Program for Advanced Vehicle Evaluation

PAVE

at AUBURN UNIVERSITY

1600 Lee Road 151
Opelika, AL 36804
www.pavetrack.com
334-844-6857

Report on

SAE J1321 (TMC RP-1102)
Type II Fuel Consumption Test

Conducted for

SPP
236 Rowan St.
Salem, VA 24153

September 10, 2010

Prepared by:

R. Buzz Powell, PhD, PE
Research Engineer

Bob Rosenthal
Technical Consultant

ABSTRACT

The Program for Advanced Vehicle Evaluation (PAVE) was established at Auburn University as a complementary research program at the National Center for Asphalt Technology's (NCAT) Pavement Test Track (www.pavetrack.com). In order to damage experimental pavements on the 1.7-mile test oval, it is necessary to run a fleet of heavy trucks over ¾ million miles a year. Trucking operations at the Track provide a unique opportunity to study issues that are important to the trucking industry in a highly controlled and cost effective manner. The purpose of the series of tests described herein was to determine the impact of the I-PHI (Partial Hydrogen Injection) product on fuel economy when used in the 14L diesel engine of class 8 tractors.

In these comparisons, two treatment tractors (each with a different test hardware setting) and one control tractor were used in two separate mileage based evaluations. The test plan for the two evaluations each included a baseline segment and two different test segments. Treatment data was collected after approximately 8000 conditioning miles, then again after approximately 23,000 conditioning miles.

The "Type II Test Procedure" published by both the Technology and Maintenance Council (TMC) and the Society for Automotive Engineers (SAE) was used to perform these evaluations (RP-1102 and J1321, respectively). The longer 40-mile minimum run distance required in the SAE version was used in order to be in strict conformance with both test procedures. All test runs were executed on the NCAT Pavement Test Track in Opelika, Alabama between June 15th and August 11th in 2010. The gross combined weight (GCW) of the tractor-trailers used for the evaluations was approximately 155,000 pounds. All three trucks (one control vehicle and two treatment vehicles) were run at a target speed of between 45 and 48 mph with the tractors in direct gear (1:1 ratio) and with a demand wheel horsepower of 200 to 350 horsepower.

During testing, fuel consumption was measured in 17-gallon portable weigh tanks. The calibration of the weigh scale was checked before and after each stage of testing. The measured specific gravity of the #2 diesel fuel used for testing was 0.840 at 60°F. The same drivers remained with the control vehicle and both test vehicles for the duration of testing. The cooling system fans on all three trucks were locked in the on position during all phases of testing to eliminate the fan as a possible confounding variable.

No vehicle or operational issues were encountered during any phase of testing. The wind was calm with a maximum gust of 12 mph. Ambient air temperature conditions ranged from 80° to 95° F. Wheel hub temperatures were monitored throughout testing. The valid treatment-to-control (T/C) ratios for fuel usage for all runs in both the baseline and treatment segments ranged from 0.5% to 1.7%, with the typical range being less than 1%. This is well inside the 2% filter, which is indicative of a highly controlled test. The following results were observed in the four evaluations:

Test #	Hardware Setting	Tractor #	Mileage	% Improvement
10-8	A	1	8071	+ 0.6
10-8	A	1	22,915	+ 4.4
10-7	B	3	8554	- 0.2
10-7	B	3	24,053	+ 3.2

With the accumulation of extended miles, it was necessary to change 26 tires on the control vehicle, 22 tires on treatment vehicle #1, and 15 tires on treatment vehicle #3. Other repaired components during the extended mileage accumulation included the replacement of seals on an air tank, charging one air conditioner, rebuilding one air compressor, and replacing sensors on the I-PHI hardware. These types of repairs were expected at the outset of this evaluation and are not considered to have a major impact on the results.

The two tractors equipped with the I-PHI product showed no improvement in fuel economy after the initial 8000-mile evaluation, but did show an improvement of + 3.2% and + 4.4% (depending on the hardware setting of the test device) after the second evaluation at approximately 23,000 miles.

TABLE OF CONTENTS

INTRODUCTION

Recent historical increases in the cost of diesel fuel have resulted in an unprecedented interest in products that have the potential to improve fuel economy. At the request of SPP, the PAVE research program at Auburn University recently conducted a fuel economy test. The purpose of the testing program described herein was to determine the impact of the I-PHI (Partial Hydrogen Injection) product on fuel economy, by consecutively running two treatment tractors (each with a different test hardware setting) and one control tractor, in two separate mileage based evaluations.

The procedure chosen for this evaluation was *Joint TMC/SAE Fuel Consumption Test Procedure – Type II*, also known as SAE's J1321 and TMC's RP 1102. This procedure was developed specifically to meet the needs of the trucking industry, and it is an integral part of TMC's *Guidelines for Qualifying Products Claiming a Fuel Economy Benefit* (RP 1115).

TEST PROCEDURE

Vehicle Identification

The control and treatment tractors used in this evaluation were part of the Pavement Test Track's operational fleet. The control tractor was a 2006 Sterling LT9500 day cab with no aerodynamic modifications, an odometer reading of approximately 115,000 miles, and pre-2007 emissions systems. Both the treatment tractors were 2004 Freightliner Columbia Series Model C120 day cabs with no aerodynamic modifications and odometer readings of approximately 750,000 miles. All three units were equipped with Detroit Diesel 60 Series DDEC-IV (EGR) engines rated at 435 hp at 2,100 rpm. All three units were in good mechanical condition and were equipped with Eaton Fuller 9-speed manual transmissions and cruise control, which produced approximately 1500 - 1580 rpm at cruise speeds. A full tractor-trailer unit is shown in Figure 1 in operation on the Pavement Test Track at the National Center for Asphalt Technology (NCAT) during a warm-up period.

Figure 1 – Truck Configuration Used During the Testing Process

All fuel used was off-road (non-taxed) ultra low sulfur #2 diesel from a single source. At the time of testing, the specific gravity of the diesel fuel was 0.825 @ 88° F corrected to 0.840 @ 60° F. Any accessories that would have pulled auxiliary power were used in an identical manner in each tractor during all stages of Type II testing. Cooling fans were locked in the on position for the duration of testing. Mirrors and windows were maintained in the same position at all times. Before the warm-up period, cold tire pressure was set at 110 psi in the steer tires and 100 psi in all other positions. The trailer combinations were loaded with sheet steel, giving the tractor-trailer configurations a gross combined weight (GCW) of 155,000 pounds.

Test Route

As seen in Figure 2, the test route consisted of a 1.7-mile closed loop oval adjacent to a research staging area. The Pavement Test Track at Auburn University is a controlled-access facility on which a fleet of five heavy triple trucks each run over 3,000 miles a week in order to damage experimental pavements. Interest in the Track is not limited to pavements, and the operation of the heavy truck fleet on the closed loop oval provides an excellent opportunity to study the effect of various treatments on fuel economy.

Figure 2 – Auburn University Track Used for Type II Test Route

The due east-west straight sections on the Auburn track are precisely 2600 feet long, connected with spiral-curve-spiral sections approximately 1900 feet in length. The engine load factor for the straight sections is approximately 50 percent at an approximate wheel horsepower of 200. The east curve profile travels down a –0.5 percent grade with less than a 10 percent engine load factor. The west curve profile travels up a +0.5 percent grade with a 100 percent engine load factor at an approximate wheel horse power of 350-380. This power demand is very similar to that of a standard class 8 tractor on the interstate with a GCW of 80,000 pounds. The maximum side slope (i.e., super elevation) of both curves is 15 percent, which supports a design speed of approximately 46½ mph.

Research Methodology

A work plan was developed based upon the *Joint TMC/SAE Fuel Consumption Test Procedure – Type II* methodology (RP-1102 and J1321, respectively). In this procedure, fuel consumption measurements in each test vehicle were compared to measurements from a control vehicle before and after treatment. The difference between the before and after treatment-to-control (T/C) ratios were used to calculate a fuel savings percentage presumably resulting from the treatment. For the purpose of this study, a test run was defined as at least 40 miles of continuous driving in order to be in strict conformance with both test procedures.

Vehicle operation was synchronized using handheld radios and digital stopwatches to ensure precisely identical duty cycles. The same drivers remained with both the control vehicle and the treatment vehicles for the duration of testing. Both trucks were outfitted with 17-gallon portable weigh tanks that accommodated one test run on a single fill (shown in Figure 3). During testing, fuel consumption was calculated by measuring the weight of fuel consumed after each run. An Ohaus Champ II Model CH300R digital scale with a 650-pound capacity was used. Scale calibration was checked before and after each stage of testing. The weighing process is shown in Figure 4. The T/C ratios for all test runs were calculated, and the first 3 ratios that fell within the prescribed 2 percent filtering band were used to compute an average value representing each segment of testing.

Figure 3 – Portable Fuel Tank

Figure 4 – Weighing of Portable Fuel Tank

The T/C ratios were used to qualify runs as either valid or invalid. The T/C ratios for valid test runs must pass through a 2 percent filter (i.e., the difference between the highest and lowest values cannot exceed 2 percent) in order to be included in fuel economy improvement computations. The first 3 points that fall within the 2 percent window form the basis of a valid test.

Test Data

Testing began on June 15, 2010, and was completed on August 11, 2010. Temperatures during most valid test runs were between 80°F and 95°F. No precipitation occurred during the test segments, and wind speeds were generally less than 12 mph.

Four different evaluations were included in this series of tests. In the first two evaluations, treatment data for hardware setting A (Figure 5) was collected after the accumulation of miles for each conditioning period. In the last two evaluations, treatment data for hardware setting B was collected after the accumulation of miles for each conditioning period. All raw experimental data collected in the field during the testing process are provided in Table 1.

Figure 5 – Addition of I-PHI product to Test Truck

Run Date	Test Segment	40-mile Test Runs	$Fuel_T$ (lbs)	$Fuel_C$ (lbs)	Run Date	Test Segment	40-mile Test Runs	$Fuel_T$ (lbs)	$Fuel_C$ (lbs)
6/15/2010	Baseline A	1	66	70.5	6/15/5010	Baseline B	1	65.1	70.5
		2	66	71.2			2	66	71.2
		3	67.9	72.3			3	67	72.3
		4	68.4	735			4	68.1	73.5
7/6/2010	Test 10-8A	1	65.3	70.5	1/20/2010	Test 10-7B	1	65.2	70.5
		2	65.3	70.2			2	65.1	70.2
		3	65.9	71			3	66.1	71
8/11/2010	Test 10-8A	1	68.1	76.9	8/11/2010	Test 10-7B	1	69	76.9
		2	67.7	75.6			2	67.6	75.6
		3	71.1	75.8			3	68.4	75.8
		4	68	75.5			4	67.7	75.5

Table 1 – Type II Test Raw Data

Conditioning mileages prior to test segments were as follows:

- Test 10-8A: 8071 miles
- Test 10-8A: 22,915 miles
- Test 10-7B: 8554 miles
- Test 10-7B: 24,053 miles

During the baseline and test segments of qualified runs, no operational or vehicle issues (e.g., check engine lights) were encountered. Rolling times were within the specified range, and road speed averaged 45 mph. Wheel hub temperatures were monitored throughout each test.

With the accumulation of extended miles, it was necessary to change 26 tires on the control vehicle, 22 tires on treatment vehicle #1, and 15 tires on treatment vehicle #3. Other repaired components during the extended mileage accumulation included the replacement of seals on an air tank, charging one air conditioner, rebuilding one air compressor, and replacing sensors on the I-PHI hardware. These types of repairs were expected at the outset of this evaluation and are not considered to have a major impact on the results.

Calculations

The first three runs of the baseline and test segments that passed through the 2 percent band and met the requirements of the test procedure were used to compute fuel savings (in accordance with the test procedure). As shown in Table 2, the third segment of Test 10-8A did not meet the requirement that T/C values fall within a 2 percent band. This measurement was not used for fuel economy calculations as specified in the test procedure. Further investigation indicated the cause of this anomalous data point was likely an erroneous fuel measurement. Using the first three valid runs, it was determined that the addition of the I-PHI product in the first two evaluations (Test 10-8A) showed an improvement of 0.6 percent and 4.4 percent in fuel economy. In the last two evaluations (Test 10-7B), the addition of the I-PHI product showed an improvement of -0.2 percent and 3.2 percent in fuel economy. The valid T/C ratios for all runs, in both the Baseline and Test Segments, fell within a statistical window of 0.5 percent to 1.7 percent (well within the allowed 2 percent range).

Run Date	Test Segment	40-mile Test Runs	Fuel T (lbs)	Fuel C (lbs)	T/C (All)	T/C (Band)	T/C (Filt)	T/C (Avg)	T/C (% Improved)
6/15/2010	Baseline A	1	66	70.5	0.9234	x	0.9362		
		2	66	71.1	0.9270	x	0.9283		
		3	67.9	72.3	0.9267	x	0.9391		
		4	68.4	73.5	0.9265	x	0.9306	0.9336	Baseline
7/6/2010	Test 10-8A	1	65.2	70.5	0.9248	x	0.9248		
		2	65.1	70.2	0.9274	x	0.9274		
		3	66.1	71	0.9310	x	0.9310	0.9277	0.63%
8/11/2010	Test 10-8A	1	68.1	76.9	0.8856	x	0.8856		
		2	67.7	75.6	0.8955	x	0.8955		
		3	71.1	75.8	0.9380				
		4	68	75.5	0.9007	x	0.9007	0.8939	4.43%

Run Date	Test Segment	40-mile Test Runs	Fuel T (lbs)	Fuel C (lbs)	T/C (All)	T/C (Band)	T/C (Filt)	T/C (Avg)	T/C (% Improved)
6/15/2010	Baseline B	1	65.1	70.5	0.9362	x	0.9234		
		2	66	71.1	0.9270	x	0.9283		
		3	67	72.3	0.9391	x	0.9267		
		4	68.1	73.5	0.9306	x	0.9265	0.9262	Baseline
7/6/2010	Test 10-7B	1	65.3	70.5	0.9262	x	0.9262		
		2	65.3	70.2	0.9302	x	0.9302		
		3	65.9	71	0.9282	x	0.9282	0.9282	-0.21%
8/11/2010	Test 10-7B	1	69	76.9	0.8973	x	0.8973		
		2	67.6	75.6	0.8942	x	0.8942		
		3	68.4	75.8	0.9024	x	0.9024		
		4	67.7	75.5	0.8967	x	0.8967	0.8977	3.18%

Table 2 – Type II Fuel Economy Test Calculations

CONCLUSIONS

Based on test results from these four evaluations, the following conclusions were made:

- The two tractors equipped with the I-PHI product showed no improvement in fuel economy after the initial 8000-mile evaluation.

- The two tractors equipped with the I-PHI product did show an improvement of + 3.2% and + 4.4% (depending on the hardware setting of the test device) after the second evaluation at approximately 23,000 miles.