Class 8 Truck Fuel Consumption Analysis Using ARCHOIL AR6200 Fuel Modifier Complex and the Carbon Mass Balance Test Procedure

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1. CARBON MASS BALANCE TEST PROCEDURE – INTRODUCTION

The Carbon Mass Balance test procedure is a highly reliable method of testing, which first identifies the carbon chain length of the fuel being consumed and secondly, compares that data with the carbon fraction emitted via the exhaust port, or outlet, of the equipment being evaluated. The Carbon Mass Balance invokes the understanding and laws of thermodynamics, wherein it is understood that energy can neither be created nor destroyed. Understanding this mathematical model helps one to more clearly identify and process the scope of the procedure. In essence, any carbon fuel type introduced to the fuel cell must exit or be emitted through the exhaust port. The carbon is constant. The oxidation rate and level is obviously altered due to thermal combustion conditioning, loading and expansion (introduction of air and pressure).

The Carbon Mass Balance is accepted worldwide, throughout the engineering field. Professional papers have been written documenting the positive attributes of the process, while scores of governmental agency test procedures have included the Carbon Mass Balance as an intricate part of their established evaluations. Expanded to a field test procedure, the Carbon Mass Balance uses the engine operational dynamics to simulate a dynamometer. Although an actual engine load cannot be incorporated into many field trials, the engine dynamics offer a very reliable indicator as to current combustion trends and efficiency changes.

2. ABSTRACT

This document will discuss one very important aspect of fuel combustion in an internal combustion engine. It will document one significant area of potential cost reduction wherein operators of various diesel fleets introduce a chemical fuel catalyst to improve the combustion of the diesel fuel. Included in this document is the evaluation of a fuel catalyst provided by ARCHOIL INC., which is used in carbon fuels and will hereafter be referred to as AR6200 Fuel Modifier Complex.

The ever increasing costs of diesel fuel, the increasing cost of engine overhauls, and the high expenses involved in mobile equipment downtime are having a major influence on diesel fleet operations. Since expenses relating to these areas are accounting for an increasingly larger share of fleet operational budgets it follows that any significant improvement can have a substantial impact upon the bottom line of fleet operational costs.

This document will explore the effects identified under field conditions when an iron based (Ferrocene) fuel catalyst (AR6200) is introduced into diesel fuel in an effort to attain an improvement in combustion of the fuel. As part of, and included in, this field test were two (2) 2007 Peterbilt trucks equipped with C-13 Caterpillar diesel engines. Both were properly maintained and underwent general preventative maintenance procedures prior to both test periods included in this evaluation.

It is recognized that field studies relating to an assessment of fuel economy under actual operational conditions lack the precision of the controlled laboratory environment. This is particularly true when off-the-road mobile equipment is being considered. However, measurement of engine fuel consumption under these controlled conditions is more consistent and relative when compared to the same process using volumetric testing measures. The problem of fuel economy measurement can be compounded by fleet operational conditions which may include the absence of metered fuel control into equipment, fluctuating workloads and engine operating conditions, inconsistent weather and ground conditions, inconsistent mechanical conditions and much more.

The raw fuel (untreated) test segment and AR6200 treated fuel periods of the evaluation, were conducted on June 23, 2010 and August 5, 2010, respectively. The individual drivers were instructed in the process to treat the fuel tanks on their own trucks, with the catalyst, at a ratio of 1:10,000 with the addition of fuel during each fuel stop.

The accumulated emissions data, which identified consistent reductions in general emissions of $C0_2$, C0 and HC did coincide with a general reduction in fuel usage of 8.1%. Further documentation identifies consistent reductions in particulate solids.

3. TEST METHOD

The Carbon Mass Balance looks at carbon in its aqueous (liquid), solid (particulates) and gaseous (HC, C0, $C0_2$) forms. Since carbon can only be changed in form, not created or destroyed, it is important to understand and note the changes in the carbon, in their entirety, while performing the Carbon Mass Balance.

It is well understood that all of the fuel contained in the fuel tank on a truck with a spark or compression ignition system, is emitted through the exhaust. In essence, the liquid carbon is chemically oxidized and emitted in either a solid or gaseous form. By testing the fuel in a liquid form (fuel density) prior to Carbon Mass Balance testing, it allows one to understand the fuel quality and potential energy (BTU). For instance, If the fuel density was determined to be a 0.78 by weight, then the carbon chain length of the fuel would equate to C_8H_{15}. This is critical in that all fuels are not created equal. Any deviation in the carbon chain (C_8H_{15}) length has a direct affect on BTU and fuel/engine performance.

It's important to understand that the first law of Thermodynamics underscores the importance of this by clearly stating that for a thermodynamic cycle, the net heat supplied by the system equals the net work done by the system. Further, current over-the-road diesel fuel specifications range from approximately .810 to a .860 in density. This equates to nearly a 12% potential change in fuel energy from tank to tank. So, if fuel density or specific gravity changes (fuel quality), then net heat supplied to the system changes, which ultimately affects net work. This is why fuel consumption is always in a state of change, randomly cycling up and down in all fleets around the world.

If it were not the case, then all like trucks would manifest the same fuel consumption and power, provided time and load were constant.

Finally, since carbon cannot be created nor destroyed, the once aqueous (liquid fuel) carbon now emitted in an oxidized state from the exhaust in either a solid or gaseous carbon form is monitored via the exhaust at a specific load and RPM. By clearly identifying a specific load and engine speed, common carbon exhaust constituents can be more readily compared during an A – B type test procedure (A=baseline, B=treated). During the emissions test of the Carbon Mass Balance, carbon emissions levels are tested to determine solid and gaseous fuel flow (the same as measuring the fuel flow to the engine) to determine carbon oxidation changes or volumetric carbon changes between the baseline and treated segments of the Carbon Mass Balance.

Fundamentals of the First Law of Thermodynamics suggest that for a thermodynamic cycle, the net heat supplied by the system equals the net work done by the system. In situations where a fuel catalyst is used, or fuel type/quality is inconsistent from load to load, net heat supplied is affected, which will ultimately increase or decrease net work. This data is easily identified when performing the Carbon Mass Balance . Understanding the type of fuel (fuel density or specific gravity) used in the test helps to identify fuel changes relative to a fuel type/quality, or a specific application augmentation (addition of a fuel catalyst) to the fuel.

Next, non-boundary testing conditions that adversely produce significant placebo improvements or reductions in fuel economy such as fuel quality and conditions, driver or driving conditions, tire pressure or load conditions, speed or time conditions, high idle conditions, etc., etc., etc., do adversely affect volumetric fuel tests, but have no impact on the integrity of the Carbon Mass Balance. This test procedure was designed to remove variables from testing processes and has now been incorporated into numerous processes for energy measurement. In many cases, the net energy from charcoal briquettes is measured via the Carbon Mass Balance as a means to determine product quality.

In conclusion, the Carbon Mass Balance looks at only the fuel consumed during the specific load being tested (baseline vs. treated). All fuel goes through the exhaust and will be identified as a solid or oxidized form. The quantity of the carbon in the exhaust, as it relates to the quality of the fuel in the fuel tank is what identifies the fuel consumption improvement from test segment to test segment (baseline vs. treated). Hence, the name Carbon Mass Balance. To perform a successful Carbon Mass Balance the following test equipment criteria must be met:

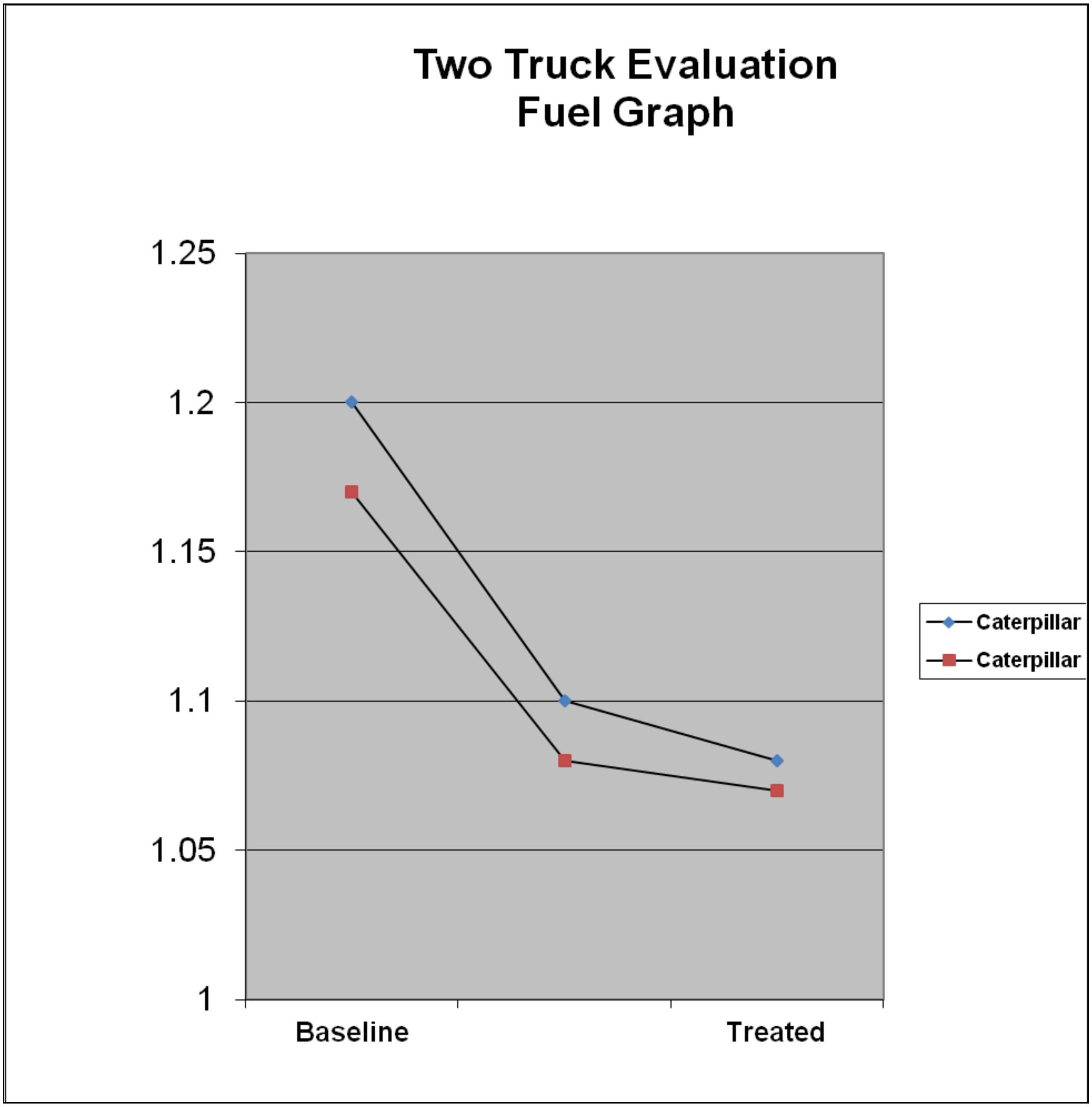
- Test equipment must be in sound mechanical condition. To perform this evaluation, two (2), 2007 Peterbilt trucks were selected with similar power systems (see Section 2 Abstract).
- Select at least 10% of fleet for the Carbon Mass Balance, for fleets under 40 total units of equipment (4 test units). All other larger fleets, select at least 5 test units, or whatever number of test units the customer is comfortable with.
- Record equipment miles or hours (both, if possible). Select test equipment with mid to low-range miles/hours for testing. Examples - Over-the-road trucks: at least 100,000 miles. Light automotive: at least 50,000 miles. Off-road equipment: at least 1,000 hours.
- Instrumentation that is gas calibrated before each test segment which is accurate, reliable and manifests a low repeatability deviation.
- Air filter must be clean and operable and uncontaminated (test duration).
- Test fuel density (specific gravity).
- Engine must be at operating temperature for test (dash gauges).
- Engine RPM must be identical for both baseline and treated test segments. Identify if the test equipment has a tachometer or if selected test units are not equipped with a tachometer. An external magnetic tachometer must be used.
- Check exhaust manifold temperature to verify “uniform” engine combustion.
- Onsite dedicated fuel tank for catalyst treated fuel, or a responsible party/employee validating catalyst treatment with each fill up.
- Other specific inclusions for the process of performing the Carbon Mass Balance are necessary as they relate to each individual test procedure.

4. TEST RESULTS

4.1 Fuel Efficiency Utilizing the Carbon Mass Balance

Carbon Mass Balance fuel efficiency results are provided in the Conclusion section of this report and is further documented in Figure 1. Figure 1 (below), compares the results of the initial (baseline) fuel consumption data against the AR6200 treated fuel consumption data compiled roughly 3 months later.

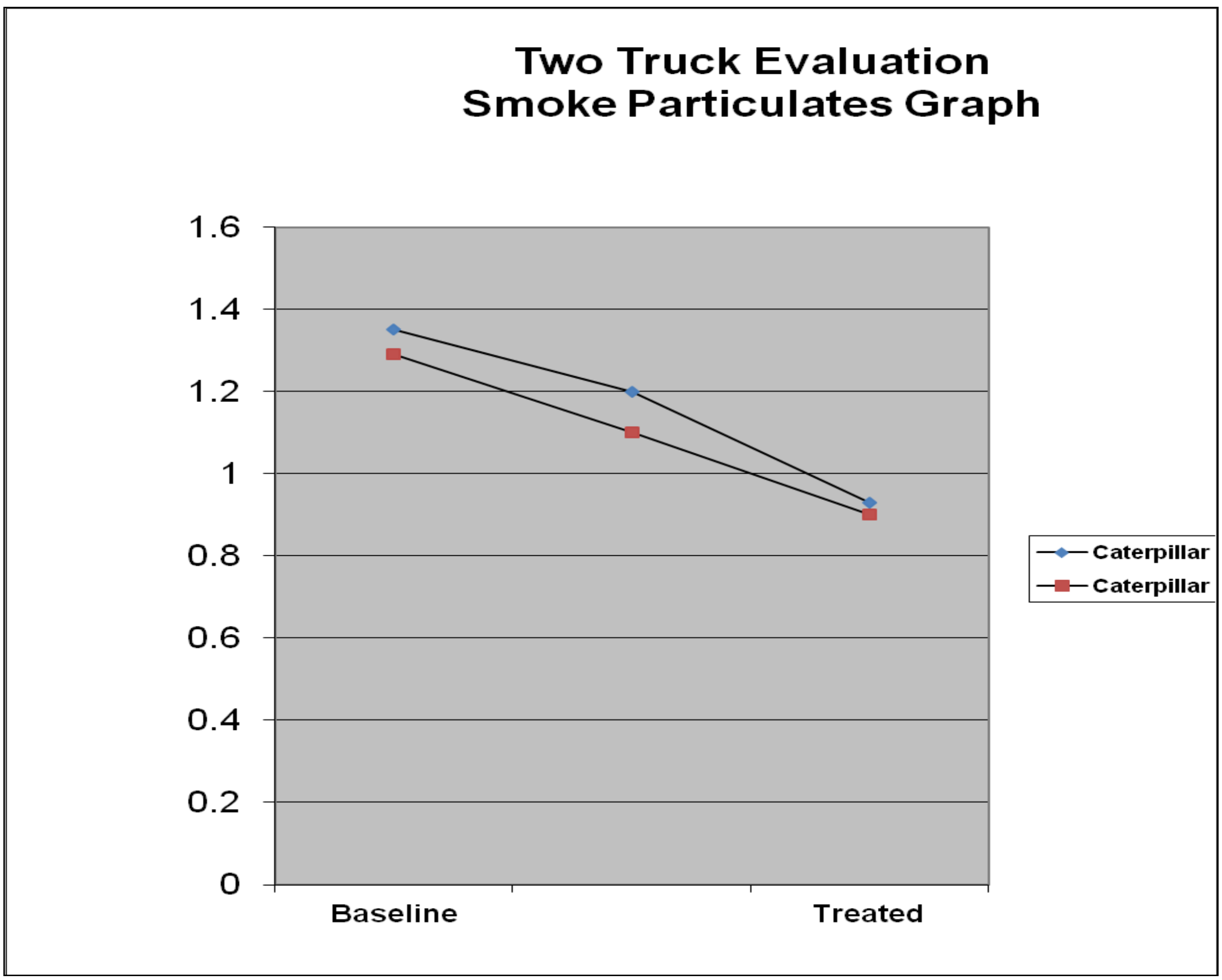
Figure 1: Fuel Analysis (Carbon Mass Balance) expressed in grams per second.



4.2 Soot Particulate Tests

Concurrent with Carbon Mass Balance data extraction, smoke particulate measurements were conducted. The results of these tests are summarized in Figure 2 below. Generally, soot particulate reductions manifest a combustion related improvement, with the catalyst, prior to any conclusive fuel consumption changes. Reductions in soot particulates are the most apparent and immediate indicator of improved carbon emissions.

Figure 2: Smoke Particulate Graph expressed in (mg/m^3).



The reduction in soot particulate density (the mass of smoke particles) was reduced by an average 29% after fuel treatment and engine conditioning with the AR6200 Fuel Modifier Complex.

5. CONCLUSIONS

The Carbon Mass Balance procedure conducted utilizing the two (2), 2007 Peterbilt trucks manifested the following improvements with the AR6200 Fuel Modifier Complex:

- Reduced fuel consumption in the range of 8.1%.
- Reduced soot particulates in the range of 29%.
- Reduced emissions aggregate in the range of 25%.