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PIT Energotest

Spring 2012

Contract Report 740-02:

Fuel Consumption Tests for Counteract Balancing Beads, from Counteract Balancing Beads Inc.

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Contract Report 740-02:

Fuel Consumption Tests for Counteract Balancing Beads, from Counteract Balancing Beads Inc.

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FPInnovations – PIT

July 2012

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Context

The objective of the Energotest™ project is to conduct controlled test-track studies of solutions for achieving higher fuel efficiency and lower emissions of greenhouse gases (GHG) in the trucking industry. Energotest not only allows fleets to choose the most efficient solutions, but also allows technology suppliers to better focus their development efforts. The 9th Energotest campaign was held from May 29 to June 6, 2012, at the Transport Canada Motor Vehicle Test Centre in Blainville, Quebec.

Technologies from fourteen suppliers were chosen for testing by Performance Innovation Transport (PIT) partners for the 9th campaign. Counteract Balancing Beads Inc. was one of the selected suppliers, and they submitted for testing the Counteract Balancing Beads. This device is an automatic self-adjusting balancing material for vehicles' wheels. The objective of this device is to keep the wheel assembly in balance, which according to the manufacturer, will reduce uneven tire wear, extend tire life and decrease fuel consumption.

Test Site

The fuel-consumption tests were performed on the BRAVO high-speed test track (Figure 1). This track is a high-banked, parabolic oval that is 6.4 km (4 miles) long. The length of a test run was 13 laps (87 km), with departure and arrival at the same position along the track.

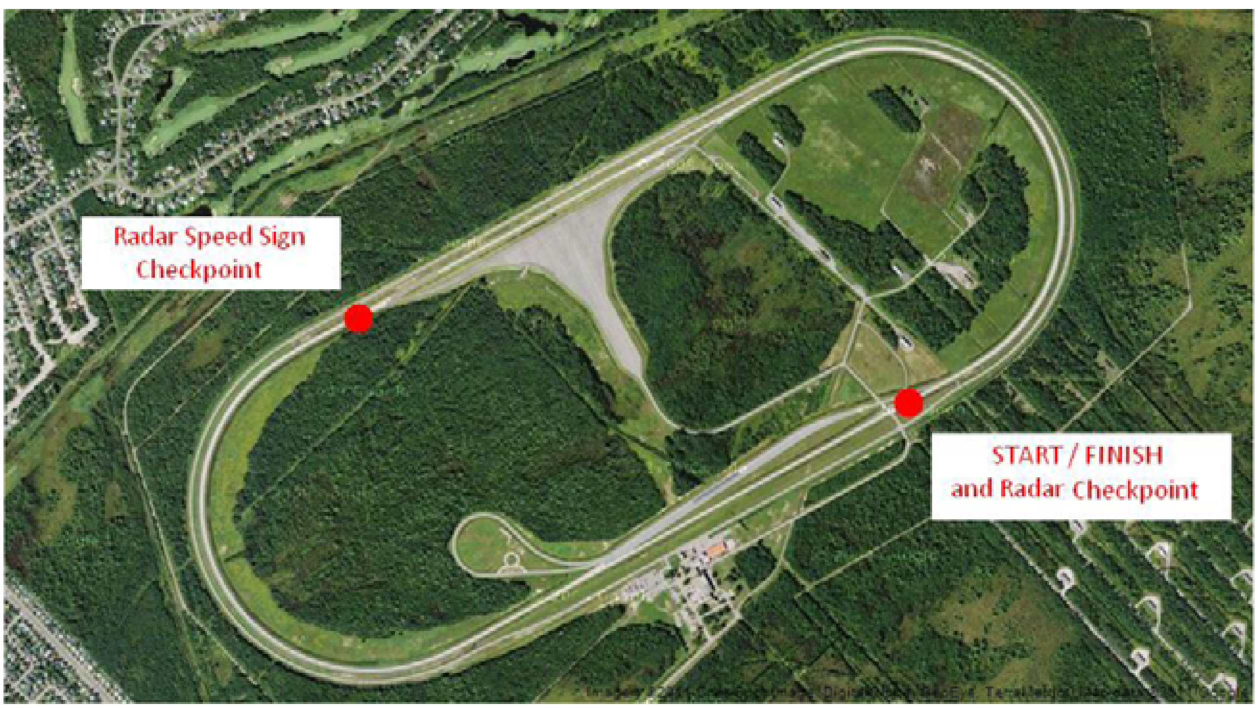

Figure 1. Test site.

Test Vehicles

Test and control vehicles were 2006 Freightliner tractors powered by CAT C13 engines, pulling Manac 2003 53-foot two-axle Cube Van semi-trailers. The tractor-trailer gap was also similar on both pairs of vehicles. Details of the vehicles configurations are presented in Table 1, detailed description is provided in Appendix A. Figures 2, and 3 present the test vehicles and the control vehicle.

Table 1. Vehicle data.

Parameters	***Vehicles***	
	Control	***Test***
Device	-	Counteract Balancing Beads
Tractors		
Vehicle test ID	C11	C12
Vehicle fleet ID	T452	T456
VIN	1FUJA6DE46LW13927	1FUJA6DE86LW13929
Make and model	Freightliner	Freightliner
Year	2006	2006
Engine make and model	CAT C13	CAT C13
Rated power	321 kW (430HP)	321 kW (430HP)
Peak torque	2238.8 Nm (1650lb-ft)	2238.8 Nm (1650lb-ft)
Transmission	Ultrashift RTLO-16913L DM3	Ultrashift RTLO-16913L DM3
Differential ratio	3.9	3.9
Tires	Michelin/11R22.5	Michelin/11R22.5
Tire pressure (cold)	690 kPa (100 psi)	690 kPa (100 psi)
Trailers		
Vehicle test ID	T8	T9
Vehicle fleet ID	418	407
VIN	2M592161841095908	2M592171041096762
Make and model	Manac Vert/ALL A10N P48	Manac Vert/ALL A10N P48
No. of axles	2	
Year	2003	2003
Type	53-foot Cube Van	
Tires	B.F. Goodrich 275/80R22.5/ST230	B.F. Goodrich 275/80R22.5/ST230
Tire pressure (cold)	690 kPa (100 psi)	690 kPa (100 psi)
Vehicle test weight	20990 kg (46274 lbs.)	21000 kg (46296 lbs.)

Figure 2. Test vehicle C12-T9.

Figure 3. Control vehicle C11-T8.

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Tested Technology

The tested Counteract Balancing Beads had the following characteristics (Appendix B):

- Automatic self-adjusting balancing material with [redacted]

  Information on how this product works is censored by court order for U.S. Citizens to protect a competitor.
- Consists of many beads that spread out based on the imperfections within the tire;
- Beads diameter: 1mm;
- The beads are inserted directly into tires. Recommended quantities: 0.284 kg (10 ounces) for steer tires), 0.340 kg (12 ounces) for other tires;
- Beads material: tempered glass with a silicone seal.

For the final test segment, the device was installed to all wheel positions on both test tractor and trailer (Figure 4).

Figure 4. Installation of Counteracting Balancing Beads on the test vehicle.

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Test Methodology

Fuel Consumption Test Procedure

According to the SAE J1321 Joint TMC/SAE Fuel Consumption Test Procedure - Type II (SAE International 2012), the test compared the fuel consumption of a test vehicle, operating under two conditions, with that of an unmodified control vehicle. Fuel consumption was accurately measured by weighing temporary tanks before and after each trip. The repeatability of the scale measurements was periodically checked during the tests using a set calibration weight (Figure 5).

Figure 5. Scale checking using a calibration weight set.

For each test, control and test vehicles had the same general configuration and were coupled to the same semi-trailers for the base and test trials. The load weights remained the same throughout the entire test period. The vehicles were in good working condition, with all settings adjusted to the manufacturer's specifications.

The test consisted of a baseline stage (using non-modified vehicles) followed by a final stage (using the test vehicle equipped with the technology to be tested). The baseline stage was conducted before installing the technology on the test vehicle. For this stage, the control and test vehicles completed a minimum of three test runs. For the final stage, the test vehicle was equipped with the technology being tested, while the control vehicle stayed in its original state. As in the baseline stage, the vehicles completed the test runs a minimum of three times. For both the baseline and final stages, the representative results were the ratio between the average fuel consumed by the test vehicle and the average fuel consumed by the control vehicle (the T/C ratio).

The nominal value was determined from the analysis of the measured fuel data and reflects the measured change in consumed fuel resulting from the modification being tested on the test vehicle. This nominal value consisted of the percentage difference between the final ratio $(T/C)_f$ and baseline ratio $(T/C)_b$:

$$P_d = 100 \times \frac{(T/C)_b - (T/C)_f}{(T/C)_b} \quad (1)$$

The result was expressed for the confidence level of 95% according to the SAE J1321 Joint TMC/SAE Fuel Consumption Test Procedure - Type II (SAE International 2012), determined from the variation in the measured fuel consumption data relative to the nominal value and the number of data values obtained.

Driving Procedure

Each day, before the start of testing, all vehicles were warmed up for the same amount of time (minimum one hour) at the test speed.

The driver's influence on the results was minimized as much as possible by conducting the tests on a closed circuit and by strictly controlling the driving cycle as follows:

- A fixed idling time was used.
- Drivers started with maximum acceleration.
- A cruising speed of 104.6 km/h (65 mph) was set.
- Drivers steered as close as possible to the painted line at the right side of the track, without touching it.
- Drivers maintained a constant driving speed.
- After the established test duration was complete, drivers stopped using the cruise control at the designated point.
- During deceleration, drivers used only the service brakes and did not accelerate.
- Once at the meeting point, the trucks idled for the same duration before stopping the engine.

The time interval between two consecutive trucks remained the same in order to avoid the effects of turbulence caused by other trucks and prevent multiple trucks from being present at the same place and time on the track. The driving cycle was controlled with two radars. A radar speed sign displayed the speed of oncoming vehicles using highly visible LEDs, and was checked by the test drivers at every lap. The other device was a radar gun, operated by the test personnel, and placed on the opposite side on the track. Drivers received instructions by two-way radio, to ensure that the speed of the vehicles and the distance between them on the track remained constant. The duration of the runs was also checked. The vehicle were also instrumented with global positioning system (GPS) units, which were used for checking vehicles speed and spacing control.

Test Equipment

The following equipment was used during the tests:

- Portable tanks with a capacity of 144 L (38 gallons): Norcan Aluminum 103461.
- Calibrated scale with a capacity of 226.80 kg and a resolution of 0.02 kg: Weigh-Tronix WI-152/DS S/N 000341, calibration certificate dated May 25, 2012.
- Wind Monitor: Young model SE 09101, serial no. 118857, range 0-100 m/s; 0°-360°; accuracy ±0.3 m/s; ± 2°; Factory calibration (May 2012).
- Wind Speed Sensor: Campbell Scientific, model 014A, serial no. N5094, range 0-100 mph, accuracy 0.25 mph (0.40 km/h), calibration April 5, 2012.
- Barometric Pressure Transducer: Omega, model PX2760-600A5V, serial no. 4892413, accuracy ± 0.25%, Calibration - Factory (May 2012).
- Data Acquisition System: Fluke, model Hydra (2635A) Data Bucket, serial no. 5796307, accuracy ± 0.018% , calibration August 26, 2011.
- Onboard computers: ISAAC DRU900, with GPS.

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Test Results

Baseline trial was conducted in the evening of May 30 and the morning of May 31, 2012, whilst the final trial was conducted in the evening of May 31 and the morning of June 1, 2012.

The results expressed according to the SAE J1321 (SAE International 2012):

- Fuel savings: 1.58% ± 0.94%;
- Fuel improvement: 1.60 ± 0.95%;
- These results were obtained at:
    - Mean vehicle speed: 104.6 km/h (65 mph),
    - Trailer weight: 20990 kg (46274 lbs.), tractor weight: 8200 kg (18078 lbs.),
    - Tractor-trailer gap[1]: 1397 mm (55in.); aerodynamic gap[2]: 889 mm (35in.),
    - Mean air temperature: 16.71 ± 1.17 °C (62.08 ± 2.10 °F),
    - Mean wind speed: 4.77 ± 0.88 km/h (6 ± 1.42 mph).

Table 2 presents the summary of the test results, whilst full details of the baseline and final trials (segments data collection and fuel use summaries) are presented in Appendix C[3]. Appendix D presents data analysis.

Table 2. Summary of test results

Baseline stage, May 30 -31, 2012				**Final stage, May 31 - June 1, 2012**			
Valid test runs	Consumed fuel, kg		T / C ratio	Valid test runs	Consumed fuel, kg		T / C ratio
	Control vehicle C11-T8 (T452-418)	Test vehicle C12-T9 (T456- 407)			Control vehicle C11-T8 (T452-418)	Test vehicle C12-T9 (T456- 407)	
1	31.32	32.52	1.0383	1	32.02	32.42	1.0125
2	32.50	33.78	1.0394	2	31.82	32.62	1.0251
3	32.22	33.24	1.0317	3	33.08	33.76	1.0206
				4	32.52	33.24	1.0221
Average T/C ratio			1.0365	**Average T/C ratio**			1.0201
Fuel savings, %							
1.58 ± 0.94							
Fuel improvement, %							
1.60 ± 0.95							

[1] Longitudinal distance between the vertical flat surface of the back of the cab/sleeper to the vertical flat surface on the front of the trailer (SAE International 2012).

[2] Longitudinal distance between the aft most point of the cab external surface, including aerodynamic side fairings, and the forward most point of the cargo-carrying portion of the vehicle (SAE International 2012).

[3] Discrepancies in odometer readings between the vehicles resulted from inaccuracy of these instruments.

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Discussions

Discussion of Test Limitations

Road tests and track tests are subject to variations in conditions between runs, and controlling or accounting for these variables as much as possible is an important part of ensuring accurate results.

Air density varies with temperature, relative humidity and barometric pressure, and changes in air density affect aerodynamic resistance. Ambient temperatures, humidity, barometric pressure, and wind speeds and directions were measured at the test site (Figure 6) and these data were verified using climate data from the Mirabel weather station, located 12 km from the test site (Environment Canada). The density of the air can be computed from measurements of these parameters (Surcel et al. 2008). Figure 7 presents the variation in air density during the testing of the Counteract Balancing Beads. The maximum difference in air density between baseline and final stages during the tests was 0.061 kg/m^3.

For aerodynamic device testing, results may also be higher or lower than under average conditions depending upon the wind velocity and direction. The elevation height for the wind measurement was 23 feet (7 m). According to SAE International (2012), the wind speed data was corrected to the elevation of 10 feet (3.05 m), using the scale factor of 0.896. As shown in Appendix C, the mean wind speed observed during the tests was 4.77 km/h, which was much less than the acceptable limit of 19.4 km/h (SAE International 2012 and EPA 2011). Figures 10 and 11, and Appendix C show that the maximum wind gust speed was 12.88 km/h, which was less than the acceptable limit of 24.1 km/h (SAE International 2012 and EPA 2011). However, in order to minimize the effects of wind yaw angle, a closed-loop parabolic oval was used.

Figure 6. Measurement of environmental conditions at the test site.

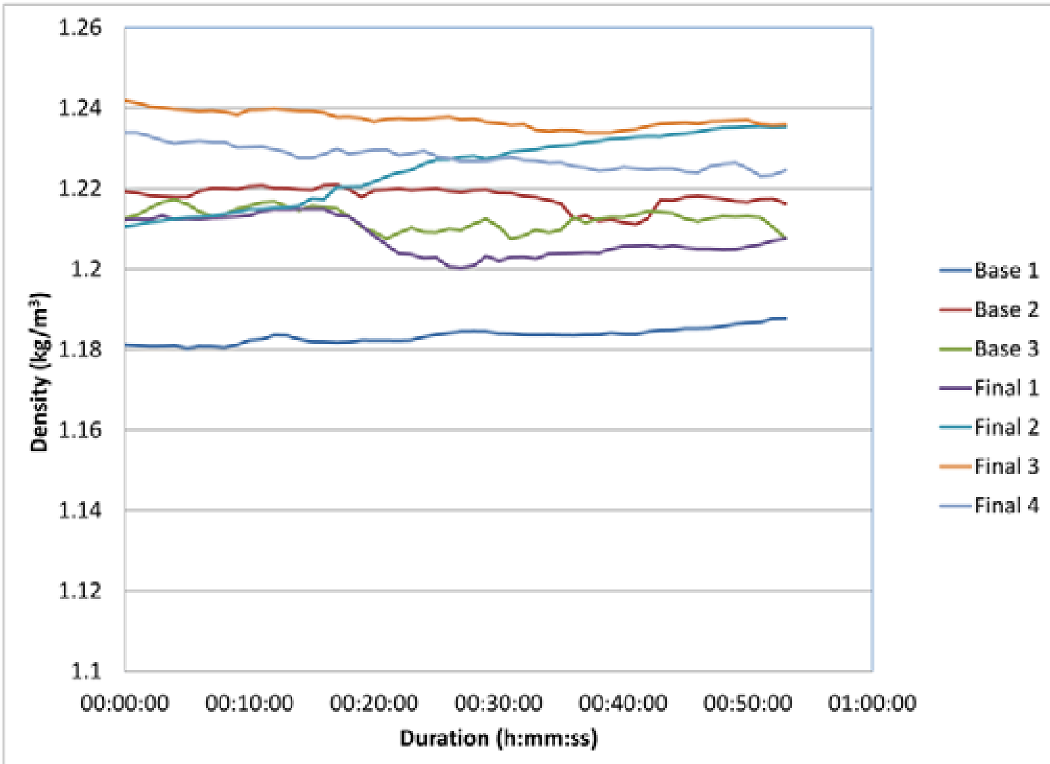

Figure 7. Air density variation during the tests.

The only possibility for minimizing the influence of varying ambient conditions is to use unchanged control and test vehicles (with the exception of the modification being tested on the test vehicle), with the assumption that both vehicles will be equally affected by these variations. For this purpose, the test and control vehicles were of the same general configuration and confirmed to be in proper operating condition prior to and during the tests (Vehicle Check Forms and Observer and Driver Comments Forms are available on request) . The trailers were matched to each test and the control vehicles remained matched with their respective tractors throughout the entire series of tests.

Another variable was the driver. Testing took place on a closed test track at a fixed speed of 104.6 km/h (65 mph), with a standard acceleration and braking protocol for all drivers, in order to eliminate the influences of traffic and variations in driver response. In addition, travel speeds were monitored throughout the trials using radars, and drivers were instructed by radio if it became necessary to adjust their travel speed. Moreover, the vehicles were instrumented with GPS, and GPS data was used to confirm vehicle speed and spacing. The driver's influence on the results was thus minimized as much as possible by strictly controlling the driving cycle.

To minimize measurement uncertainties, the only measured parameter used to calculate the test results was the weight of the portable tanks. Other parameters, such as vehicle speed, distance and time, were recorded for information purposes only. In order to avoid potential problems related to the instruments, two recently calibrated scales were available on-site. For each run, the portable tanks were weighed using the same portable scale. Furthermore, the scales were periodically checked against a known weight of 80 kg. The portable scales were not moved between the initial and final weighing for a given test run. Distance measurement was not a factor because for each run, all vehicles departed and arrived at the same point after travelling the same number of laps and following the same path along the track.

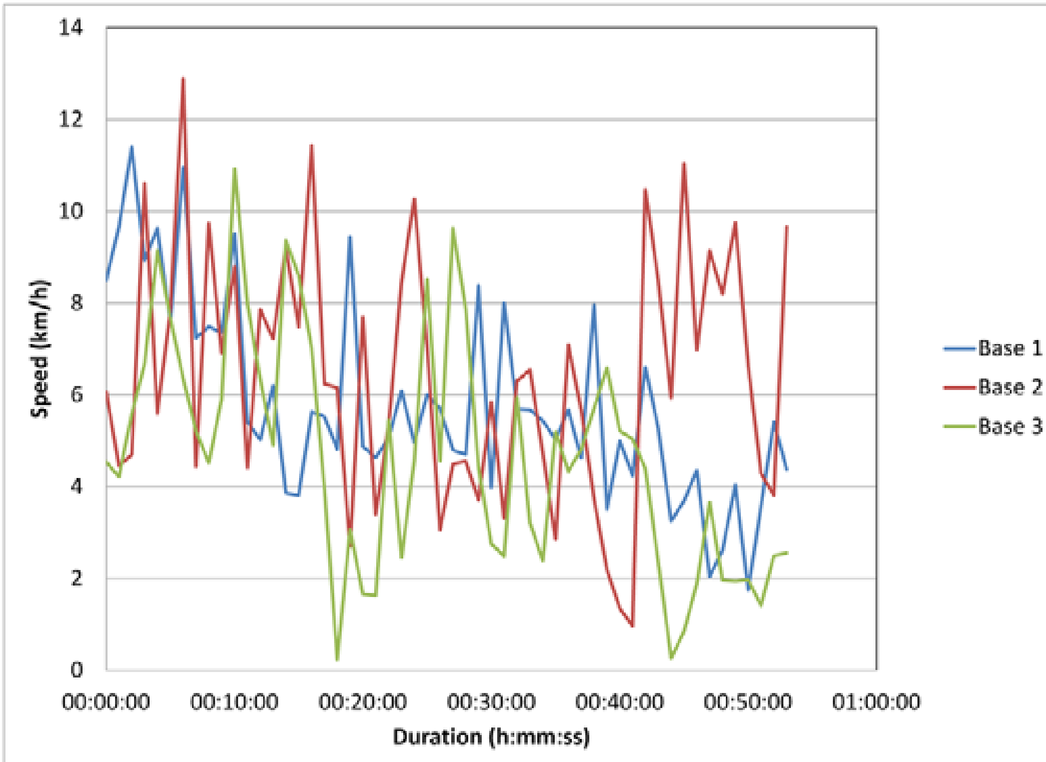

Figure 8. Wind speed variation during baseline trial.

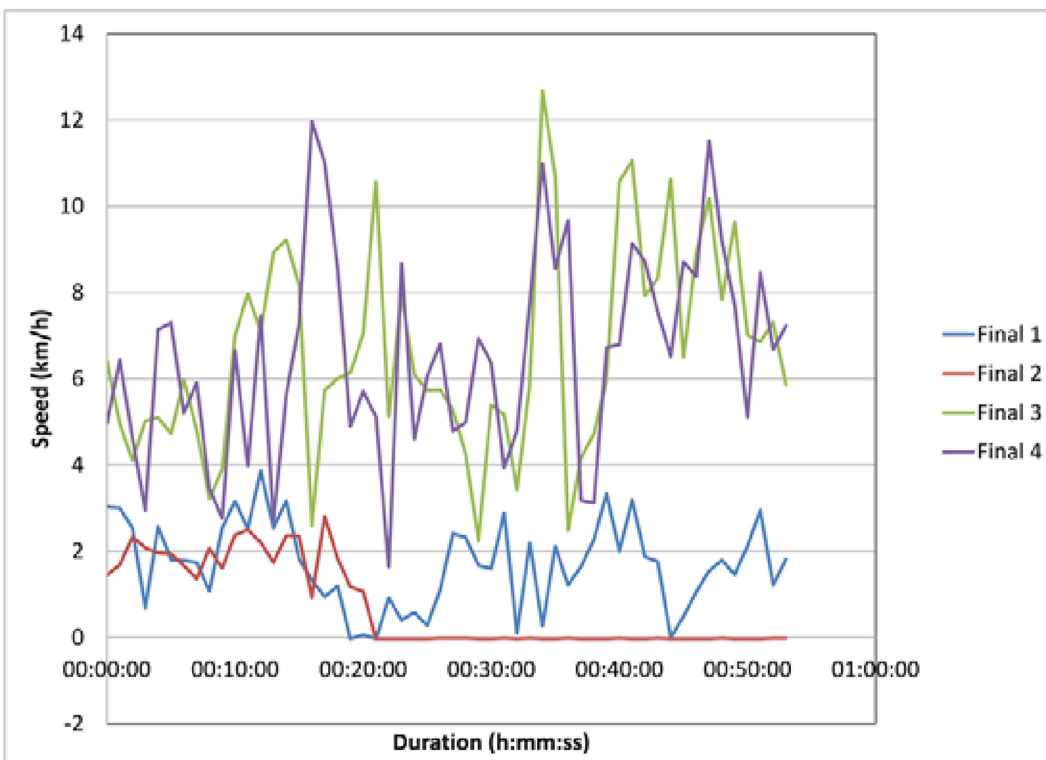

Figure 9. Wind speed variation during final trial.

Discussion and Recommendations Regarding the Tested Technology

FPInnovations tested in previous Energotest campaigns two self-adjusting wheel balancers. These devices also have the objective to keep the wheel assembly in balance, which, according to the manufacturers, would reduce uneven tire wear, help to ensure a comfortable ride and to prolong the life of tires and suspension components, and decrease fuel consumption. Tested devices contained a fluid that is free moving inside of a ring, which would offset spots and create equilibrium within the rotating mass. The two tested devices showed practically no influence on fuel consumption. It should be also mentioned that the drivers reported noticeable smoother ride of the truck with the devices installed (Surcel and Michaelsen 2010).

The result obtained by the Counteract Balancing Beads, 1.6 % fuel improvement, it is superior to the performances shown by these approaches.

However, out of balance wheels can create vibrations and loss of traction, which could cause deterioration of fuel economy. The deterioration would depend on the degree of tire imbalance and the vehicle's speed. Therefore, the loss of fuel economy due to out-of-balance wheels would mainly apply to the drive wheels.

According to Michelin, balancing is generally not necessary with Michelin tires, being a part of tire verification checks performed during the manufacturing process, and Michelin generally does not recommend any balancing at installation (Park 2008). According to Bridgestone Bandag Tire Solutions (BBTS), if mounting procedures are followed and care is taken to seat the tire properly, tire balance should not be an issue (Park 2008).

According to Goodyear, balance is most critical on free-rolling wheels, such as those installed on steer and trailer. Goodyear suggests that on-vehicle balancing with a properly calibrated spin balancer may aid in correcting the vibration problem by balancing that particular tire and wheel, or rim and hub assembly (The Goodyear Tire & Rubber Company 2003).

Conclusions

The Counteract Balancing Beads from Counteract Balancing Beads Inc. showed the following results, expressed for the confidence level of 95% according to the SAE J1321 Joint TMC/SAE Fuel Consumption Test Procedure - Type II (SAE International 2012):

- Fuel savings: 1.58% ± 0.94%;
- Fuel improvement: 1.60 ± 0.95%;

Disclaimer

This result refers only to the vehicle and specimen of technology tested according to the procedure and conditions described in this report. FPInnovations cannot guarantee the reproducibility of this result in particular operating conditions.

The representatives of Counteract Balancing Beads Inc. assisted during the two stages of tests performed on their products, and validated the installation of their devices on the vehicles used to perform the tests, prior to the beginning of said tests. The representatives of Counteract Balancing Beads Inc. also acknowledged that the tests they assisted were conducted in conformity with the test protocol.

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Appendix A. Vehicle Data Forms

ENERGOTEST 2012

Performance Innovation Transport

An FPInnovations Group

Vehicle and Equipment Description			
Testing Organization: FPInnovations - Performance Innovation Transport			
Base Test Date:	May 30-31, 2012	Test Number:	5
Final Test Date:	May 31-June 1, 2012		
Technology:	Counteract Balancing Beads		
Supplier:	Counteract Balancing Beads Inc.		

Part 1: Power Units		
Parameters	*Vehicles*	
	Control	*Test*
Vehicle Test ID	C11	C12
Vehicle Fleet ID	T452	T456
VIN	1FUJA6DE46LW13927	1FUJA6DE86LW13929
Make and Model	Freightliner	Freightliner
Year	2006	2006
Number of Axels	3	3
Number of Drive Axels	2	2
Engine Make and Model	CAT C13	CAT C13
Engine Build Year	2006	2006
Emission Label Info	EPA 2007 Compliant	EPA 2007 Compliant
Governed Speed @ no load (High Idle)	2100 RPM	2100 RPM
Rated Power	321 kW (430HP)	321 kW (430HP)
Rated Speed	2100 RPM	2100 RPM
Peak Torque	2238.8 Nm (1650lb-ft)	2238.8 Nm (1650lb-ft)
Peak Torque Speed	1200 RPM	1200 RPM
Transmission Make/Model	Ultrashift RTLO-16913L DM3	Ultrashift RTLO-16913L DM3
Geared for	105 km/h (65mph)	105 km/h (65mph)
at	1300 RPM	1300 RPM
at	1500 RPM	1500 RPM
Differential Make/Model	CAT DS405P	CAT DS405P
Differential Ratio	3.9	3.9
Vehicle Test Weight	8200 kg (18078 lbs.)	8200 kg (18078 lbs.)
Steer Tire Type/Make/Model	Michelin/11R22.5/XZ A-1	Michelin/11R22.5/XZ A-1
Tire Pressure (cold)	689 kPa (100 psi)	
Drive Tire Type/Make/Model	Michelin/11R22.5	Michelin/11R22.5
Drive Tire Pressure (cold)	689 kPa (100 psi)	
5th Wheel Setting (distance fulcrum is ahead or behind bogie centerline)	560 mm (22in.)	560 mm (22in.)

Prepared by	*Martin Ahrens*

ENERGOTEST 2012

Performance Innovation Transport

An FPInnovations Group

Vehicle and Equipment Description

Testing Organization: FPInnovations - Performance Innovation Transport

Base Test Date:	May 30-31, 2012	**Test Number:**	5
Final Test Date:	May 31-June 1, 2012		
Technology:	Counteract Balancing Beads		
Supplier:	Counteract Balancing Beads Inc.		

Part 2: Trailer/ Body

Parameters	*Vehicles*	
	Control	*Test*
Vehicle Test ID	T8	T9
Vehicle Fleet ID	**418**	**407**
VIN	2M592161841095908	2M592171041096762
Make and Model	Manac Vert/ALL A10N P48	Manac Vert/ALL A10N P48
No. of Axles	2	
Year	2003	2003
Type	Van	
Type of Side	Aluminium panel	Aluminium panel
Type of Corner/Radius	Front: round 152 mm (6 in); Back: square	Front: round 152 mm (6 in); Back: square
Height	4064 mm (13ft 4in.)	4064 mm (13ft 4in.)
Length	16154 mm (53ft.)	16154 mm (53ft.)
Width	2591 mm (102 in.)	2591 mm (102 in.)
Type Door	Barn Door	Barn Door
Number of Trailer Axles/Type	2/Tandem	2/Tandem
Truck Trailer Gap	1397 mm (55in.)	1397 mm (55in.)
Aerodynamic Gap	889 mm (35in.)	889 mm (35in.)
Gross Vehicle Weight	33500 kg (73855lbs.)	33500 kg (73855lbs.)
Tire Type/Make/Model	B.F. Goodrich 275/80R22.5/ST230	B.F. Goodrich 275/80R22.5/ST230
Tire pressure (cold)	690 kPa (100psi)	
King Pin Setting	914 mm (36in.)	914 mm (36in.)
Vehicle test weight	20990 kg (46274 lbs.)	21000 kg (46296 lbs.)

Prepared by	***Martin Ahrens***

ENERGOTEST 2012

Performance Innovation Transport

Vehicle and Equipment Description

Testing Organization: FPInnovations - Performance Innovation Transport

Base Test Date:	May 30-31, 2012	**Test Number:**	5
Final Test Date:	May 31-June 1, 2012		
Technology:	**Counteract Balancing Beads**		
Supplier:	**Counteract Balancing Beads Inc.**		

Part 3: Devices, Components or Systems that are Incorporated into Control and Test Vehicle Specification

Item	Control Vehicle			Test Vehicle		
	C11	-	T8	C12	-	T9
	No	Yes	Type	No	Yes	Type
Radiator Shutters (on-off or modulating)		x			x	
Engine Cooling Fan Sys. (Describe below -A)		x			x	
Aerodynamic Device (Describe below -B)		x			x	
Engine Oil		x	15W-40		x	15W-40
Transmission Lube		x	Synthetic SAE 50W		x	Synthetic SAE 50W
Differential Lube		x	Synthetic 75W-90		x	Synthetic 75W-90
Fuel Heater		x	In tank		x	In tank
Oil Cooler		x	Water to oil transmission cooler		x	Water to oil transmission cooler
Tag Axle	x			x		
Air Lift Axle	x			x		
Low Back Pressure Exhaust System	x			x		
Other.						

A: Automatic fan control.

B: Side Panels, cab deflector.

Prepared by	***Martin Ahrens***

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Appendix B. Detailed description of Counteract Balancing Beads

ENERGOTEST 2012

Performance Innovation Transport
An FPInnovations Group

Vehicle and Equipment Description			
Testing Organization: FPInnovations - Performance Innovation Transport			
Base Test Date:	May 30-31, 2012	Test Number:	5
Final Test Date:	May 31-June 1, 2012		
Test Vehicle:	C12 - T9		
Technology:	**Counteract Balancing Beads**		
Supplier:	**Counteract Balancing Beads Inc.**		

Part 4: Detailed Description Vehicle Component or System Modifications Being Tested

Description/Manufacturer/Part Number/Year:

Automatic self-adjusting balancing material with Information on how this product works is censored by court order for U.S. Citizens [redacted] and balances out everything in the wheel, not just the tire. Consists of many beads that will be spread out based on the imperfections within the tire.

Dimensions:

Beads diameter: 1mm.

Installation Location and Attachment:

The beds are inserted directly into tires (both steer and drive tires). Recommended quantities: 0. 284 kg (10 ounces for steer tires), 0. 340 kg (12 ounces for other tires).

Material/Weight/Power Requirements:

Tempered glass with a silicone seal.

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Appendix C. Segment Data Collection and Fuel Use Summary

ENERGOTEST 2012 — **SEGMENT DATA COLLECTION**

Performance Innovation Transport

Date: May 30-31, 2012 **Segment:** BASE **Vehicle:** *Test Vehicle* *C12-T9 (T456-407)*

Testing Organization:	FPInnovations - Performance Innovation Transport	**Test no.:**	5
Supplier:	Counteract Balancing Beads Inc.	**Test Site/Type:**	PMG Technologies / Track test
Technology:	Counteract Balancing Beads	**Duty Cycle:**	Constant speed 104.6 km/h (65 mph)

Meteorological conditions:

Wind Data (km/h, at 3 m, 10 ft)

Run	*Wind Dir.*	*Min Wind Speed*	*Max Wind Speed (≤ 24.1 km/h, 25 mph)*	*Mean Wind Speed (≤ 19.3 km/h, 12 mph)*	*Segment Mean Wind Speed Variation (recommended ≤ 8 km/h, 5 mph)*	*Test Mean Wind Speed Variation (recommended ≤ 8 km/h, 5 mph)*
1	W	1.75	11.40	5.83	1.77	1.76
2	NW	0.96	12.88	6.44		
3	NW	0.23	10.92	4.67		*Test Mean Wind Speed*
4						4.77
5						
Segment	S/O	0.23	12.88	5.65		

Run	*Temperature Data, (°C)*						*Other Data*			
	Min Temp. (≥ 4°C, 40°F)	*Max Temp. (≤ 38°C, 100 F°)*	*Mean Temp.*	*Run Temp. Variation*	*Segment Temp. Variation (≤ 17°C, 30 F°)*	*Test Temp. Variation (≤ 17°C, 30 F°)*	*Mean Humidity (%)*	*Mean pressure (mbar)*	*Weather*	*Scale Check Weight*
1	20.82	22.69	21.94	1.87	6.77	2.34	39.45	1006	Mostly Cloudy	YES-OK
2	14.49	16.75	15.17	2.26			66.32	1012	Mostly Cloudy	YES-OK
3	15.53	17.66	16.52	2.13		*Test mean temperature*	58.6	1012	Mostly Cloudy	YES-OK
4						16.71				
5										
Segment	14.49	22.69	17.88	S/O			54.79	1010	S/O	S/O

Test Runs Details:

Run	*Tank ID*	*Start*			*Finish*			*Difference*		
		Vehicle Time	*Odometer (km)*	*Fuel tank weight*	*Vehicle Time*	*Odometer (km)*	*Fuel tank weight*	*Vehicle Time*	*Odometer (km)*	*Fuel tank weight*
1	F4	19:13:00	1063544.0	98.24	20:05:02	1063630.0	65.72	00:52:02	86.0	32.52
2	T1	09:07:00	1063842.0	103.84	09:59:00	1063928.0	70.06	00:52:00	86.0	33.78
3	1	10:14:00	1063928.0	97.20	11:06:04	1064014.0	63.96	00:52:04	86.0	33.24
4										
5										

Autofill after each row

Notes:
1. Run Time for each vehicle must be within 0.25% of a vehicle's Segment Run #1 Time.
2. All wind speed and wind temperature constraints must be satisfied.
3. No equipment failure or malfunction or drive error.
4. If the three criteria above are not satisfied the Run must be repeated.

Observer	***Martin Ahrens***	***Driver***	***Donald***
Prepared by		***Marius-Dorin Surcel, Eng. (135765)***	

ENERGOTEST 2012 — SEGMENT DATA COLLECTION

Performance Innovation Transport

Date: May 30-31, 2012	**Segment:** BASE	**Vehicle:**	*Control Vehicle C11-T8 (T452-418)*
Testing Organization:	FPInnovations - Performance Innovation Transport	**Test no.:**	5
Supplier:	Counteract Balancing Beads Inc.	**Test Site/Type:**	PMG Technologies / Track test
Technology:	Counteract Balancing Beads	**Duty Cycle:**	Constant speed 104.6 km/h (65 mph)

Meteorological conditions:

Wind Data (km/h, at 3 m, 10 ft)

Run	Wind Dir.	Min Wind Speed	Max Wind Speed (≤ 24.1 km/h, 25 mph)	Mean Wind Speed (≤ 19.3 km/h, 12 mph)	Segment Mean Wind Speed Variation (recommended ≤ 8 km/h, 5 mph)	Test Mean Wind Speed Variation (recommended ≤ 8 km/h, 5 mph)
1	W	1.75	11.40	5.83	1.77	1.76
2	NW	0.96	12.88	6.44		
3	NW	0.23	10.92	4.67		*Test Mean Wind Speed*
4						4.77
5						
Segment	S/O	0.23	12.88	5.65		

Run	Temperature Data, (°C)						Other Data			
	Min Temp. (≥ 4°C, 40°F)	Max Temp. (≤ 38°C, 100 F°)	Mean Temp.	Run Temp. Variation	Segment Temp. Variation (≤ 17°C, 30 F°)	Test Temp. Variation (≤ 17°C, 30 F°)	Mean Humidity (%)	Mean pressure (mbar)	Weather	Scale Check Weight
1	20.82	22.69	21.94	1.87	6.77	2.34	39.45	1006	Mostly Cloudy	YES-OK
2	14.49	16.75	15.17	2.26			66.32	1012	Mostly Cloudy	YES-OK
3	15.53	17.66	16.52	2.13		*Test mean temperature*	58.6	1012	Mostly Cloudy	YES-OK
4						16.71				
5										
Segment	14.49	22.69	17.88	S/O					S/O	S/O

Test Runs Details:

Run	Tank ID	Start			Finish			Difference		
		Vehicle Time	Odometer (km)	Fuel tank weight	Vehicle Time	Odometer (km)	Fuel tank weight	Vehicle Time	Odometer (km)	Fuel tank weight
1	5	19:12:00	1385786.0	98.80	20:04:04	1385873.0	67.48	00:52:04	87.0	31.32
2	9	09:07:00	1386104.0	105.04	09:59:03	1386191.0	72.54	00:52:03	87.0	32.50
3	5	10:14:00	1386191.0	101.80	11:06:06	1386279.0	69.58	00:52:06	88.0	32.22
4										
5										

Autofill after each row

Notes:
1. Run Time for each vehicle must be within 0.25% of a vehicle's Segment Run #1 Time.
2. All wind speed and wind temperature constraints must be satisfied.
3. No equipment failure or malfunction or drive error.
4. If the three criteria above are not satisfied the Run must be repeated.

Observer	*Martin Ahrens*	*Driver*	*Ghislain*
Prepared by		*Marius-Dorin Surcel, Eng. (135765)*	

ENERGOTEST 2012 **SEGMENT DATA COLLECTION**

Date: May 31-June 01, 2012 **Segment:** FINAL **Vehicle:** *Test Vehicle C12-T9 (T456-407)*

Testing Organization:	FPInnovations - Performance Innovation Transport	**Test no.:**	5
Supplier:	Counteract Balancing Beads Inc.	**Test Site/Type:**	PMG Technologies / Track test
Technology:	Counteract Balancing Beads	**Duty Cycle:**	Constant speed 104.6 km/h (65 mph)

Meteorological conditions:

Wind Data (km/h, at 3 m, 10 ft)						
Run	*Wind Dir.*	*Min Wind Speed*	*Max Wind Speed (≤ 24.1 km/h, 25 mph)*	*Mean Wind Speed (≤ 19.3 km/h, 12 mph)*	*Segment Mean Wind Speed Variation (recommended ≤ 8 km/h, 5 mph)*	*Test Mean Wind Speed Variation (recommended ≤ 8 km/h, 5 mph)*
1	NW	0	3.86	1.70	5.89	1.76
2	NW	0	2.81	0.71		
3	NE	2.25	12.68	6.60		*Test Mean Wind Speed*
4	NE	1.64	11.98	6.54		4.77
5						
Segment	S/O	0	12.68	3.89		

Run	*Temperature Data, (°C)*						*Other Data*			*Scale Check Weight*
	Min Temp. (≥ 4°C, 40°F)	*Max Temp. (≤ 38°C, 100 F°)*	*Mean Temp.*	*Run Temp. Variation*	*Segment Temp. Variation (≤ 17°C, 30 F°)*	*Test Temp. Variation (≤ 17°C, 30 F°)*	*Mean Humidity (%)*	*Mean pressure (mbar)*	*Weather*	
1	17.03	20.33	18.66	3.3	5.41	2.34	40.43	1014.5	Mainly Clear	YES-OK
2	12.36	18.09	14.82	5.73			56.07	1015.6	Mainly Clear	YES-OK
3	12.17	14.03	13.25	1.86		*Test mean temperature*	54.6	1020	Mostly Cloudy	YES-OK
4	14.04	16.51	15.42	2.47			49.07	1020	Cloudy	YES-OK
5						16.71				
Segment	12.17	20.33	15.5	S/O			50.0425	1017.5	S/O	S/O

Test Runs Details:

Run	*Tank ID*	*Start*			*Finish*			*Difference*		
		Vehicle Time	*Odometer (km)*	*Fuel tank weight*	*Vehicle Time*	*Odometer (km)*	*Fuel tank weight*	*Vehicle Time*	*Odometer (km)*	*Fuel tank weight*
1	F4	18:51:00	1064114.0	105.72	19:43:04	1064200.0	73.30	00:52:04	86.0	32.42
2	10	20:03:00	1064200.0	98.70	20:55:02	1064286.0	66.08	00:52:02	86.0	32.62
3	23	07:53:00	1064385.0	97.28	08:45:06	1064472.0	63.52	00:52:06	87.0	33.76
4	T1	09:00:00	1064472.0	98.62	10:52:03	1064558.0	65.38	01:52:03	86.0	33.24
5										

Autofill after each row

Notes:
1. Run Time for each vehicle must be within 0.25% of a vehicle's Segment Run #1 Time.
2. All wind speed and wind temperature constraints must be satisfied.
3. No equipment failure or malfunction or drive error.
4. If the three criteria above are not satisfied the Run must be repeated.

Observer	***Martin Ahrens***	***Driver***	***Donald***
Prepared by		***Marius-Dorin Surcel, Eng. (135765)***	

ENERGOTEST 2012			SEGMENT DATA COLLECTION
Date: May 31-June 01, 2012	**Segment:** FINAL	**Vehicle:**	*Control Vehicle* *C11-T8 (T452-418)*
Testing Organization:	FPInnovations - Performance Innovation Transport	**Test no.:**	5
Supplier:	Counteract Balancing Beads Inc.	**Test Site/Type:**	PMG Technologies / Track test
Technology:	Counteract Balancing Beads	**Duty Cycle:**	Constant speed 104.6 km/h (65 mph)

Meteorological conditions:

Wind Data (km/h, at 3 m, 10 ft)						
Run	*Wind Dir.*	*Min Wind Speed*	*Max Wind Speed (≤ 24.1 km/h, 25 mph)*	*Mean Wind Speed (≤ 19.3 km/h, 12 mph)*	*Segment Mean Wind Speed Variation (recommended ≤ 8 km/h, 5 mph)*	*Test Mean Wind Speed Variation (recommended ≤ 8 km/h, 5 mph)*
1	NW	0	3.86	1.7	5.89	1.76
2	NW	0	2.81	0.71		
3	NE	2.25	12.68	6.6		*Test Mean Wind Speed*
4						4.77
5						
Segment	S/O	0	12.68	3.89		

Run	*Temperature Data, (°C)*						*Other Data*			*Scale Check Weight*
	Min Temp. (≥ 4°C, 40°F)	*Max Temp. (≤ 38°C, 100 F°)*	*Mean Temp.*	*Run Temp. Variation*	*Segment Temp. Variation (≤ 17°C, 30 F°)*	*Test Temp. Variation (≤ 17°C, 30 F°)*	*Mean Humidity (%)*	*Mean pressure (mbar)*	*Weather*	
1	17.03	20.33	18.7	3.3	5.41	2.34	40.43	1014.5	Mainly Clear	YES-OK
2	12.36	18.09	14.8	5.73			56.07	1015.6	Mainly Clear	YES-OK
3	12.17	14.03	13.3	1.86		*Test mean temperature*	54.6	1020	Mostly Cloudy	YES-OK
4										
5						16.71				
Segment	12.17	20.33	15.54	S/O			50.0425	1017.5	S/O	S/O

Test Runs Details:

Run	*Tank ID*	*Start*			*Finish*			*Difference*		
		Vehicle Time	*Odometer (km)*	*Fuel tank weight*	*Vehicle Time*	*Odometer (km)*	*Fuel tank weight*	*Vehicle Time*	*Odometer (km)*	*Fuel tank weight*
1	71	18:50:00	1386381.0	98.06	19:42:05	1386468.0	66.04	00:52:05	87.0	32.02
2	6	20:02:00	1386468.0	99.74	20:54:01	1386555.0	67.92	00:52:01	87.0	31.82
3	8	07:52:00	1386672.0	105.58	08:44:04	1386759.0	72.50	00:52:04	87.0	33.08
4	1	08:59:00	1386759.0	96.04	10:51:04	1386846.0	63.52	01:52:04	87.0	32.52
5										

Autofill after each row

Notes:
1. Run Time for each vehicle must be within 0.25% of a vehicle's Segment Run #1 Time.
2. All wind speed and wind temperature constraints must be satisfied.
3. No equipment failure or malfunction or drive error.
4. If the three criteria above are not satisfied the Run must be repeated.

Observer	*Martin Ahrens*	*Driver*	*Ghislain*
Prepared by		*Marius-Dorin Surcel, Eng. (135765)*	

ENERGOTEST 2012 — TEST FUEL USE SUMMARY

Testing Organization:	FPInnovations - Performance Innovation Transport	**Test no.:**	5
Supplier:	Counteract Balancing Beads Inc.	**Test Site/Type:**	PMG Technologies / Track test
Technology:	Counteract Balancing Beads	**Duty Cycle:**	Constant speed 104.6 km/h (65 mph)

Test Run Data Acceptance Criteria

1. All Run Time criteria must be satisfied.
2. All wind speed and wind temperature constraints must be satisfied.
3. No equipment failure or malfunction or drive error.
4. Test Run data is valid if the three criteria listed above are satisfied.

Baseline Segment — *Date: May 30-31, 2012*

Run	*Valid Run*	*Test Vehicle (T) C12-T9 (T456-407)* Fuel Used, kg	*Control Vehicle (C) C11-T8 (T452-418)* Fuel Used, kg	*T/C Ratio*	*Equipment failure / malfunction or driver error*
1		32.52	31.32	1.038	None
2		33.78	32.50	1.039	None
3		33.24	32.22	1.032	None
4					
5					

Final Segment — *Date: May 31-June 01, 2012*

Run	*Valid Run*	*Test Vehicle (T) C12-T9 (T456-407)* Fuel Used, kg	*Control Vehicle (C) C11-T8 (T452-418)* Fuel Used, kg	*T/C Ratio*	*Equipment failure / malfunction or driver error*
1		32.42	32.02	1.012	None
2		32.62	31.82	1.025	None
3		33.76	33.08	1.021	None
4		33.24	32.52	1.022	
5					

Observer	***Martin Ahrens***	***Driver***	***Donald***	***Ghislain***
Prepared by		***Marius-Dorin Surcel, Eng. (135765)***		

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Appendix D. Data Analysis

ENERGOTEST 2012 — RESULTS DATA ANALYSIS

Performance Innovation Transport

Testing Organization:	FPInnovations - Performance Innovation Transport	Test no.:	5
Supplier:	Counteract Balancing Beads Inc.	Test Site/Type:	PMG Technologies / Track test
Technology:	Counteract Balancing Beads	Duty Cycle:	Constant speed 104.6 km/h (65 mph)

Baseline Segment		Date:	May 30-31, 2012
Consumed fuel (kg)			
	Test	Control	
Run	C12-T9 (T456-407)	C11-T8 (T452-418)	T/C
1	32.52	31.32	1.0383
2	33.78	32.50	1.0394
3	33.24	32.22	1.0317
4			
5			
6			

Final Segment		Date:	May 31-June 01, 2012
Consumed fuel (kg)			
	Test	Control	
Run	C12-T9 (T456-407)	C11-T8 (T452-418)	T/C
1	32.42	32.02	1.0125
2	32.62	31.82	1.0251
3	33.76	33.08	1.0206
4	33.24	32.52	1.0221
5			
6			

Summary Stats	Baseline	Final
Mean T/C	1.0365	1.0201
Number of Data Points	3	4
Standard Deviations	0.0042	0.0054
Variances	0.000018	0.000029
Difference in Means	0.0164	

F-Test for Equal Variances	
Baseline T/C Variance	0.00002
Test T/C Variance	0.00003
F test stat (test/baseline)	1.66710
F low	0.06233
F high	39.16549
Are Variances Equal ?	YES

T-Test with Equal Variances (2-tailed)	
Pooled St dev	0.00495
t-crit	2.571
t-stat	4.326
Is Fuel Economy Improved ?	YES
P-value	0.0075265
lower CI bound	0.00664
upper CI bound	0.02610

T-Test with Unequal Variances (2-tailed)	
df (nu)	4.959
t-crit	2.577
t-stat	4.514
Is Fuel Economy Improved ?	YES
P-value	0.0064
lower CI bound	0.00703
upper CI bound	0.02571

Test Result	Nominal	Confidence Interval	
Fuel Savings	**1.58%**	**±**	**0.93846%**
Fuel Improvement	**1.60%**	**±**	**0.95352%**

CI t-critical	2.571
CI std err term	0.00378

Prepared by	*Marius-Dorin Surcel, Eng. (135765)*

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PIT Performance Innovation Transport

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