Evaluation: LDTE-071-509

Xtreme Fuel Optimizer Fuel Catalyst Evaluation
For
Fuel Efficiency and Emissions Reductions In a Light Duty Diesel Engine
Utilizing
The Carbon Mass Balance Procedure

Final Report

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WHAT IS THE CARBON BALANCE TEST PROCEDURE?

PREFACE

Fuel consumption measurements by reliable and accredited methods have been under constant review for many years. The weight of engineering evidence and scientific theory favors the carbon balance method by which carbon measured in the engine exhaust gas is related to the carbon content of the fuel consumed. This method has certainly proven to be the most suitable for field-testing where minimizing vehicle down time is a factor.

The inquiries of accuracy and reliability to which we refer include discussions from international commonwealth and government agencies responsible for the test procedure discussed herein. This procedure enumerates the data required for fuel consumption measurements by the “carbon balance” or “exhaust gas analysis” method. The studies conducted show that the carbon balance has been found to be a more precise fuel consumption test method than the alternative volumetric-gravimetric methods.

The carbon balance test is a fundamental part of the Australian Standards **AS2077-1982**. Further, the carbon balance test procedure has proven to be an intricate part of the United States EPA, FTP and HFET Fuel Economy Tests. Also, Ford Motor Company characterized the carbon balance test procedure as being “at least as accurate as any other method of volumetric-gravimetric testing.” (**SAE Paper No. 750002 Bruce Simpson, Ford Motor Company**) Finally, the Carbon Balance procedure is incorporated in the Federal Register Voluntary Fuel Economy Labeling Program, Volume 39.

The following photographic report captures a few of the applicable steps necessary for conducting a reliable and accurate carbon balance test. As will be documented, every effort is made to insure that each test is consistent, repeatable, and precise. More importantly, it will be even clearer as to why the Carbon Balance Test has such a high degree of acceptance and reliability.

EXECUTIVE SUMMARY

The Xtreme Fuel Optimizer fuel catalyst manufactured and marketed by Xtreme Fuel Optimizer, has proven, in laboratory and field-testing, to reduce fuel consumption in the range 3% to 10% under comparable load conditions. It also has proven to significantly reduce carbon emissions.

Following discussions it was determined that a fuel consumption analysis should be conducted in a late model diesel fuelled vehicle, utilizing the Carbon Mass Balance test procedure. As such, a 2008 Dodge pickup with a 6.7 litre inline six cylinder engine was selected for the study. The pickup is equipped with a Diesel Particulate Filter (DPF) and a regeneration catalyst. As important, the new Cummins diesel was specifically selected for testing as a result of the added technology, which is required for compliance by all light duty diesel engine manufacturers to achieve the new 2010 diesel emissions standards. Most notably, the new technology consists of a diesel particulate filter (DPF) and regeneration catalyst. Of interest is the ability of the active ingredient in the catalyst to reduce exhaust soot levels, while at the same time reducing active and passive regeneration temperatures (See Dept. of Interior, Dept. of Mines Paper no. RI 9438, SAE paper no. 900154, Southwest Research paper Diesel Engine Emissions Control Technologies, appendix B, NIOSH paper no. 9462).

A baseline test (untreated) was conducted on May 7, 2009 using the Carbon Mass Balance test procedure. After which, the pre-selected test vehicle was then treated by adding the Xtreme Fuel Optimizer fuel catalyst to the mobile fuel tank via the use of a pre-measured 8 oz. catalyst filled bottle. On July 7, 2009, the test was then repeated (Xtreme Fuel Optimizer treated) following the same parameters. The results are contained within this report.

The data showed that the average improvement in fuel consumption, for the vehicle tested, was 4.6%**,** during steady state testing, using the Carbon Mass Balance test procedure.

The treated engine also demonstrated a large percentage reduction in soot particulates, in the range 22%, and reductions in harmful exhaust related carbon fractions. Carbon dioxide reductions, based upon the measured reduction in fuel consumption, are also substantial.

INTRODUCTION

Baseline (untreated) fuel efficiency tests were conducted with the test vehicle on May 7, 2009, employing the Carbon Mass Balance (CMB) test procedure. Xtreme Fuel Optimizer Global supplied sufficient product to correctly treat the mobile fuel tank, on the test vehicle, used for the purpose of this evaluation. The vehicle owner was then instructed as to the proper method for catalyst treatment and was allotted the necessary fuel catalyst based on fuel usage. The test vehicle was then operated on Xtreme Fuel Optimizer catalyst treated fuel for at least 4,000 miles of engine operation. At the end of the engine-conditioning period (July 7, 2009), the engine test was repeated, reproducing all engine parameters. The final results, along with the data sheets, are contained within this report.

TEST METHOD

Carbon Mass Balance (CMB) is a procedure whereby the mass of carbon in the exhaust is calculated as a measure of the fuel being burned. The elements measured in this test include the exhaust gas composition, its temperature, and the gas flow rate calculated from the differential pressure and exhaust stack cross sectional area. The CMB is central to the both US-EPA (FTP and HFET) and Australian engineering standard tests (AS2077-1982), although in field-testing we are unable to employ a chassis dynamometer. However, in the case of a stationary vehicle test, the engine can be loaded sufficiently to demonstrate fuel consumption trends and potential.

The Carbon Mass Balance formula and equations employed in calculating the carbon flow are a supplied, in part, by doctors' of Combustion Engineering at the university and scientific research facility level.

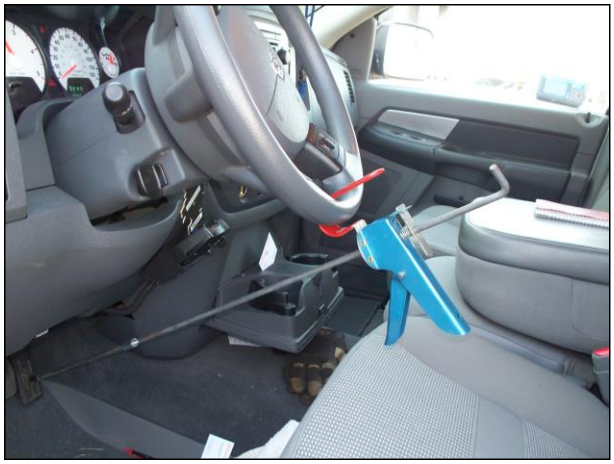
The Carbon Mass Balance test procedure follows a prescribed regimen, wherein every possible detail of engine operation is monitored to insure the accuracy of the test procedure. Cursory to performing the test, it is imperative to understand the type and quality of fuel utilized in the evaluation. As important, the quality of fuel must be consistent throughout the entirety of the process.

Fuel density and temperature tests are performed for both the baseline and treated segments of the evaluation to determine the energy content of the fuel. A Precision Hydrometer calibrated at .800 to .910, columnar flask and Raytek Minitemp were utilized to determine the fuel density for each prescribed segment of the evaluation.

Next, and essential to the Carbon Balance procedure, are test vehicles that are mechanically sound and free from defect. Careful consideration and thorough vehicle screening is utilized to verify the mechanical stability of each vehicle prior to testing. Preliminary data is scrutinized to disqualify any vehicle that may be mechanically suspect. Once the vehicle selection process is complete, the Carbon Balance test takes only 10 to 20 minutes, per unit, to perform.

Once the test unit has met the prescribed pre-mechanical parameters; pertinent engine criteria needs to be evaluated as the Carbon Mass Balance test proceeds.

When the selection process is complete, engine RPM is increased and locked in position. This allows the engine fluids, block temperature, and exhaust stream gasses to stabilize. Data cannot be collected when there is irregular fluctuation in engine RPM and exhaust constituent levels. Therefore, all engine operating conditions must be stable and consistent.



An after-market throttle position lock is utilized, as one method, to secure engine RPM. This provides a steady state condition in which consistent data can be collected. Should the engine RPM fluctuate erratically and uncontrollably, the test unit would be disqualified from further consideration.

Next**,** engine RPM and fluid temperatures are monitored throughout the Carbon Balance evaluation. As important, exhaust manifold temperatures are monitored to ensure that engine combustion is consistent in all cylinders. It is imperative that the engine achieve normal operating conditions before any testing begins.

Once engine fluid levels have reached normal operating conditions the Carbon Balance study may begin. The above photograph shows that the engine RPM is locked in place at 2000 r.p.m. It should be noted that any deviation in r.p.m., temperature, either fluid or exhaust, would cause this unit to be eliminated from the evaluation due to mechanical inconsistencies.

Once all of the mechanical criteria are met, data acquisition can commence; it is necessary to monitor the temperature and pressure of the exhaust stream. Carbon Balance data cannot be collected until the engine exhaust temperature has peaked. Exhaust temperature is monitored carefully for this reason.

Once the exhaust temperature has stabilized, the test unit has reached its peak operating temperature. Exhaust temperature is critical to the completion of a successful evaluation, since temperature changes identify changes in load and RPM. As previously discussed, RPM and load must remain constant during the Carbon Balance study.

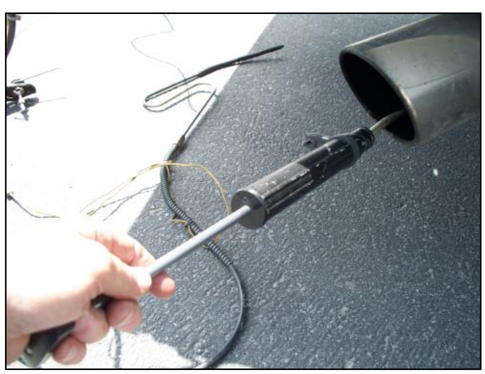
When all temperatures are stabilized, and peak operating parameters are achieved; it is time to insert the emissions sampling probe into the exhaust tip of each test vehicle utilized in the study group. The probe has a non-dispersive head, which allows for random exhaust sampling throughout the cross section of the exhaust.

While the emission-sampling probe is in place, and data is being collected, exhaust temperature and pressure are monitored throughout the entirety of the Carbon Balance procedure. This photograph shows the typical location of the exhaust emissions sampling probe.

While data is being collected, exhaust pressure is monitored, once again, as a tool to control load and RPM fluctuations. Exhaust pressure is proportional to load. Therefore, as one increases, or decreases, so in turn does the other. The Carbon Balance test is unique in that all parameters that have a dramatic affect on fuel consumption, in a volumetric test, are controlled and monitored throughout the entire evaluation. This ensures the accuracy of the data being collected. Exhaust pressure is nothing more than an accumulation of combustion events that are distributed through the exhaust matrix.

The above photograph identifies one method in which exhaust pressure can be monitored during the Carbon Balance test procedure. In this case, exhaust pressure is ascertained through the use of a Magnahelic gauge. This type of stringent regime further documents the inherent accuracy of the Carbon Balance test.

At the conclusion of the Carbon Balance test, a soot particulate test is performed to determine the engine exhaust particulate level. This valuable procedure helps to determine the soot particulate content in the exhaust stream. Soot particulates are the most obvious and compelling sign of pollution. Any attempt to reduce soot particulates places all industry in a favorable position with environmental policy and the general public.



The aforementioned photograph demonstrates a typical method in which soot particulate volume is monitored during the Carbon Balance test. This method is the Bacharach Smoke Spot test. It is extremely accurate, portable, and repeatable. It is a valuable tool in smoke spot testing when comparing baseline (untreated) exhaust to catalyst treated exhaust.

Finally, the data being recorded is collected through a non-dispersive, infrared analyzer. Equipment such as this is EPA approved and CFR 40 rated. This analyzer has a high degree of accuracy, and repeatability. It is central to the Carbon Balance procedure in that it identifies baseline carbon and oxygen levels, relative to their change with catalyst treated fuel, in the exhaust stream. The data accumulated is exact, as long as the criteria leading up to the accumulation of data is exact. For this reason, the Carbon Balance test is superior to any other test method utilized. It eliminates a multitude of variables that can adversely affect the outcome and reliability of any fuel consumption evaluation.

The above photograph identifies one type of analyzer used to perform the Carbon Balance test. The analyzer is calibrated with known reference gases before the baseline and treated test segments begin. The data collected from this analyzer is then computed and compared to the carbon contained within the raw fuel. A fuel consumption performance factor is then calculated from the data. The baseline performance factor is compared with the catalyst treated performance factor. The difference between the two performance factors identifies the change in fuel consumption during the Carbon Balance test procedure.

Essential to performing the aforementioned test procedure is the method in which the task for dosing the gasoline is performed. It is critical to the success of the Carbon Mass Balance procedure to insure that the vehicles evaluated be given meticulous care and consideration to advance the process of testing.

INSTRUMENTATION

Precision state of the art instrumentation was used to measure the concentrations of carbon containing gases in the exhaust stream, and other factors related to fuel consumption and engine performance. The instruments and their purpose are listed below:

Measurement of exhaust gas constituents HC, CO, CO_2 and O_2, by Horiba Mexa Series, four gas infrared analyser.

Note: The Horiba MEXA emissions analyser is calibrated with the same reference gas for both the baseline and treated segments of the evaluation. In this case, a Scott specialty mother gas no. CYL#ALM018709 was utilized for calibration purposes.

Temperature measurement; by Fluke Model 52K/J digital thermometer.

Exhaust differential pressure by Dwyer Magnahelic.

Ambient pressure determination by use of Brunton ADC altimeter/barometer.

The exhaust soot particulates are also measured during this test program.

Exhaust gas sample evaluation of particulate by use of a Bacharach True Spot smoke meter.

The Horiba infrared gas analyser was serviced and calibrated prior to each series of CMB engine efficiency tests.

TEST RESULTS

Fuel Efficiency

A summary of the CMB fuel efficiency results achieved in this test program are provided in the following tables and appendices. **See Table I, and Individual Carbon Mass Balance results, in Appendix II.**

Table I: provides the final fuel consumption results for the test vehicle selected for this evaluation, before and after Xtreme Fuel Optimizer fuel catalyst treatment **(see Graph II, Appendix I)**.

TABLE I

Test Segment	Miles	Fuel Change
2008 Dodge 2500 Pickup		
Treated	4,115	**- 4.6%**

The computer printouts of the calculated CMB test results are located in **Appendix II.** The raw engine data sheets used to calculate the CMB are contained in **Appendix III**. The raw data sheets and carbon balance sheets include and account for the environmental and ambient conditions during the evaluation.

Soot Particulate Tests

Concurrent with CMB data extraction, soot particulate measurements were conducted. The results of these tests are summarized in **Table II**. Reductions in soot particulates are the most apparent and immediate. Laboratory testing indicates that carbon and solid particulate reductions occur before observed fuel reductions. Studies show that a minimum 2,000 to 3,000 miles, Xtreme Fuel Optimizer fuel catalyst treated engine operation, are necessary before the conditioning period is complete. Then, and only then, will fuel consumption improvements be observed.

Table II

Fuel Type Diesel **Density** .848 Specific Gravity	**Soot Particulates**
2008 Dodge 2500 Pickup	
Untreated	.27 mg/m^3
Treated	.21 mg/m^3
	- 22%

The reduction in soot particulate density (the mass of the smoke particles) was reduced by an average 22**%** after fuel treatment and engine conditioning with Xtreme Fuel Optimizer fuel catalyst **(See Graph 1, Appendix I).** Concentration levels were provided by Bacharach.

Conclusion

These carefully controlled engineering standard test procedures conducted on this 2008 Dodge pickup; provide clear evidence of reduced fuel consumption in the range of 4.6%**.** In general, improvements utilizing the Carbon Mass Balance test, under static test conditions, generate results 2% - 3% (percentage points) less than those results generated with an applied load.

Xtreme Fuel Optimizer fuel catalyst's effect on improved combustion is also evidenced by a significant reduction in soot particulates (smoke) in the range of 22% **(see Appendix I)**. Soot reductions are significant in light of the implementation of diesel particulate filters (DPF's) and soot regeneration units in general. Similar reductions in other harmful carbon emissions likewise substantiate the improved combustion created by the use of Xtreme Fuel Optimizer fuel combustion catalyst **(see raw data sheets, Appendix III)**.

Additional to the fuel economy benefits measured and a reduction in soot particulates, a significant reduction, over time, in engine maintenance costs will be realized following treatment with Xtreme Fuel Optimizer. These savings are achieved through lower soot levels in the engine lubricating oil, which is a result of more complete combustion of the fuel. Engine wear rates are reduced resulting in less carbon build-up in the combustion area. Xtreme Fuel Optimizer also acts as an effective biocide in the event of water contamination or water bottoms in fuel storage tanks; and, an excellent fuel system lubricant, which improves fuel system lubrication with today's low sulphur diesel fuels.