Olson-EcoLogic
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A White Paper

Important Planning Considerations for Engine and/or Vehicle Emission Testing Objectives Including Fuel Economy and Power Performance Measurements

Introduction:

Engine and vehicle emission testing is an expensive and time-consuming activity. It requires several million dollars of sensitive equipment and experienced test technicians to be done properly in a manner acceptable to the client and to government agencies such as EPA, TCEQ (Texas) and the California Air Resources Board (CARB). Accordingly, it is very important that the client in consultation with appropriate government agencies and the Olson-EcoLogic engineering staff select the specific test protocol to properly satisfy the client objectives.

The purpose of this White Paper is to bring attention to the multitude of test protocols that are used by various government agencies to certify new model vehicles and engines and/or to verify emission reduction strategies for in-use vehicles or engines to benefit candidate emission testing clients wishing to show positive results with their emission control products.

Background:

To better understand the various testing options one first must recognize that all emission standards are set by EPA and these standards usually become more stringent over time requiring continual upgrades and new technology. Actually, this is the market driver for new emission control strategies and solutions. Furthermore the applicable emission standards are based on engine applications that are in turn based on typical use patterns for the application of interest. As an example the new engine certification protocol and emission standards for heavy-duty diesel engines in off-road applications are quite different than the test protocols and standards for the same engine designed for on-road applications. Small off-road engine equipment (called S.O.R.E.) is all tested and certified by steady state protocols on an engine dynamometer while the same engine in an ATV or motorcycle must be tested using a transient cycle test protocol on a chassis dynamometer. Automobiles and light duty trucks are originally certified as new vehicles on a chassis dynamometer over a transient cycle test protocol intended to simulate actual on-road use. Of course, in the development of engines, vehicles and emission control products many R&D testing variants are used to optimize results and better understand the factors that influence and affect performance. But, ultimately the

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products must be proof-tested by the standard test protocol for the specific product of interest.

The two categories of major interest are:

1. Original certification of new engine (and vehicle) products and
2. Verification of emission reductions for retrofit of products on in-use engines and vehicles, or for the provision of alternative fuels that can result in lower emissions

Nationwide there are various programs, many funded by State or Federal agencies, that provide the impetus and therefore the market opportunity for retrofit products that significantly reduce the emissions from in-use engine applications. Some of these programs finance the required testing for retrofit devices and others for alternative fuel configurations. The impetus for this testing is the extensive market applications that result from government-mandated requirements.

Most of these programs don't require fuel consumption savings as part of the proof-testing obligation, but it is obvious that the final client using the solution will always be interested in the fuel savings, if any.

The point and objective of this white paper is to assist the new client in proper test protocol selection for obtaining maximum benefit from his testing expense. Usually, this will be comparative testing with and without the client product on selected engines under specified test protocols – usually by test protocols required by government agencies.

<u>The Various Official Test Protocols and Implications for Emission Reductions:</u>

<u>Heavy-duty engines for off-road stationary applications</u> involve steady-state engine dynamometer testing over different modes of operation. These steady-state modes range from full load, rated speed to idle testing conditions.

<u>Heavy-duty engines for off-road mobile applications</u> involve testing with a non-road transient cycle (NRTC) conducted from a hot-start after stabilizing the engine.

<u>Heavy-duty engines for on-road applications</u> involve engine dynamometer transient cycle testing over a 20- minute variable load and variable speed testing cycle. One test cycle is done from a cold start followed by at least three of the same cycles with a fully warmed up engine.

<u>Automobiles and light duty trucks for on-road applications</u> involve chassis dynamometer testing over a transient test cycle that has segments of interurban driving and highway driving. This complete test cycle officially begins from a cold start after the vehicle has

soaked indoors overnight under controlled conditions and is conducted using a chassis dynamometer with a special 48 inch chassis roll.

Small engines for off-road applications are usually tested by steady-state operation over specified load and speed modes. The number of modes and the specified loads depend on the intended engine application. The exception to this is if the engine application is for all terrain vehicles (ATVs), motorcycles or engine powered scooters where the testing is done over a transient cycle on the chassis dynamometer.

It is important to know that emission results are quite different from test protocol to test protocol. It has been demonstrated time after time that a product which reduces emissions when tested by one protocol cannot be expected to be as effective in another protocol. For this reason it is important to always select the target market for a given product before specifying the protocol for proof-testing. By the same reasoning, it is important to understand the mechanism for reduction of candidate emissions by a particular strategy since the test protocol selected may not favor the strategy or product of interest. For example, oxides of nitrogen (NOx) are generated in the combustion cycle under high temperature conditions as is particulate matter (both are engine emissions that must be reduced). Unfortunately, mechanisms to reduce NOx by lowering combustion temperatures tend to increase the particulate matter generated during combustion and vice versa.

The Importance of Testing Products Using Official Test Protocols:

The emission testing of candidate retrofit products and alternative fuels or lubricants almost always involves comparison testing with and without the product installed or used in a selected (and representative) engine. Since so much previous data that is ultimately used for comparison has been obtained by official testing protocols it significantly enhances the credibility of new data obtained by the same protocol and testing procedures.   Previous data obtained by special procedures is usually not considered very seriously by government agencies who will ultimately be certifying or verifying the new product emission reduction performance. Furthermore, when data are obtained by official testing protocols at reputable and appropriately recognized labs, government agencies are more likely to accept the data as part of a subsequent verification objective for the client. Often data not obtained by official test protocols can provide misleading results since so many variables can affect the ultimate product performance. Also, such data may be influenced by improper consideration of important variables. For example, because a product in normal use creates more power or reduces visible smoke does not mean that it will subsequently reduce the engine exhaust emissions. All comparison testing for candidate retrofit products is measured over exactly the same speed and load conditions as the baseline data without the product. This may result in better fuel economy or other benefits with use of the product, but not necessarily reduced emissions, and as mentioned earlier, no credit is given for fuel economy improvements.

Use of the Proper Testing Protocol:

For comparison testing with and without the product the client should always select the test protocol that is used to officially certify or verify engines in the client's target market. What works on heavy-duty engines may be worthless for automobiles or small engines and vice versa. In any event, the testing protocols are entirely different and the required emission standards are different for different applications. If the client is conducting emission testing to certify new engines then he has no option except to test by the official test protocol for that engine application.

The Statistical Basis for Comparative Differences:

As in all experimental work it is important to know the statistical significance of absolute measurements and differences in comparative measurements for engine emission work. EPA, TCEQ and CARB all expect data to be analyzed with 95% confidence levels. Accordingly, it is pertinent to design the testing experiment with enough replication to assure the expected differences caused by the product are real at the 95% confidence level. This can result in a very large number of tests if the expected differences are small. For example, EPA and CARB may require a minimum of 42 transient cycle tests when testing alternative fuel configurations since differences of 2-5% are typical (21 tests with the baseline and 21 tests with the alternative fuel). This testing expense alone can cost in excess of $150,000. CARB specifies at least 85% reduction in PM as the minimum effectiveness for on-road retrofit verification testing and since this is a much larger number they only require the average of triplicate data sets for the baseline and again for the product testing. Triplicate data sets are considered to be the bare minimum number of tests to average for practically any emission testing.

A single emission comparison test can usually be expected to repeat within +/- 5%. The average of triplicate tests can be expected to be within +/- 2% (sometimes better). In a gross sense if the product is not expected to demonstrate at least 5% improvement in any emission variable the experiment design will require a significantly larger number of tests. Of course if 25% or more improvement is expected from the product, triplicate data comparisons to the baseline fuel will likely be adequate at the 95% confidence level.

Costs and Time Schedule:

Emission testing expenses include several factors. For engine testing on engine dynamometers there is an engine installation and set-up charge, usually on the order of $3,500 plus the basic engine cost. Transient cycle emission tests cost $3,500-$4,500 each and the final engineering report costs on the order of $1,000. The total cost for one evaluation then is on the order of $25,000-$30,000 for transient cycle comparative testing using triplicate data sets with a client supplied engine. Steady-state engine dynamometer testing (for off-road engine applications) is about 10% less. A typical time schedule once an engine is installed is about one week of testing for either transient cycle testing or steady-state testing. The scheduling problem is more difficult since often the backlog is two to three months after receipt of the required advance payment.

For chassis dynamometer testing the cost is considerably less and the work can usually be scheduled to start within a few days. A typical comparative test project using triplicate tests with and without the product can be done within a couple of days using a client supplied test vehicle for a cost on the order of $10,000 complete. However, the same considerations for data accuracy and numbers of replicate tests apply as in engine dynamometer testing.

Certification testing of new engine models or new vehicles involves the requirement to accumulate hours of durability testing in addition to several emission tests per model. This work ranges in price from $12,000 to $30,000 per model depending on engine size and other EPA/CARB specified requirements. Often this program can require several weeks for completion once the new model engines have been received.

Miscellaneous Considerations:

There are a variety of factors as summarized above that should dictate the test design for a most cost-effective emission testing program. The first consideration should be identification of the optimum market focus for the particular product of interest since there are so many different protocols with a wide range in testing costs. Secondly, there should be a good technical understanding of why the product can be effective in reducing engine emissions with no deleterious effects. And finally, there needs to be a conscientious business plan justifying the emission testing expense.

Olson-EcoLogic has tested dozens of devices and other emission reduction solutions over the years and despite some incredible client claims based on “other testing” and a variety of strange beliefs most products don’t work anywhere near the level represented. In fact less than 10% of the devices provide any benefit whatsoever. This low success ratio is caused by ignoring one or all three of the above considerations.

Olson-EcoLogic is an independent testing lab. We do the emission testing of client’s products, but we do not do any product development or provide any recommendations for effective emission control systems. We strongly recommend that any product ultimately intended for acceptance by EPA, CARB, TCEQ or any government agency begin by having a conference with the respective agency and submitting a preliminary application for their consideration. These agencies will critique the product, describe the testing requirements and suggest appropriate labs for conducting the testing if such testing is justified.