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Energotest July 2010:
Fuel Consumption Tests of the RM2J FMZ Device

Contract Report CR-550-6

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2010

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Introduction

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 5th Energotest™ campaign was held from July 7 to 13, 2010, at the Transport Canada Motor Vehicle Test Centre in Blainville, Quebec, and was targeted to fuel consumption tests for specific duty cycles.

Technologies from three suppliers were chosen for testing by Project Innovation Transport (PIT) partners. RM2J inc. was one of the selected suppliers, and they submitted for testing the Fuel MaximiZer – FMZ device. According to the supplier, the Fuel MaximiZer is an electronic device used to efficiently regulate the available power of an engine in relation with the load transported by the vehicle for the purpose of reducing the fuel consumption. The FMZ is installed between the acceleration pedal and the engine control module (ECM) and controls the engine power available to the driver. In order to do so, the FMZ reads in the vehicle load in real time and limits the maximum power of the engine based on the configuration set by the user. The programming software is provided with the FMZ, and the parameters controlling the available power relative to the load are configurable and modifiable by the user.

Test Site

The fuel-consumption tests were performed on the low-speed test track (ALFA). This track is a parabolic oval that is 6.9 km long. The length of a test run was 4 laps (almost 28 km), with departure and arrival at the same position along the track. Figure 1 shows the test site.

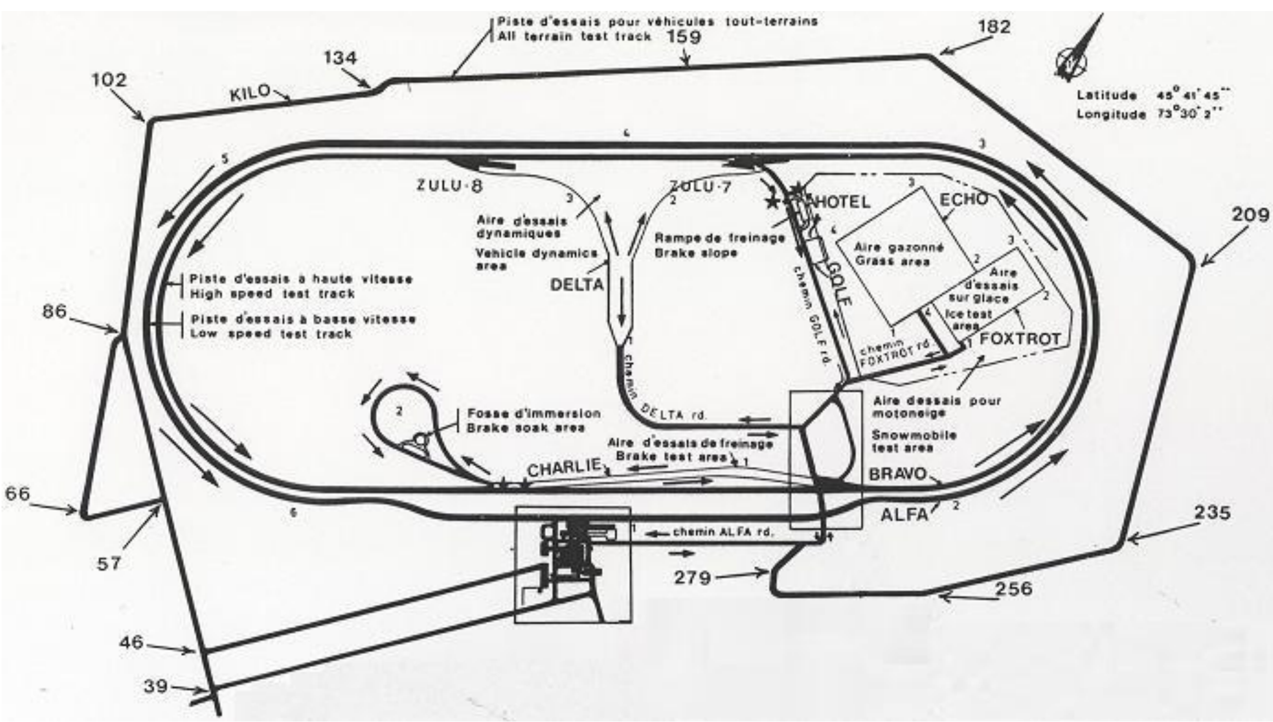

Figure 1. Blainville test site (courtesy of PMG Technologies).

Test Vehicles

The control and test vehicles were 2008 International Transtar tractors powered by Cummins ISM 400 engines, pulling unloaded Manac 53-foot Cube Van semi-trailers. Details of the vehicles configurations are given in Table 1 and Figure 2 shows a photo of the test vehicle.

Table 1. Vehicle data

Parameters	***Vehicles***	
	Control	***Test***
Tractors		
Vehicle test ID	C6	C5
Vehicle fleet ID	M09-310	M09-309
VIN	1HSHXAHR49J141692	1HSHXAHR29J141691
Make and model	NAVISTAR International Transtar 8600 SRA 6x4	
Year	2008	
Engine make and model	Cummins ISM 410	
Rated power	410 HP (306 kW) / 2000 RPM	
Peak torque	1550 lb-ft (2102 Nm)	
Transmission	Allison 6 speed	
Differential ratio	4.88	
Vehicle test weight	6916 kg	
Tires	Michelin 11R22.5	
Tire pressure (cold)	100 psi (690 kPa)	
Semi-trailers		
Vehicle test ID	T4	T3
Vehicle fleet ID	123089	123087
VIN	2MS92161861106067	2MS92161461106065
Make and model	Manac 94253001	
No. of axles	2	
Year	2005	
Type	TRA/REM	
Tires	Goodyear G314 11R22.5	Goodyear G314, Continental HSR 11R22.5
Tire pressure (cold)	100 psi (690 kPa)	
Vehicle test weight	6359 kg	6358 kg

Figure 2. Test vehicle.

Test Methodology

Fuel Consumption Tests

The test was based on the SAE J1321 Joint TMC/SAE Fuel Consumption Test Procedure - Type II (SAE International 1986) and FPInnovations' handbook for heavy-duty cycles fuel consumption tests (Surcel, 2008).

Figure 3 presents the stop-and-go cycle used during the tests. The length of one cycle was 6.9 km (the length of a complete test track lap), with 9 stops and 9 speed sections, from 20 to 60 km/h, with 10 seconds of idling at each stop. One test run was composed of 4 cycles, with a total length of 28 km and total duration of 1 h.

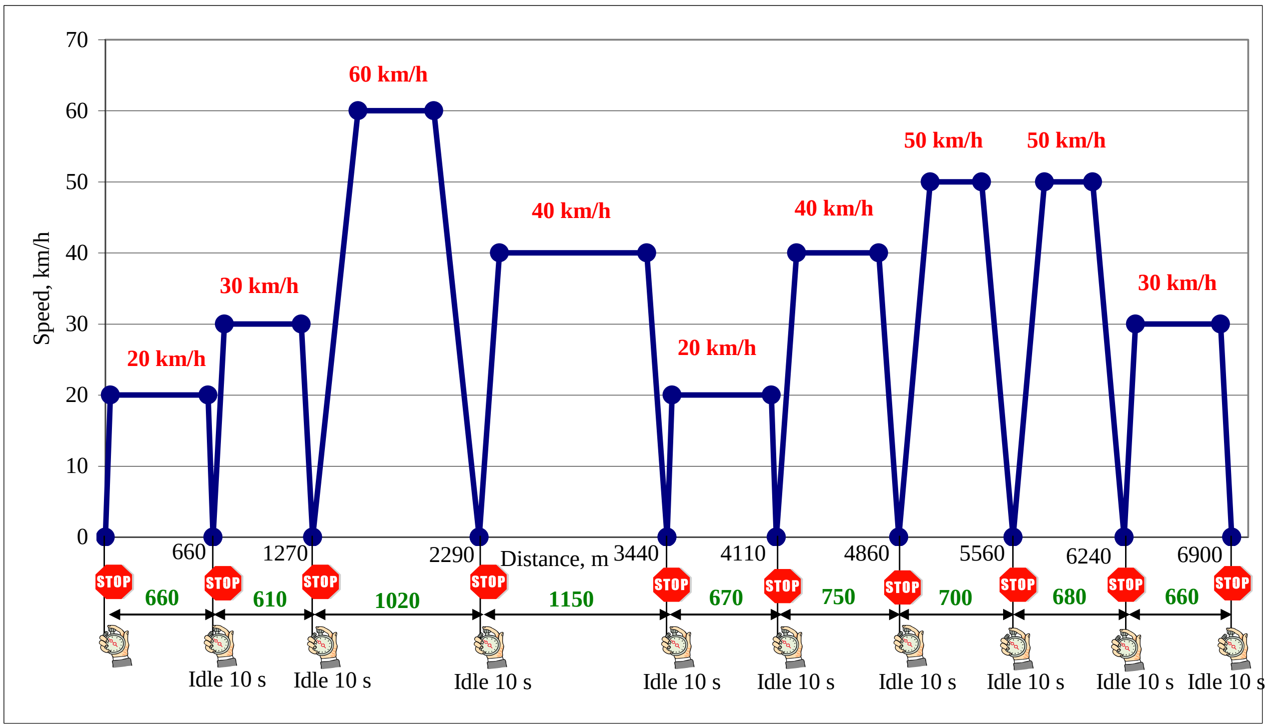

Figure 3. Stop-and-go cycle used for the tests.

The driving cycle was controlled by on-board observers and using on-board computers: an observer was assigned to each vehicle to instruct the driver on how to follow the driving-cycle. Drivers and observers experienced the test route at least twice before testing started. One driver drove the same vehicle during both the baseline and final stages. Observers received instructions by two-way radio from the command point, to ensure that speed requirements were fulfilled and the distance between vehicles on the track remained constant. The duration of the runs was also checked.

Each day, before the start of testing, all vehicles were warmed up by completing one test cycle. Fuel consumption was accurately measured by weighing temporary fuel tanks before and after each test run. The repeatability of the scale measurements was periodically checked during the tests using a set calibration weight. Figure 4 presents the installation of the temporary fuel tanks.

The fuel-consumption test compared the fuel consumption of a test vehicle, operating under two conditions, with that of an unmodified control vehicle.

For each test, the control and the 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.

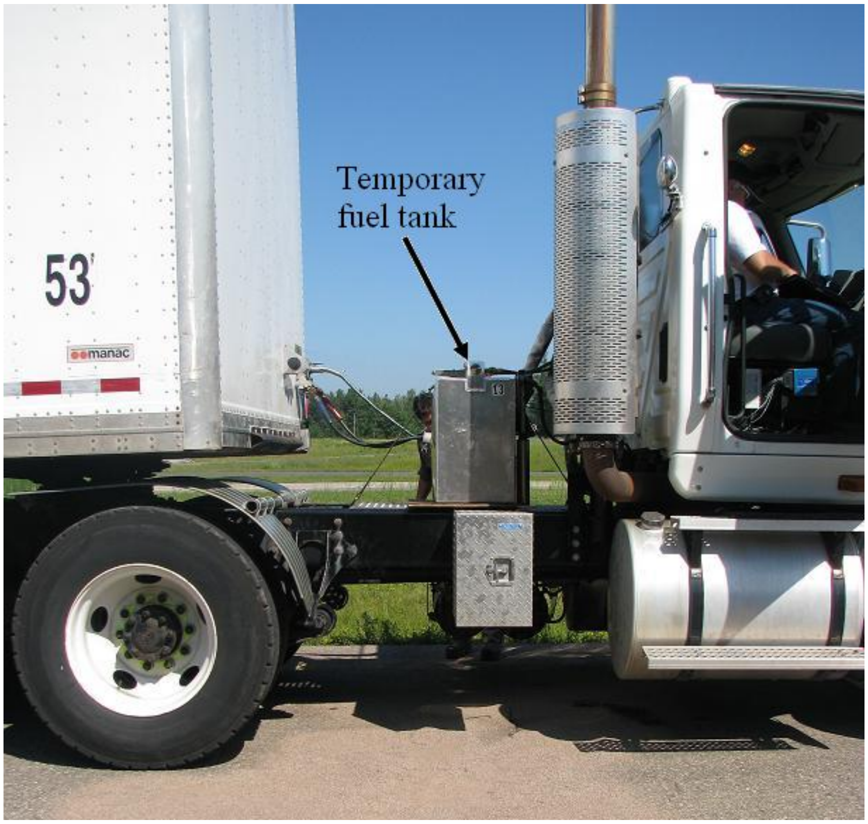

Figure 4. Installation of the temporary fuel tanks.

The test consisted of a baseline stage (FMZ device inactive) followed by a final stage (FMZ device activated on the test vehicle only, while the control truck stayed in its original state). For both baseline and final stages, the control and test trucks completed a minimum of three test runs until the results of a group of three runs were within 2% of each other. For both the baseline and final stages, the representative results were the ratio between the average fuel consumed by the test truck and the average fuel consumed by the control truck (the T/C ratio). Details of the baseline and final trials are presented in Appendix A.[1]

The result of the complete trial consisted of the percentage difference between the final ratio $(T/C)_f$ and baseline ratio $(T/C)_b$:

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

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

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 150 kg and a resolution of 0.02 kg: Ohaus 3000, serial number 0015208-635; calibration certificate dated September 14, 2009.
- Calibrated scale with a capacity of 100 kg and a resolution of 0.02 kg: Acculab SVI 100-E , S/N 15511, calibration certificate dated September 14, 2009.
- Weather station Davis Instrument Vantage Vue.

The repeatability of the scale measurements was periodically checked during the tests using a calibration weight set.

Test Results

The baseline stage was conducted before activating the device on the test vehicle, on July 08, 2010, in the morning. Three test runs were necessary to obtain three valid T/C ratios. The final stage was on July 09, 2010, in the morning. FMZ device was activated on the test vehicle by Eng. Jean Poulin, one of RM2J inc. representatives at the trials. Five test runs were required to obtain three valid ratios between the two trucks' fuel consumptions.

The FMZ device showed 5.01 % fuel consumption improvement. Table 2 summarizes the results and details are presented in Appendix B.

The repeatability of the tests can be evaluated using the coefficient of variation (c_V) , which is defined as the percentage ratio of the standard deviation (σ) to the mean (μ):

$$c_V = 100 \times \frac{\sigma}{\mu} \qquad (3)$$

As can be seen in Table 2, the coefficients of variation for T/C ratio were 0.99 and 0.70 %, which shows very good consistency and repeatability of the tests.

Figure 5 presents the installation of the FMZ Device on the test vehicle.

Table 2. Summary of test results

Baseline stage, 08.07.2010, AM				**Final stage, 09.07.2010, AM**			
Valid test runs	Consumed fuel, kg		T / C ratio	Valid test runs	Consumed fuel, kg		T / C ratio
	Control vehicle C6-T4 (M09-310-123089)	Test vehicle C5-T3 (M09-309-123087)			Control vehicle C6-T4 (M09-310-123089)	Test vehicle C5-T3 (M09-309-123087	
1	9.640	9.800	1.017	1	9.520	9.160	0.962
2	9.760	10.040	1.029	2	9.700	9.360	0.965
3	9.840	9.930	1.009	5	9.620	9.380	0.975
Average T/C ratio							
1.018				0.967			
T/C ratio coefficient of variation, %							
0.99				0.70			
Fuel saved, %							
5.01							

Figure 5. FMZ Device installed on the test vehicle.

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 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 6 presents the variation in air density during the testing of the FMZ device. It can be observed that the difference in air density between baseline and final stages during the tests was between 0.01 and 0.04 kg/m^3.

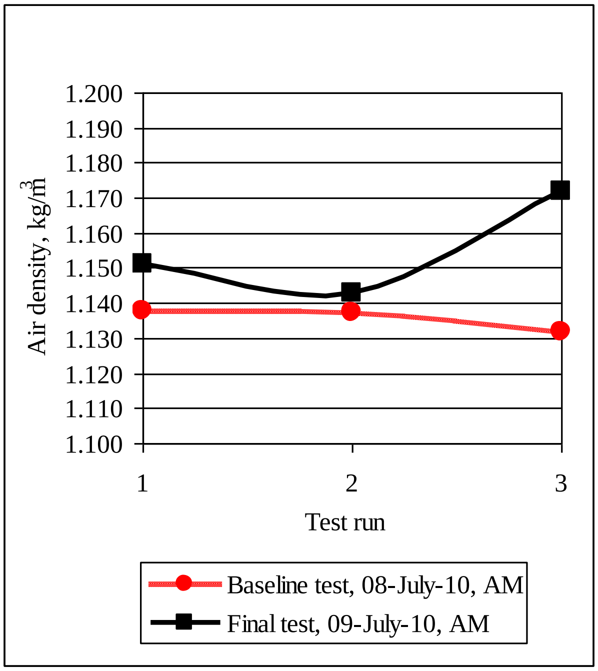

Figure 6. Air density variations during FMZ device testing.

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. 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. The driver's influence on the results was minimized as much as possible by strictly controlling the driving cycle: observers were assigned in each vehicle to instruct the driver how to follow the test speed and idle times. Testing took place on a closed test track, with a standard acceleration (full throttle) and braking protocol for all drivers, in order to minimize the influences of variations in driver response. In addition, travel speeds were monitored throughout the trials by observers, and they were instructed by radio if it became necessary to adjust their travel speed.

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 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 weighings 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.

Discussion and Recommendations Regarding the Tested Technology

The result obtained with FMZ device was consistent with the performance of comparable designs: FPInnovations tested a similar concept in 2006, developed in partnership by Allison Transmission, Cleral inc. and Detroit Diesel. This system involved using an onboard weigh scale to determine whether the truck is loaded or empty. This information then triggered the engine's electronic controls to operate at economic rating when empty (lower power, torque and fuel consumption) and at performance rating when loaded (higher power and torque). The two different performance settings, both available in the engine control module, were 325 kW / 1966 Nm and 384 kW / 2237 Nm. One SAE Type II test conducted with unloaded vehicles on public roads showed a 10.6% improvement when compared with the manual transmission control truck, and 7.9% when compared with the automatic transmission control truck (Surcel et al. 2007). It should be noted that this device is not available on the market and that dual performance setting programming are not available on all engines.

Cummins offers the LBSC feature (Load Based Speed Control), integrated into engine's Electronic Control Module (ECM). According to Cummins, LBSC senses how much load engine is pulling, and adjusts the engine speed that is available (in all but the top two gears). Under low or intermediate power demands, LBSC helps the driver to upshift earlier in the rpm range, which would help to lower average engine operating speeds, and increase the fuel economy (Cummins 2005).

A prototype of FMZ device was equally tested by FPInnovations in 2007 using the SAE Type II test procedure, on a 66 km test route on public roads, with unloaded vehicles. The manufacturer wanted to test several available settings, and the results showed fuel savings from 3 to 11%, depending on the adjustment (Surcel, 2007).

For the tests which are making the object of this report, it should be highlighted that in both baseline and final stages, the drivers of both test and control vehicles were instructed to accelerate the vehicles with maximum acceleration (full throttle). This accelerating technique was requested by RM2J representatives for providing the optimum conditions for the device to show its potential, which implies that the FMZ device would show different performances for different driving styles. However, using the same acceleration technique (full throttle) also assured the repeatability of the driving style throughout the tests. . As well, this acceleration technique is the standard technique used in Energotest tests.

We also recommend considering other possible implications with the use of the FMZ device, such as the influences on climbing, passing and taking-off abilities.

Conclusions

The percentage fuel savings differences between the final ratio[2] and baseline ratio[3] was 5.01%, for the test vehicles equipped with RM2J inc. Fuel MaximiZer – FMZ device, when the vehicle was empty, which is certainly worthwhile for operations where vehicles are driven unloaded a good percentage of the time.

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 RM2J inc. assisted during the two stages of tests performed on their product and validated the installation of their device on the vehicle used to perform the tests, prior to the beginning of said tests. The representatives of RM2J inc. also acknowledged that the tests were conducted in conformity with the test protocol.

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[2] The average mass of fuel consumed by the test vehicle in the final test / average mass of fuel consumed by the control vehicle during the final test.
[3] The average mass of fuel consumed by the test vehicle in the baseline test / average mass of fuel consumed by the control vehicle during the baseline test.

References

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Appendix A: Test trial forms

ENERGOTEST 2010 **TEST TRIAL FORM**

Date: 8-Jul-10 **Trial:** **BASE** **Vehicle:** ***Test Vehicle***
C5-T3 (M09-309-123087)

Supplier: **RM2J Inc.**
Technology: **FMZ**
Meteorological conditions:

Run	*Temp. (^0C)*	*Wind speed (km/h)*	*Wind direction*	*Relative humidity*	*Weather*
1	32.0	8	SE	50	Clear
2	32.0	11	SWW	48	Clear
3	33.0	3	SWW	49	Clear
4					
5					
6					

Test Runs Details:

Run	*Tank ID*	*Start*			*Finish*			*Difference*		
		Time	*Odometer (km)*	*Fuel tank weight*	*Time*	*Odometer (km)*	*Fuel tank weight*	*Time*	*Odometer (km)*	*Fuel tank weight*
1	11	10:55:00	105292	98.96	11:58:00	105320	89.16	1:03:00	28.0	9.80
2	6	12:23:00	105320	101.02	13:26:00	105348	90.98	1:03:00	28.0	10.04
3	10	13:35:00	105348	98.48	14:38:00	105376	88.55	1:03:00	28.0	9.93
4										
5										
6										
								Autofill after each row		

Observer	***Marius-Dorin Surcel, Eng. (135765), Anthony Proust, Jr. Eng. (5007119)***
Prepared by	***Marius-Dorin Surcel, Eng. (135765)***

ENERGOTEST 2010 **TEST TRIAL FORM**

Date: 8-Jul-10 **Trial:** **BASE** **Vehicle:** ***Control Vehicle***
C6-T4 (M09-310-123089)

Supplier: **RM2J Inc.**
Technology: **FMZ**
Meteorological conditions:

Run	*Temp. (^0C)*	*Wind speed (km/h)*	*Wind direction*	*Relative humidity*	*Weather*
1	32.0	8	SE	50	Clear
2	32.0	11	SWW	48	Clear
3	33.0	3	SWW	49	Clear
4					
5					
6					

Test Runs Details:

Run	*Tank ID*	*Start*			*Finish*			*Difference*		
		Time	*Odometer (km)*	*Fuel tank weight*	*Time*	*Odometer (km)*	*Fuel tank weight*	*Time*	*Odometer (km)*	*Fuel tank weight*
1	10	10:56:00	101436	108.12	11:59:00	101464	98.48	1:03:00	28.0	9.64
2	F4	12:24:00	101464	102.86	13:29:00	101492	93.10	1:05:00	28.0	9.76
3	7	13:36:00	101492	64.20	14:39:00	101520	54.36	1:03:00	28.0	9.84
4										
5										
6										
								Autofill after each row		

Observer	***Marius-Dorin Surcel, Eng. (135765), Anthony Proust, Jr. Eng. (5007119)***
Prepared by	***Marius-Dorin Surcel, Eng. (135765)***

ENERGOTEST 2010 **TEST TRIAL FORM**

Date: 9-Jul-10 **Trial:** FINAL **Vehicle:** *Test Vehicle*
C5-T3 (M09-309-123087)

Supplier: **RM2J Inc.**
Technology: **FMZ**
Meteorological conditions:

Run	*Temp. (^0C)*	*Wind speed (km/h)*	*Wind direction*	*Relative humidity*	*Weather*
1	27.0	2	NE	79	Mostly Cloudy
2	29.0	8	NE	71	Mostly Cloudy
3	29.0	6	SW	69	Cloudy and haze
4	29	3	SW	71	Rain showers
5	22	2	E	78	Cloudy
6					

Test Runs Details:

Run	*Tank ID*	*Start*			*Finish*			*Difference*		
		Time	*Odometer (km)*	*Fuel tank weight*	*Time*	*Odometer (km)*	*Fuel tank weight*	*Time*	*Odometer (km)*	*Fuel tank weight*
1	5	8:12:00	105391	68.24	9:15:00	105419	59.08	1:03:00	28.0	9.16
2	2	9:33:00	105419	99.08	10:36:00	105447	89.72	1:03:00	28.0	9.36
3	5	10:53:00	105447	86.64	11:56:00	105474	77.46	1:03:00	27.0	9.18
4	11	12:28:00	105474	87.24	13:31:00	105502	78.06	1:03:00	28.0	9.18
5	11	14:12:00	105502	78.06	15:15:00	105530	68.68	1:03:00	28.0	9.38
6										
								Autofill after each row		

Observer	***Marius-Dorin Surcel, Eng. (135765), Anthony Proust, Jr. Eng. (5007119)***
Prepared by	***Marius-Dorin Surcel, Eng. (135765)***

Date: 9-Jul-10 **Trial:** FINAL **Vehicle:** ***Control Vehicle***

C6-T4 (M09-310-123089)

Supplier: **RM2J Inc.**

Technology: **FMZ**

Meteorological conditions:

Run	*Temp. (^0C)*	*Wind speed (km/h)*	*Wind direction*	*Relative humidity*	*Weather*
1	27.0	2	NE	79	Mostly Cloudy
2	29.0	8	NE	71	Mostly Cloudy
3	29.0	6	SW	69	Cloudy and haze
4	29.0	3	SW	71	Rain showers
5	22.0	2	E	78	Cloudy
6					

Test Runs Details:

Run	*Tank ID*	*Start*			*Finish*			*Difference*		
		Time	*Odometer (km)*	*Fuel tank weight*	*Time*	*Odometer (km)*	*Fuel tank weight*	*Time*	*Odometer (km)*	*Fuel tank weight*
1	12	8:13:00	101535	100.86	9:16:00	101563	91.34	1:03:00	28.0	9.52
2	11	9:34:00	101563	96.94	10:37:00	101591	87.24	1:03:00	28.0	9.70
3	10	10:54:00	101591	85.80	11:57:00	101619	75.96	1:03:00	28.0	9.84
4	71	12:29:00	101619	90.36	13:32:00	101647	80.32	1:03:00	28.0	10.04
5	71	14:13:00	101647	80.32	15:16:00	101675	70.70	1:03:00	28.0	9.62
6										
								Autofill after each row		

Observer	***Marius-Dorin Surcel, Eng. (135765), Anthony Proust, Jr. Eng. (5007119)***
Prepared by	***Marius-Dorin Surcel, Eng. (135765)***

Appendix B: Test result form

ENERGOTEST 2010 **TEST RESULTS FORM**

Technology: **RM2J Inc.**
Supplier: **FMZ**

RESET BASE DATA

VALIDATE BASE DATA

BASE TRIAL **DATE:** 8-Jul-10

T/C ratio calculation			
Test run	*Consumed fuel (kg): vehicle "**C**"* ***C6-T4 (M09-310-123089)***	*Consumed fuel (kg): vehicle "**T**"* ***C5-T3 (M09-309-123087)***	*T / C ratio*
1	9.640	9.800	1.017
2	9.760	10.040	1.029
3	9.840	9.930	1.009
4			
5			
6			
Valid test runs and T/C average (T/CavB)			
Test run	1	2	3
T/C ratio	1.017	1.029	1.009
T/CavB	1.018		

RESET FINAL DATA

VALIDATE FINAL DATA

FINAL TRIAL **DATE:** 9-Jul-10

T/C ratio calculation			
Test run	*Consumed fuel (kg): vehicle "**C**"* ***C6-T4 (M09-310-123089)***	*Consumed fuel (kg): vehicle "**T**"* ***C5-T3 (M09-309-123087)***	*T / C ratio*
1	9.520	9.160	0.962
2	9.700	9.360	0.965
3	9.840	9.180	0.933
4	10.040	9.180	0.914
5	9.620	9.380	0.975
6			
Valid test runs and T/C average (T/CavT)			
Test run	1	2	5
T/C ratio	0.962	0.965	0.975
T/CavT	0.967		

TEST RESULTS

Parameter	***Notation***	***Equation***	***Value***
Base trial T/C average	T/CavB		1.018
Test trial T/C average	T/CavT		0.967
Percent fuel saved	PS	100(T/CavB - T/CavT) ÷ T/CavB	5.010

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