2. This test plan and the emissions testing shall include:

Evaluation method. The method used to evaluate the accuracy of the short test shall be identified and described. For example, the reference method ('gold standard') could be chassis dynamometer testing using urban and highway test cycles.

Selection and procurement of test fleet. The contractor shall specify the test method evaluation fleet that spans a wide domain of engine model years and emitting regimes. The test fleet should be on the order of about 20-40 HDTs or more, depending on the specific proposed methods.

Engine/Vehicle inspection. The test plan shall include vehicle inspection and diagnostic forms that would be filled out as part of a statewide program, and that will also be completed as part of the Task 3 evaluation testing for all vehicles.

Baseline 'reference method' emissions testing, and I/M short cycle testing. The contractors shall describe and prescribe exactly how the reference method testing will be conducted, and also how the I/M short test testing will be conducted. This includes vehicle and test system preconditioning and/or warm-up.

Diagnosis and repairs of high emitting vehicles. The test plan shall describe and discuss how high engines will be diagnosed and then repaired. The bidder shall discuss sequence of repairs if more than one component is identified as being bad.

After-repairs testing using both reference method and I/M short test. This section of the test plan shall discuss after-repairs retesting, for both the short test and reference method.

The data analyses shall include:

Evaluation of accuracy of diagnoses and effectiveness of repairs. The contractor will evaluate the accuracy and effectiveness of the short test in identifying high emitters, and in the ability of the project team to effectively repair high emitting engines.

Determination of emissions reductions (or increases). The contractors will analyze emissions results to determine emissions changes on a pollutant-by-pollutant basis, including CO_2 and fuel economy.

Evaluation of individual vehicle repair cost-effectiveness. The contractor will determine the cost-effectiveness of individual repairs on a pollutant-by-pollutant basis.

Evaluation of total test fleet repair cost-effectiveness. The contractor will perform an analysis of overall test fleet costs, including costs for passing vehicles.

Task 4. Conduct an economic and environmental impact analysis based on the results of the evaluation testing

The investigators shall use the Task 3 emissions and repair-cost results, and data from other sources, to develop an economic analysis for the implementation of large-scale statewide HD I/M program scaled up from the program demonstrated in Task 3. The analysis shall include:

- Potential initial and annual operating costs for vehicle owners/operators, implementing agencies, and testing station owners (if applicable);
- A comparison of the improved program costs to existing program costs for all stakeholders and implementing agencies; and
- Projected cost-effectiveness (cost per emission benefit achieved) for a full-scale program.

IV. DELIVERABLES

- Quarterly progress reports and conference calls;
- Interim report(s);
- Draft final report;
- Peer-reviewed publication(s), as appropriate;
- Final report and research seminar in Sacramento;
- All data and analyses generated through the course of this project;
- Additional deliverables to be determined in consultation with ARB staff.

V. TIMELINE

ARB anticipates this project will be completed in 24 months from the start date. This schedule allows 18 months for the completion of all work through delivery of a draft final report; the last 6 months are for ARB review of the draft final report and the delivery of a revised final report and data files to ARB. The estimated budget for this project is $500,000.

REFERENCES

1. Demonstration of a Heavy-Duty Vehicle Chassis Screening Test for Compliance Testing Heavy-Duty Engines. ARB contract 94-347; West Virginia University; 1998.
2. Proposed Diesel National Environment Protection Measure; Parsons Australia Pty Ltd; 2000.
3. California Air Resources Board. Public meeting to update the Board on the status of California's M17 SIP strategy to reduce emissions from on-road heavy-duty diesel vehicles in-use; Board item 03-1005; Available at www.arb.ca.gov/msprog/m17/m17.htm.
4. Heavy-Duty Vehicle Chassis Dynamometer Testing for Emissions Inventory, Air Quality Modeling, Source Apportionment, and Air Toxics Emissions Inventory. CRC E-55/59 Phase 1 report; West Virginia University; 2003.

5. Heavy-Duty Vehicle Chassis Dynamometer Testing for Emissions Inventory, Air Quality Modeling, Source Apportionment, and Air Toxics Emissions Inventory. CRC E-55/59 Phase 1.5 report; West Virginia University; 2004.
6. St. Denis, M.; Lindner, Review of Light-Duty Diesel and Heavy-Duty Diesel Gasoline Inspection Programs; Journal of the Air and Waste Management Association, 2005, 55:12, 1876-1884.
7. Pollution Testing on Exhaust Emissions from Heavy-Duty Vehicles, Report 2008-S-65; New York State Department of Environmental Conservation; 2008.
8. Development of Emission Rates for Heavy-Duty Vehicles in the Motor Vehicle Emissions Simulator MOVES 2010 Final Report; Appendix A2, Tampering and Mal-maintenance. EPA-420-B-12-049, August, 2012.
9. Remote Sensing Device Trial for Monitoring Heavy-Duty Vehicle Emissions; Envirotest Canada; 2013.
10. Heavy-Duty Diesel Inspection and Maintenance Pilot Program; Texas A&M Transportation Institute; 2013.
11. Pollution Testing on Exhaust Emissions from Heavy-Duty Vehicles, Report 2013-F-3; New York State Department of Environmental Conservation; 2013.